Causes and Implications of Shifts in Financial Participation in Commodity Markets

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February 13, 2013

Abstract

We assess the causes and implications of the greater financial participation in commodity markets post-2003. Focusing on crude oil, we build a calibrated macro-finance model of oil prices and quantities that also determines consumer welfare. We show that shifts in the preferences and constraints of financial speculators cannot explain the observed movement in the futures spread and so are unlikely to expose consumer welfare to shocks, even in the presence of belief disagreements. Shifts in the supply and demand for spot oil can better explain many of the features often attributed to financialization including financial participation itself.

JEL-Classification: C63, G12, G13, G17, Q43

Keywords: Commodities, Financialization, Macro-finance, Asset Pricing, Belief Disagreements

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1 Introduction

One of the most important developments in the commodities markets in the last ten years has been the greater participation in futures and derivatives markets by players such as hedge funds, pension funds, insurance companies, and retail investors, with no business in the production or consumption of the physical products. Financial innovation has lowered the cost of investment in derivatives of commodities and helped these financial players increase their exposure to commodities through a wide variety of financial instruments such as futures, options, index funds, exchange traded funds (ETFs), and other bespoke products.

A burgeoning empirical literature links changes in commodity price behaviour to shifts in financial participation. Among the striking effects attributed to this trend rise in participation are: a greater volatility of the spot price (Tang and Xiong (2010); Hamilton and Wu (2012)); an increased price co-movement between crude oil and financial assets and between crude oil and other non-energy commodities (Silvennoinen and Thorp (2010); Büyükşahin and Robe (2011); the fact that financial players' investment strategies, preferences, degree of risk aversion, and financial constraints can impact futures prices (Acharya et al. (2011); Etula (2009); Singleton (2011)); a breakdown of the relationship between oil prices and inventories (Masters (2008)); and increasing mutual causality between the current spot price, the spot price in the future, and the price for delivery in the future (Hannesson (2012)).

These findings have triggered concerns among policymakers that a surge of speculative forces has distorted the functioning of the commodity market with adverse consequences on final consumers' welfare.[1] Yet, the studies that have found a significant effect of financial participation on recent commodity price behaviour have been highly empirical in nature (Fattouh et al. (2012)). Our view is that appropriate policy actions should be consistent with both theory and evidence. Thus, there is a need to demonstrate if underlying shifts in financialization can produce changes in commodity prices that not only match the size and direction of actual observations but that can also hurt final consumers. A comprehensive test should also consider whether standard supply and demand shifts cannot better explain these same observations including the rise in

[1] In 2007, a US Senate Permanent Subcommittee on Investigations Staff Report determined that 'market speculation contributed to rising oil and gasoline prices, perhaps accounting for $20 out of a $70 barrel of oil.' (Senate (2006)). More recently, a United Nations body has called not just for tighter regulation of financial investors, and even, if all else fails, for surveillance authorities to be mandated to intervene directly in exchange trading to deflate commodity price bubbles or avert collapses (UNCTAD (2012)).

financial participation.

In this paper, we fill this gap. We focus on crude oil in part because oil takes a large share in financial investment in commodities (see Baker (2012) for evidence). But in principle our results would apply to any storable futures-traded commodity. We build an innovative calibrated macro-finance model of the oil market that distinguishes the incentives and constraints of purely financial intermediaries in the oil market.[2] The model is used to assess 'the financialization hypothesis': that the recent (post-2003) greater participation of purely financial players has significantly affected commodity market behaviour and damaged final consumers' welfare.

The model features oil consumers, financial speculators, and physical speculators (or inventory managers). We assume that financial speculators cannot store physical oil but hold oil futures in portfolios of financial instruments. Physical speculators can store oil, which they can either wait and sell in spot markets, or can write a contact for. Therefore, the model in this paper separates physical storage from oil production and the writing of oil contracts from production and final consumption. Since the breakup of the OPEC administered system in 1986 (Fattouh and Mahadeva (2013)), intermediaries have played a key role in managing the exposure of producers and final consumers to oil price volatility.[3]

The model solves for a term structure of oil prices. Distant prices can either be probabilistic expectations of the spot price or contracted futures prices. Inventory need not be fully hedged and there is a difference between the expected future spot price and the price of a contract determined now for that future date. A key feature is the separate endogenous determination of all three oil market prices (current spot, expected future spot, and the futures price) and the spreads between them (the risk premium, the basis, and expected spot appreciation) to current and future news. Each spread plays a differentiated role in determining the returns of each player. This stands in contrast to the empirical literature that links financial intermediary participation to price levels, without recognizing that the returns to intermediaries are in the

[2]See Smith (2009) for a survey of macro-finance models.

[3]Adrian et al. (2013) have shown that for a broad range of assets, broker-dealer leverage is a valid representation of the stochastic discount factor using equity and bond prices; a finding that supports an asset pricing theory which highlights the role of intermediaries. Yet in most of the commodity literature, the only speculator is the physical producer (it is assumed that the stock is held underground), this speculator sells inventory fully on the forward or futures market and the only counterparty to these sellers are consumers of spot oil (see for example Baker (2012)). Telser (1958), Stein (1987), and recently Hamilton and Wu (2012) do allow for short speculators who do not store on consume physical commodities. But they do not allow for physical speculators to partially hedge inventory or for distinct final consumers.

form of spreads. This matters because modelling the interplay of spreads brings out the role of margins through which structural changes such as financialization can be absorbed.

While welfare played a role in an early literature that discussed the costs and benefits of futures markets and price stabilization (Newbery and Stiglitz (1981) and Turnovsky (1983)), the recent literature has not sought to evaluate financialization in normative terms.[4] Whether or not financialization matters is thus left dangerously open. Büyükşahin and Robe (2011) argued that 'additional work is needed, if one is to ascertain whether the impact of financialization represents a welcome improvement in market efficiency or, instead, is a worrisome development.'

Our paper also fills this gap, by assessing financialization in terms of its impact on the welfare of final consumers. Consumers' welfare is completely consistent with spot demand for oil: both are derived from the same utility function and prices adjust to clear spot and futures markets. One of the main drivers of welfare is the predictability of consumption. The resulting welfare costs are measured in terms of compensating consumption adjustments to this utility function; in other words what percentage of current and future consumption should be sacrificed relative to the baseline to obtain equivalent utility.

Markets in this model are not complete. Final consumers cannot buy futures to hedge, financial speculators cannot store oil and physical speculators cannot access stock markets. To emphasize further that our results do not depend on implausible assumptions about the completeness of financial markets, we also explore the situation when there are unresolved disagreements about beliefs between physical and financial speculators. As shown recently by Sismek (2012), this means that a share of the outstanding futures contracts does not reflect risk-sharing, but rather pure speculation.

Our emphasis is on deriving quantitative predictions. While there are papers which have derived some of our predictions algebraically (Acharya et al. (2011), Alquist and Kilian (2010)), only by establishing the quantitative predictions of financialization can we compare them against the consequences of other structural changes. Even if the predictions are in the right direction, they may be of a minuscule size or better explained by other factors.

Our methodology is as follows. As a first step, we calibrate the model to match the period prior to 2003, since when there is great increase in financial participation. We then summarize

[4]The one exception is Baker (2012). His work differs from ours in that he allows for a bound on storage but does not separate financial speculators as we do. His results on the effect of a lower futures transaction costs seem complementary to ours.

the observed changes in oil market variables since 2003. This gives us some post-sample empirical observations that a valid theory should be able to match. Then we define a financialization shift as any shift in the preferences or constraints affecting financial speculators (those with no capacity to hold physical oil). By distinguishing financialization (a causal structural shift) from greater financial participation (a possible consequence), we allow for the possibility that the greater financial participation was caused by something else. In parallel, we also explore the consequences of shifts of the level and uncertainties in the supply of and demand for spot oil. These changes, independent of the preferences of purely financial intermediaries, act as controls in our experiments. The inclusion of these controls also serve to confirm that there is nothing inherent in our model that precludes consumer welfare from being affected by structural changes.

The quantitative effects of these shocks are compared both against observed changes in the financialization period compared to the past, and also against what we consider to be the predictions of the financialization hypothesis. Therefore we are testing the hypothesis in many dimensions: in quantitative terms, and for theoretical consistency, empirical plausibility, and against an alternative control explanation.

To summarize our findings, we reject the possibility that the financialization had much effect on oil market variables or final consumers welfare post-2003. In contrast, our numerical results suggest that shifts in the supply and demand for physical oil were more likely to explain the observed behaviour of spreads in this period and were more likely to have affected welfare. Not only that, our results suggest that physical supply and demand variations can more plausibly explain the correlated movement of oil prices with financial participation. Indeed, we show that this implication arises from a general property — not just of this model, nor depending on this calibration — that financialization changes must have equal and opposite effects on near and distant prices: they can only twist the term structure of spot prices but not shift it up or down. Unless consumers are very differentially affected by near and future prices, which seems unlikely, a financialization change needs to be large to have the same effect on welfare as a supply or demand shift (which can raise and lower the entire spot term structure). We show that if a financialization change of this magnitude were to happen, two key spreads — the inverse basis and the risk premium — would have move apart to a very great extent. This does not seem to have happened post-2003. We also show that our results hold true even when we allow a significant role for pure speculation as opposed to just risk-sharing in the futures trade.

The paper is structured as follows. In Section 2, we present the model. Next, in Section 3 we explain the most important and generalizable properties of the model. There we also justify the simplifying assumptions. We go on to assess the data on financialization and oil prices in Section 4. In Section 5, the model is calibrated and the design of our experiments to test the financialization hypothesis is explained. We present the first block of our results on matching oil market behaviour in Section 6. Section 7 extends the model to explain consumer welfare. Section 8 presents a further extension where we allow for belief disagreements and pure speculation, a stronger departure from complete markets and rational expectations. Section 9 concludes.

2 The Model

The model is of two periods and essentially describes only three groups of agents. Physical speculators can store oil and either sell it in the future or sell it forward now. It is assumed that they pay the cost of delivery to the final consumer. Financial speculators trade in futures, riskless bonds and risky shares. Consumers only buy in spot markets and producers can only sell in those markets. Storing oil incurs a fixed per unit cost of carry offset by a convenience yield. In what follows all lower case variables denote logs.

2.1 Physical speculators

The financial decision of speculators is modelled as in Campbell et al. (2003). The physical speculators' objective is to maximize a power utility function in their next period wealth:

$$U_{r,1} = \mathbb{E}_0[\frac{(W_{r,1})^{1-\tau_r}}{1-\tau_r}] \tag{1}$$

with wealth in period s denoted by $W_{r,s}$. Wealth evolves according to:

$$W_{r,1} = W_{r,0}((1-\alpha_{r1,0}-\alpha_{r2,0})(1+r_f) + \alpha_{r1,0}\frac{P_1 C_{q1,1}}{P_0} + \alpha_{r2,0}\frac{F_0^1 C_{q2,1}}{P_0}) \tag{2}$$

where P_s is the price of oil in period s $(s = 0, 1)$, and F_0^1 is the price of oil contracted at time 0 to be delivered at time 1.

$\alpha_{r1,0} + \alpha_{r2,0}$ is the share of wealth spent on purchasing oil to store in physical inventory while $\frac{\alpha_{r2,0}}{\alpha_{r1,0}+\alpha_{r2,0}}$ is the share of carry over value sold forward (also called the *hedge ratio*). In the extreme case that $\alpha_{r1,0} = 0$ and $\alpha_{r2,0} = 1$, all wealth is invested in oil and the entire value of carry over is hedged, such that the gross return will be $\frac{F_0^1 C_{q2,1}}{P_0(1+r_f)}$. The physical speculator cannot take a position unbacked by physical quantities. The rest of wealth is invested in bonds earning a risk-free rate of r_f.

The variables $C_{q1,1}$ and $C_{q2,1}$ play important roles in helping our model match the available data on spreads. They combine the convenience yield (a positive influence on physical speculators returns) with constant proportionate storage and transport costs (a negative influence). In the case of the futures position, there is also uncertainty about the margin. In log terms, we write them respectively as as:

$$c_{q1,1} = \bar{c}_{q1} - \varrho_1 prob(P_1 > P^*) \text{ and } c_{q2,1} = \bar{c}_{q1} - \varrho_2 prob(P_1 > P^*) - c_{g,1} \tag{3}$$

We focus on the convenience yield as is expected to be the most important component affecting returns, offsetting transport and storage. The convenience yield is, intuitively, a unremunerated carrying charge that only physical storers enjoy for having unique access to the physical product in the event of a shortage. It enters this expression because we assume the final buyer pays for the convenience yield to the physical speculator through the intermediary, net of storage costs. We assume that the larger the likelihood of very high prices in the next period, the greater the likelihood of a disruption and the greater the convenience yield payment. In keeping with the conclusions of those studies that have modelled the convenience yield in some depth (such as Casassus and Collin-Dufresne (2005) and Pirrong (2012)), this implies that the convenience yield is greater when underlying volatility is higher, is dependent on the expected price level and on the intrinsic likelihood of a non-mean reverting jump.[5]

Formally, the endogenous component of the yield is a function of there being a price level greater than a trigger price P^* (where $P^* > \mathbb{E}_0[P_1]$), or $prob(P_1 > P^*) = prob(p_1 > p^*) = 1 - \phi(\frac{p^* - \mathbb{E}_0[p_1]}{Var_0[p_1]^{0.5}})$ using the standard normal cumulative distribution $\phi(.)$. ϱ_1 and ϱ_2 are the respective elasticities of the convenience yield in the spot and futures price. As far as we know, the literature has not discussed whether hedged oil is likely to be more convenient than unhedged oil. So we leave this open to the calibration, and it turns out to be the case that the second

[5]This is an analytically convenient specification. In much of literature, the convenience yield is modelled explicitly as arising from the combination of lumpy inventory replenishment, short-term costs of changing output, time delays and on the presence of a lower bound on physical storage. In our experiments, we do not alter the parameters that determine our convenience yield function.

elasticity will be much greater than the first. $\bar{c}_{q1}$ is a constant component of the convenience yields implicitly net of transport and storage costs.

There is also a stochastic proportionate transaction return for writing short futures contracts ($c_{g,1}$) that is redistributed between the two counterparties to the contract and is mean zero in log terms. If $c_{g,1} > 0$, this would imply a negative return on margin for physical speculators.[6]

Proposition 1. *The solution to the physical speculators' problem of maximizing 1 subject to 2 by choice of $\alpha_{r1,0}$ and $\alpha_{r2,0}$ is approximately given by:*

$$\begin{aligned}\boldsymbol{\alpha}_{r,0}^T = & \frac{1}{1+\tau_r} \times (\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f \boldsymbol{\iota} \\ & + \frac{1}{2} diag(\mathbf{Var}_0[\mathbf{r}_{rs,1}]) + \frac{1}{2} diag([\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f \boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f \boldsymbol{\iota}]^T)) \\ & \times (\mathbf{Var}_0[\mathbf{r}_{rs,1}] + [\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f \boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f \boldsymbol{\iota}]^T)^{-1}\end{aligned} \tag{4}$$

where

$$\boldsymbol{\alpha}_{r,0} \equiv \begin{bmatrix} \alpha_{r1,0} \\ \alpha_{r2,0} \end{bmatrix} \quad \textit{and } \mathbf{r}_{rs,1} \equiv \begin{bmatrix} p_1 + c_{q1,1} - p_0 \\ f_0^1 + c_{q2,1} - p_0 \end{bmatrix}$$

$diag(\boldsymbol{A})$ signifies a vector made of the elements of matrix $\boldsymbol{A}$ and $\iota \equiv [1, 1]$.

Proof. See appendix 10.1.

The amount of carry over is related to the value invested:

$$Q_0 = \frac{W_{r,0}(\alpha_{r,1} + \alpha_{r,2})}{P_0} \tag{5}$$

As shall be shown below, a supply of storage services function follows from substituting the first-order condition (4) into expression (5).

2.2 Financial Speculators

Financial speculators have no capacity to hold inventory. This means that they expect to gain from the difference between the spot price on maturity of the futures contract and the contract price. It also means that in period 0 they do not have to sacrifice any wealth to enter into this futures contract. They also earn a gross return of $R_{e,1}$ from other investments in

[6] By introducing some risk to futures, we can determine how much wealth is held in risk-free bonds as opposed to hedged oil. In practice there is some stochastic element to futures participation (Hirshleifer (1988)).

shares. Futures transactions earn an additional stochastic element, redistributed from physical speculators. Thus their objective is to maximize

$$U_{s,1} = \mathbb{E}_0[\frac{(W_{s,1})^{1-\tau_s}}{1-\tau_s}] \tag{6}$$

subject to a budget constraint,

$$W_{s,1} = W_{s,0}((1-\alpha_{s2,0})(1+r_f) + \alpha_{s1,0}\frac{P_1 C_{g,1}}{F_0^1} + \alpha_{s2,0}R_{e,1}) \tag{7}$$

where wealth in period 1 denoted by $W_{s,1}$, $\alpha_{s2,0}$ is the share of wealth held in risky equity as opposed to riskless bonds and $\alpha_{s1,0}$ is the value of the futures commitment in terms of period 0 wealth. $\alpha_{s1,0}$ is not a share, as a futures position is essentially a bet rather than an investment.

Proposition 2. *The solution to the financial speculators' problem of maximizing 6 subject to 7 by choice of $\alpha_{s1,0}$ and $\alpha_{s2,0}$ is approximately given by:*

$$\begin{aligned} &\frac{1}{(1+\alpha_{s1,0})}\boldsymbol{\alpha}_{s,0}^T = \frac{1}{1+\tau_s} \\ &(\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota} + \frac{1}{2}diag(\mathbf{Var}_0[\mathbf{r}_{ss,1}]) + \frac{1}{2}diag([\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota}]^T)) \\ &\times (\mathbf{Var}_0[\mathbf{r}_{ss,1}] + [\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota}]^T)^{-1} \end{aligned} \tag{8}$$

where

$$\boldsymbol{\alpha}_{s,0} \equiv \begin{bmatrix} \alpha_{s1,0} \\ \alpha_{s2,0} \end{bmatrix} \; and \; \mathbf{r}_{ss,1} \equiv \begin{bmatrix} p_1 + c_{g,1} - f_0^1 \\ r_{e,1} \end{bmatrix}$$

Proof. See appendix 10.1.

2.3 The Spot Market

The objective of final consumers is to maximize their utility from consumption over both periods

$$U(C_{c,0}) + \beta\mathbb{E}_0 U(C_{c,1}) \tag{9}$$

where β is the discount rate and it is assumed that each period's utility is of the power form,

$$U(z) = \frac{(z)^{1-\chi} - 1}{1-\chi} \tag{10}$$

and that total consumption $C_{c,s}$ is a CES aggregate of the consumption of purchases of spot oil (X_s) and other items (Y_s),

$$C_{c,s} = \lambda_s \left[\Gamma^{\frac{1}{\omega}} (X_s)^{\frac{\omega-1}{\omega}} + (Y_s)^{\frac{\omega-1}{\omega}} \right]^{\frac{\omega}{\omega-1}} \tag{11}$$

with $\lambda_s \equiv (\frac{1}{1+\Gamma^{\frac{1}{\omega}}})^{\frac{\omega-1}{\omega}}$ for $s = 1, 2$.

The consumers' demand for oil in each period is then

$$X_s = Y_s \Gamma P_s^{-\omega} \tag{12}$$

with P_s being the real price of oil in terms of the price of the other items.

The total demand for spot oil is an aggregate of consumer demand and physical speculators' carry over[7][8]

$$D_0 = X_0^{\varsigma} Q_0^{1-\varsigma} \text{ and } D_1 = X_1^{\varsigma} (Q_0)^{-(1-\varsigma)} \tag{13}$$

The supply of oil combining exploration and extraction is given by a simple function[9]

$$O_s = G_s P_s^{\theta} \tag{14}$$

[7]Strictly speaking, the price of carry over should be distinguished from that received by producers according to $P_{r,s} = P_{o,s}^{\frac{1}{1-\varsigma}} P_s^{-\frac{\varsigma}{1-\varsigma}}$ since final demand and carry over are not perfect substitutes. But as it would complicate the presentation to have different prices we assumed that both of these are equal to the final consumer's price. This assumption would be consistent if physical speculator demand and final consumer demand were in a fixed proportion: $\frac{X_s}{D_s} = \frac{\varsigma}{1-\varsigma}$.

[8]In contrast to much of the theory of storage literature exemplified by Pirrong (2012), we do not impose the condition that inventory can be non-negative. This is not because we do not think that this condition is unimportant or unrealistic but rather that we do not think that it affects our main results concerning welfare. Allowing for this constraint into our analysis would substantially complicate our numerical solution technique.

[9]This can be replaced by any model of spot oil supply. For example we could incorporate the possibility of exhaustibility, extraction costs, and monopolistic or collusive behaviour.

Equating demand and supply at periods 0 and 1 and rearranging we have:

$$P_0 = A\Delta_0 Q_0^{\eta} \text{ and } Y_1^{\varsigma}\Gamma_1^{\varsigma}P_1^{-\omega\varsigma}Q_0^{-(1-\varsigma)} = G_1 P_1^{\theta} \Rightarrow \mathbb{E}_0 P_1 = \mathbb{E}_0 A\Delta_1 Q_0^{-\eta} \tag{15}$$

where $\eta \equiv \frac{1-\varsigma}{\theta+\omega\varsigma}$, $\Delta_s \equiv G_s^{-\frac{1}{\theta+\omega\varsigma}} Y_s^{\frac{\varsigma}{\theta+\omega\varsigma}}$ and $A \equiv \Gamma^{\frac{\varsigma}{\theta+\omega\varsigma}}$. The spot price of oil (P_s) depends on preferences (Γ), the net supply of spot (Δ_s), as well as the amount taken out of circulation in period 0 and released in 1 (Q_0).

In order for the futures markets to clear it must be that

$$W_{r,0}\alpha_{r2,0} = W_{s,0}\alpha_{s1,0} \tag{16}$$

while the physical inventory market settles according to equation (5).

2.4 Stochastic Processes

Y_1, G_1 , $R_{e,1}$ and $C_{g,1}$ are log-normally distributed such that

$$\begin{aligned}
y_1 &= \rho_y y_0 + (1-\rho_y)\mu_{y,1} + e_{y,1} \\
g_1 &= \rho_g g_0 + (1-\rho_g)\mu_{g,1} + e_{g,1} \\
r_{e,1} &= \rho_{r,e} r_{e,0} + (1-\rho_r)\mu_{re,1} + e_{re,1} \text{ and} \\
c_{g,1} &= e_{cg,1} \qquad (17)
\end{aligned}$$

where $\mathbf{e}_1 \equiv [e_{y,1}, e_{g,1}, e_{re,1}, e_{cg,1}]$ is a vector of normally distributed processes with zero means and respective variances, $[\sigma_y^2,\ \sigma_g^2,\ \sigma_r^2,\ \sigma_{cg}^2]$. For simplicity the only non-zero covariance between these processes is between the return on risky assets and world demand (σ_{yre}).

The unconditional mean values of the logs of Y_s, G_s, $R_{e,s}$ and $C_{g,s}$ are $\mu_{y,s}$, $\mu_{g,s}$ and $\mu_{re,s}$ (for $s = [0, 1]$). All these values are exogenous. The initial values y_0, g_0 and $r_{e,0}$ in the baseline are set at their initial means but can differ from these values in experiments. The convention is that only variables dated 0 or earlier are known at 0, the exceptions being $\mu_{y,1}$, $\mu_{g,1}$ and $\mu_{r,1}$ which are known a period earlier. Our calculations depend on straightforward expressions for the distributions of P_1 and $R_{e,1}$; of X_1 and D_1; of p_1, y_1 and x_1, all conditional on time 0 information as well as expressions for X_0 and D_0. (See Appendix 10.2).

3 Features of the Model and General Properties

3.1 The Term Structure of Spot Prices

The model describes two reactions to financialization shifts that would apply to much wider class of models.

A crucial general property follows straightforwardly from equation 15, according to which there is an inverse relationship between the term structure of spot prices that is completely independent of any changes in the financial layer. A higher carry over must raise the current spot price and lower the expected spot price: $P_0\mathbb{E}_0P_1 = A^2\Delta_0\mathbb{E}_0[\Delta_1]$, but the term $A^2\Delta_0\mathbb{E}_0[\Delta_1]$ depends only on physical demand and supply forces. Therefore financial shifts can only tilt but not shift the term structure of spot prices, and only raise the expected spot price in so far as they lower the current spot price or vice versa, by the same amount (approximately):

$$\%\delta\mathbb{E}_0[P_1]|_f \approx -\%\delta P_0|_f \tag{18}$$

where $\%\delta X|_f$ indicates the percentage change in X as a consequence of a shift in the financial layer. In more general models where $P_0 = f(A, \Delta_0, Q_0)$ and $\mathbb{E}_0[P_1] = \mathbb{E}_0 g(A, \Delta_1, Q_0)$ with $\frac{\partial f(.)}{\partial Q_0} \approx -\frac{\partial g(.)}{\partial Q_0} > 0$, property 18 must also hold (although as a poorer approximation).

It follows that, in order for financialization shifts to significantly affect consumers, their welfare must be highly differentially sensitive to twists in the term structure of spot prices. A high differential sensitivity to intertemporal prices, we would confidently argue, does not correspond to a plausible description of what movements in oil prices means to consumers.[10] Therefore property 18 represents an important restriction on the policy implications of financialization shifts, which is new to the literature.

Now consider the relationship between shifts in the risk premium and the inverse basis, both arising from an underlying drive towards greater financialization:

$$\begin{aligned} &\%\delta\mathbb{E}_0[P_1]|_f - \%\delta F_0^1|_f \approx \%\delta P_0|_f - \%\delta F_0^1|_f + \%\delta\mathbb{E}_0[P_1]|_f - \%\delta P_0|_f \\ &\Rightarrow \%\delta\mathbb{E}_0[P_1]|_f - \%\delta F_0^1|_f + (\%\delta F_0^1|_f - \%\delta P_0|_f) \approx -2\%\delta P_0|_f \approx 2\%\delta\mathbb{E}_0[P_1]|_f \end{aligned} \tag{19}$$

[10] To take an example, OBR (2010) estimated that the shares of fuel for motoring and electricity and gas bills in the UK consumers' budget are each about 4%. The passthrough of oil prices onto forecourt prices will be a question of a few months, where gas and electricity for the home may be on more fixed contracts and depend on expectations of next period prices.

Thus following a financialization shift, spot prices will only be significantly affected to the extent that there is a large differential reaction between the risk premium and the inverse basis. If a financialization shift were a phenomenon that merits consumer protection, then we should observe (or at least be able to infer) this large differential behaviour in spreads.

The behaviour of spreads in the model is thus of great importance. According to equation (4), the ratio of the values invested by physical speculators in each type of risky asset — hedged and unhedged oil — is independent of their own risk aversion.[11] But the internal margin between the hedged and unhedged inventory of physical speculators can, however, adjust to protect physical speculators' returns from shifts in the risk aversion of their counterpart, and other financial layer changes. Indeed by manipulating the hedging ratio, physical speculators can achieve returns closer to those of financial speculators. For example, a strategy of buying hedged inventory and selling unhedged inventory with the former at a proportion of $\frac{\mathbb{E}_0 P_1}{F_0^1}(\frac{P_0}{F_0^1} - 1)$ to the latter will yield a net return of $\frac{\mathbb{E}_0 P_1}{F_0^1}$ (abstracting from uncertainty or the convenience yield). Thus the physical speculator can reduce his exposure (or even eliminate it) to the spot price at the cost of increasing exposure to the financial speculators' expected return. If there is a structural change that affects the spot price but not the risk premium, the physical speculator can immunize themselves such that the amount of inventory they hold will be less affected. There is no possibility for this in models where the futures and the expected spot price are equal such as French (1986) or Alquist and Kilian (2010).[12]

3.2 The Market for Storage

We can provide more intuition on its mechanics by recasting the model in terms of the market for storage services. Combining equations 5 and 15 and rearranging gives us *the demand for storage services function*:

$$Q_0 = \left(\frac{\Delta_0}{\mathbb{E}_0[\Delta_1]} \frac{\mathbb{E}_0[P_1]}{P_0}\right)^{\frac{1}{2\eta}} \tag{20}$$

[11]This separation property does not, however, hold for the financial speculator because their futures position does not take a share in a portfolio (Lioui and Poncet (2005)). Proposition 1 is familiar from Campbell et al. (2003), but proposition 2 is, to our knowledge, new.

[12]The absorbing potential of a portfolio in which unhedged oil is but one asset was discussed in the early literature. See Dusak (1973).

The storage supply function is more complicated. To begin with, we can substitute for the current price from equation 15 into the clearing of inventory 5 and rearrange to give

$$Q_0 = \left(\frac{W_{r,0}(\alpha_{r,1} + \alpha_{r,2})}{A_0\Delta_0}\right)^{\frac{1}{1+\eta}} \tag{21}$$

According to the physical speculators' optimizing condition (4) the supply of carry over is an increasing function of both the expected appreciation and the basis: $\frac{\mathbb{E}_0[P_1]}{P_0}$ and $\frac{F_0^1}{P_0}$:

$$(\alpha_{r,1} + \alpha_{r,2}) = f(\ln(\frac{\mathbb{E}_0[P_1]}{P_0}), \ln(\frac{F_0^1}{P_0}))$$

Matching the short futures (equation (4) for $\alpha_{r,2}$) and long futures positions (equation (8) for $\alpha_{s,1}$) through futures market clearing (equation (16)), we can associate the basis with expected appreciation:

$$\ln(\frac{F_0^1}{P_0}) = g(\ln(\frac{\mathbb{E}_0[P_1]}{P_0}), \kappa)$$

Financialization parameters (such as financial speculator risk aversion τ_s or resources $W_{s,0}$) are summarized by a typical financialization parameter, κ. In contrast to most expositions where the risk premium plays no role (and where $\frac{\mathbb{E}_0[P_1]}{F_0^1} = 1$), financialization parameters affect the oil market only through this futures market relationship. Now we substitute for the basis into equation (21) to give

$$Q_0 = \left(\frac{W_{r,0}(f(\ln(\frac{\mathbb{E}_0[P_1]}{P_0}), g(\ln(\frac{\mathbb{E}_0[P_1]}{P_0}), \kappa)))}{A_0\Delta_0}\right)^{\frac{1}{1+\eta}} \tag{22}$$

Equation 22 is the upward sloping *supply of storage function* in our simplified market.

The most familiar analogue in the literature to equation (22) is Working (1948)'s supply of storage function according to which, as the interest-adjusted basis falls below zero, there is a greater incentive to carry over inventory to the future. But Working allowed other factors to also affect the supply of storage; indeed his main point was that the extent of weak backwardation is not a complete description of the return to fully hedged inventory. There are storage costs and, at low levels of inventory, a strong convenience yield that also weighs heavily on the incentive to carry over. The question here is whether financialization also can impinge on the supply of storage function so as to reduce the amount of carry over and raise the spread.

3.3 The Behaviour of the Final Consumer

Another point of discussion is our simplifying assumption about consumption behaviour. To clarify, here the amount of other items consumed is determined exogenously, as a stochastic endowment. Given expectations about the relative price of oil and their consumption of other items, consumers choose how much oil to consume. This determines their total consumption, their utility, and welfare. An unpredictable oil price will thus lower their utility.

We could instead have allowed for consumers to adjust total consumption intertemporally through saving, or even through their purchases of oil-consuming capital goods. If intertemporal adjustment were possible, we should consider the first-order conditions for spot oil final consumption at time 1 as,

$$\Gamma^{\frac{1}{\omega}}\mathbb{E}_0[(X_1)^{\frac{-1}{\omega}}(C_{c,1})^{\frac{1}{\omega}}] = \mathbb{E}_0[P_1\,(Y_1)^{\frac{-1}{\omega}}(C_{c,1})^{\frac{1}{\omega}}] \tag{23}$$

and obtain a solution for demand that takes non-linearities into account. Without intertemporal substitution, we can proceed with the linearized solution (12). Intertemporal optimization would also complicate the analysis substantially by making total consumption endogenous.

Does this matter? Intuitively, ruling out consumption smoothing and precautionary saving would mean that we are exaggerating the effects of financialization. As we find the effects to be nonetheless weak, our conclusions will most likely be strengthened by this extension. A similar argument applies to production, where we have also ruled out smoothing.

4 Evidence on Financialization and Changes in Oil Market Behaviour

Chart 1 plots the net long positions of non-commercial traders (excluding swap dealers) in WTI futures markets against the real oil price. We can identify, as others have done, a shift in the average level of participation beginning roughly in 2003. The oil price seems to have risen as financialization has increased. But it is also noteworthy that the broad trends of greater financialization and a higher price level were reversed during the second half of 2008, when the severity of the financial crisis became clear. One can validly challenge whether the net long positions of non-commercial traders measure represents an appropriate measure of speculative pressure (Büyükşahin and Harris (2011)), but as we are only interested at this point in identifying a date, in what follows, we take the period July 1986 to December 2002 to be our baseline, and the period since 2003 to be the era of greater financialization.

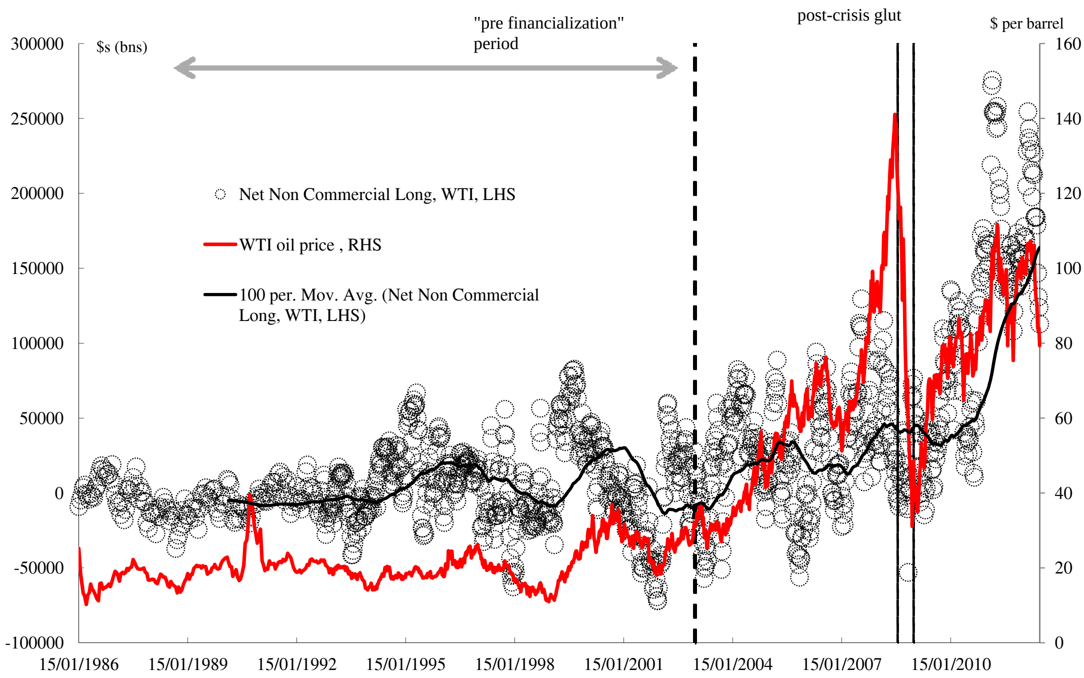

Chart 1: Net long positions of non-commercial traders and the Oil Price [a]

[a]Dark line indicates the 10 month moving average. Source: CTFC reports, St Louis Fed. and own calculations.

Chart 2 plots a measure of the inverse basis ($\ln(\frac{P_0}{F_0^1})$). As we have defined it in this paper, the basis — the future minus the spot price — is the simple return from hedged storage. The complete net excess return would also adjust for the convenience yield, futures participation costs, storage costs, risk premia, and the risk-free rate (the latter as the opportunity cost). Of these excluded components, we can assume that the convenience yield varies the most. In order for there to be no arbitrage such that the net return to storage is constant, the basis and the convenience yield must move against each other. In Chart 2, we can see that the net convenience yield — proxied by the inverse basis — rose up to a peak in 2003 and from then on has declined, interrupted only by a temporary reversal during 2006–2008. These movements in the inverse basis should be explained by an acceptable theory of post-2003 events. As the inverse basis displays similar behaviour in Brent and WTI, the pattern is not due to the pipeline frictions at Cushing (Borenstein and Kellogg (2012)). (Later on we discuss the importance of inventories, also in the chart).

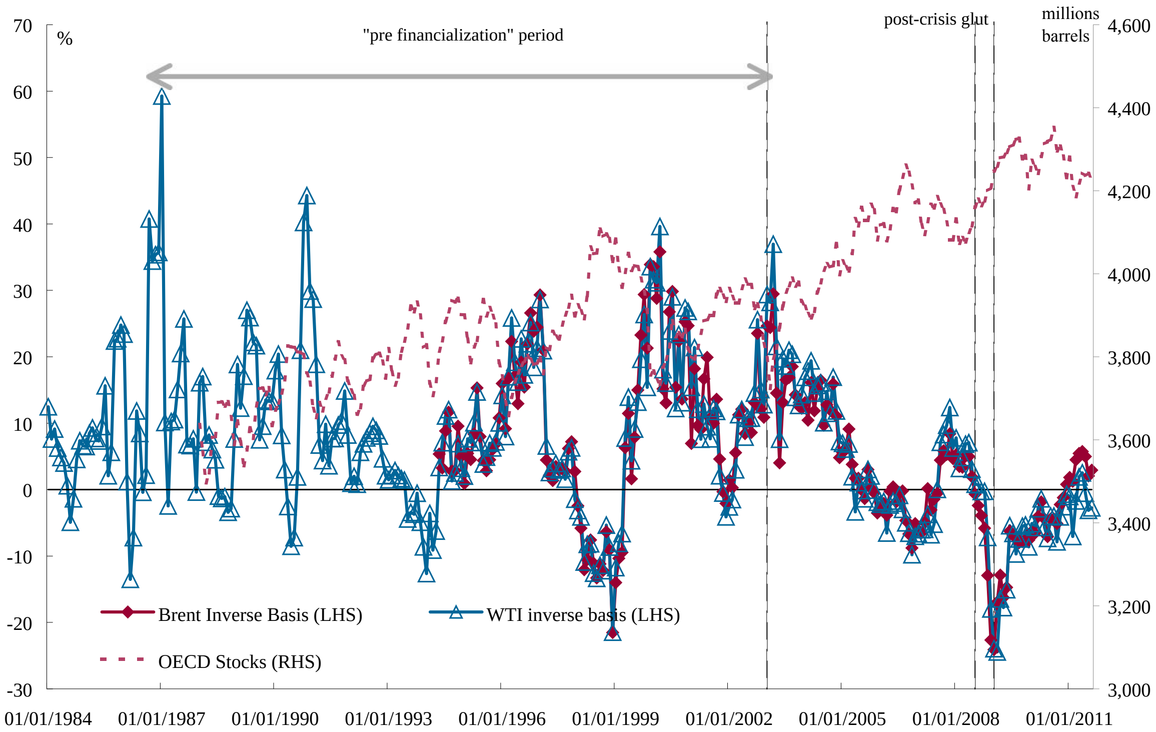

Chart 2: Real Inverted Basis (1 mnth versus 12 mnths, arithmetic)[a]

[a]Source: Bloomberg and own calculations. OECD Total Petroleum Stocks, End of Period (Millions Barrels)

Table 1: Behaviour across Different Financialization Regimes

Variable	July 1986 — Dec. 2002 Average	Jan. 2003 — Jan. 2012 Average	Units Units
Real Oil Price	15.2	36.4	Jan. 1986 $s
Real Inverted Basis	9.4%	1.9%	Annual Arithmetic Return
Interest-Rate Adjusted Real Convenience Yield	9.5%	1.1%	”
Std Devn (Annual)	31.3 pp	34.4p	of Annual Arithmetic Increase
Real Oil Price Appreciation	4.8%	17.5%	Annualized Monthly Arithmetic Increase
Excess Ex-Post Real Return	13.3%	19.2%	Annual Arithmetic Return

Source: St Louis Federal Reserve, own calculations.
Notes : Real values calculated using US CPI excluding food and energy. All oil price data based on the NYMEX WTI futures with the one-month ahead substituting for the current spot price. Treasury Bill Rates at annual maturity for the convenience yield. Excess returns assume that a 12 month contract is held until just before maturity.

Table 1 summarizes these and other differences in key variables between the pre- and post-financialization regimes. According to the first four rows of Table 1, the inverse basis ($100 \times (\frac{P_0}{F_0^1} - 1)$) has fallen by 7.5pp from (9.4 to 1.9%), and by 8.4% in interest-rate adjusted terms as the real oil price has doubled. Also the unpredictability of oil price appreciation is higher, at least in terms of the 12 month horizon oil price.[13] In market parlance, then, following financialization, a doubling of the oil price and a slightly higher long-term volatility, the market has gone from market backwardation to having an inverted futures curve. This constellation of firm stylised facts should fit any valid explanation.

Much more tentatively, we can conclude that appreciation has risen post-financialization and that the risk premium moves in the same direction as the current spot price. A simple calculation of the ex-post appreciation of real oil prices (an ex-post measure of the return to *unhedged* storage enjoyed by the physical speculator, $100 \times (\frac{\mathbb{E}_0[P_1]}{P_0} - 1)$) is on average higher post-2003. But we should be careful to draw to much from this, given the high volatility and the dominance of the temporary fall in the oil price in 2008 in the sample. Hence we do not base our calibrations on any firm prior knowledge of the size of the shift in expected appreciation, but just expect a higher appreciation. Table 1 also reports the ex-post return on financial speculation, which is a realization of the unobservable risk premium for purely financial speculators ($100 \times (\frac{\mathbb{E}_0[P_1]}{F_0^1} - 1)$), and which appears to be on average higher post-2003. However Plante and Thies (2012) document that financial speculators' average annualized oil returns were much higher from 2002-2007 and much lower in the most recent five years to February 2012 compared to the period 1984-2002, roughly describing a pattern where the risk premium moves in the same direction as the current spot oil price. As they use more appropriate data on commodity indices, we prefer to conclude that movements in the risk premium should be positively related to those in the current oil price.[14]

While it should be remembered that these averages mask substantial interperiod variation and non-linearity, these differences seem significant and are echoed in the arguments of those who would link the surging volume of financial flows into the oil market to a different oil market behaviour. The challenge is to establish that these shifts in behaviour between the two periods

[13] The monthly oil price volatility has fallen slightly in the period of increased financialization such that in the recent period, the long-horizon volatility is greater than the short-horizon volatility. Recently Pástor and Stambaugh (2012) have shown in the context of equity returns that long-horizon volatility can be greater than its short-run counterpart as the nature of uncertainty overrides mean reversion.

[14] See also Hamilton and Wu (2012).

are due to financialization shifts rather than other contending factors or explanations.

The simple visual comparison between participation and the oil price in Chart 1 certainly does not imply causation. An alternative explanation for the different oil price behaviour has little to do with financialization. For example Kilian (2009), Kilian and Murphy (2010), Plante and Yücel (2011a) and Plante and Yücel (2011b) have argued convincingly that since 2000, aggregate demand increased strongly and more persistently than before, driving up oil prices.[15] At the end of 2002, oil stocks were low following also a strike in Venezuela, the Gulf war and disruptions in Nigeria (Chart 2). Chart 2 shows that stocks recovered strongly from 2002 until 2006, presumably in anticipation of even stronger demand going forward (Kilian and Murphy (2010)). As we would expect, this drive was accompanied by a fall in the convenience yield (a falling inverse basis). In 2006, demand proved to be so strong that stocks were run down slightly and the convenience yield rose briefly. But in mid-2008, when the financial crisis struck home, the demand for oil fell and stocks accumulated again. As the market suddenly absorbed the implications of the crisis, the oil price fell sharply in the following six months. Steep though it was, the fall in the price level was remarkably short-lived — the level rose back in January 2009 (Chart 1). But the inverse basis returned once more to its prolonged slide: there is little need for convenience during a prolonged recession as long as there are high levels of stocks.[16] Thus it may well be that shifts in the expected supply and demand for crude oil have implied changes in financialization, and not the other way round.[17]

5 Experiment Design

5.1 Calibration and Solution of the Baseline

Our baseline calibrations are determined by the pre-2003 data. We take the risk-free rate to be 3.5%, based on an estimate of the average real Treasury Bill Rates at a ten year maturity in this period. The mean and variance of the log returns on equity were set so as to match the mean and standard deviation of arithmetic real annual returns on the S&P pre-2003 (8.6% and 16.9pp respectively). We did not allow for any autoregression in annual share returns. But we built in

[15] Foss and Gülen (2012) annotate a more complete set of demand and supply shifts since 2002.

[16] One must be careful about linking stocks to the basis too mechanically as stocks can be badly measured and other factors can shift this relationship.

[17] The last possibility is that changes that have occurred in both that are largely independent, but then one would have to argue that the co-movement in Chart 1 is down to coincidence.

a conditional correlation with world demand of 0.2, in keeping with the data. Judging from data on world GDP, the standard deviation of log demand for oil was 5 % and the autoregression at about 0.4. The growth in world demand is set at the growth in world GDP, 5.8%. We set the parameters of risk aversion for physical and financial speculators and also consumers to be at 2. Estimates abound in the literature, but if there is a consensus, it would be at 2.

The elasticities of oil supply and demand were set at 0.25 and -0.25 respectively. The demand elasticity is close to the median estimate of the use elasticity by Kilian and Murphy (2010) that takes account of inventories. The supply elasticity is higher than impact elasticities seen in the literature, but the second period can be interpreted as the long run, where elasticities close this value are common. The other parameters were ς, the nominal share of oil taken to inventory relative to sales for final consumption, which we set at 10%. This is meant to roughly approximate the ratio between absolute changes in US commercial and strategic inventories and US final consumption. Γ, the share of oil in consumption in both periods, is set at 5%. The mean and variance of supply were set to match an estimate of the pre-2003 period expected appreciation of the spot price level and its standard deviation. Supply is expected to diminish at a rate of 0.8%.

Values for the parameters that describe the net convenience yield (in equation 3) are not observable. Standard calculation on the storage cost of oil would make it small as a proportion of an oil price of around \$100. Though, to this we must add transport costs. And against these we might have an offsetting large constant benefit of convenience. Our solution was to calibrate these parameters so as to match the pre-2003 average estimates of the basis and the risk premium. In a similar fashion, we set the standard deviation of futures transactions cost (σ_{cg}) at 3% so as to target a share of risk-free assets for physical speculators of between 5 and 10%. (Our results were robust to values below this to even 0.5%). The price trigger for convenience (P^*) was set at two and a half times the mean price in the baseline.

The model comprising equations 4, 5, 8, 15, 16, and 17[18] was solved numerically given these parameters and a sensible starting point for the portfolio shares of physical and financial speculators. This solution was taken to be the baseline.

In our baseline, the basis was 10%, the risk premium, 13%, and expected appreciation, 3%. The conditional standard deviation of the expected oil price level as a ratio of the level was 30%, close to the value in Table 1 for the pre-financialization period. The long futures' position

[18]Equation 17 and 15 combine to give expressions for the log returns to the speculators. See Appendix 10.2.

($\alpha_{s,1}$) was 54% of financial speculator wealth ($W_{s,0}$), which was in turn about 36% greater than of that of physical speculators ($W_{r,0}$). $1-\alpha_{r,1}-\alpha_{r,2}$, the share of wealth of physical speculators held in risk-free assets, was at 7%. Their hedging ratio ($\frac{\alpha_{r,2}}{\alpha_{r,1}+\alpha_{r,2}}$) was 79%, close to Mexico's 70% hedging of its total reserves. The financial speculators' share of wealth held in risk-free assets ($1-\alpha_{s,2}$) was 4%. The exogenous component of the net convenience yield, $\bar{c}_{q1}$, was about half of the final price (0.48) and while the elasticity of the convenience yield on unhedged oil, ϱ_1 , was 0.12, the elasticity on hedged oil, ϱ_2, was larger at 0.50.

5.2 The Simulations

In this section, we explain and justify our experiment design . We attempt to understand by how much these parameters might have shifted in the data. That said, we prefer to consider the scale of our experiments more as starting points, or guidelines, rather than attempts to fit the data closely.

We simulate for two specific shifts to the underlying preferences or constraints on purely financial speculators: first a fall in the risk aversion of financial speculators and, second, a rise in the financial resources they can muster to buy shares or risk-free assets.

The fall in risk aversion is meant to proxy changes in the constraints facing financial investors. Indeed, in Acharya et al. (2011), the risk aversion parameter is interpreted as a binding leverage ratio. Bekaert et al. (2010) estimate that an empirical measure of risk aversion fell during the mid-2000s based on the implied volatility of share prices. Thus a fall which puts this parameter halfway towards risk neutrality seems both plausible and substantial enough to be a good starting point. Formally, we experiment with a fall in the financial speculators' risk aversion (τ_s) from its baseline value of 2 to 1.5.

As for the increase in wealth, we were wary of estimating this from untreated data on financial volumes, such as that in Chart 1, because this includes intra-financial trade. Some simple evidence of underlying financial wealth is provided by Brandmeir et al. (2012) who show that the net financial assets of the private households in 52 main countries increased year on year from 2003 to 2007, fell in 2008 and increased again slowly in 2009-2012, matching the financialization pattern (qualitatively at least). The annual rises they estimate were not large, of the order of 3-5%, and are of a much smaller scale than the increases in gross assets of financial firms which include claims on each other and do not adjust for liabilities. In keeping with this, we simulate for a rise in financial speculators' wealth ($W_{s,0}$) by 25%.

Of course, there are many other possible types on underlying financialization shifts that could have taken place. Recently there has been much discussion about the effect of a lowering of the risk-free interest rate, which is presumed to promote more risk-taking.[19] Another possible experiment could be to lower financial transaction costs. Baker (2012) has explored this effect and found it not to be significant. We also carried out experiments of these other changes, but have left them out of this paper for brevity and because the results were very similar, not least because the general properties of reactions to financialization shifts discussed in Section 3, applies to these cases too.

As controls, we simulate for a more expansive net supply and separately a greater uncertainty in supply and demand for physical oil. We know that the real oil price fell during the mid-2008 glut. Thus we consider a 5% expected loosening in supply (a rise in $\mu_{g,1}$) such that the current oil price would fall by 10%. Of course this is illustrative: one could reverse the sign of the effects of the loosening and consider the results as an approximate guide as to the predicted consequences of a tightening in net supply from 2003 to 2008. It seems that the oil price has been more unpredictable (at short horizons) in the period of greater financialization (Table 1). This leads us to experiment with a rise in the volatility of supply shocks (σ_g) shifting from its baseline value of 8% to 9.3%. Evidence for supply and demand changes over the period include the rapid growth in global oil demand in non-OECD countries driven by industrialization and improvements in levels of income (Kilian and Murphy (2010)), and supply shocks in oil producing countries caused by military conflicts, political instability, and industrial disputes. Furthermore, there has been a general decline in the price responsiveness of oil supply and demand over the latest cycle as consumers have reduced the share of oil in their budgets (Baumeister and Peersman (2011)).

As well as matching the stylised facts in the previous section, we find it enlightening to present the results in terms of an acceptance or rejection of different strands of the financialization hypothesis, which we formalize as follows:

[19]This is associated with what has often been described as the search for yield or the risk-taking channel of risk-free rates, which some have suggested might have been responsible for the greater financialization of commodities. See discussion in Frankel (2006) and Basu and Gavin (2011). In our data the real ten-year US Treasury bill rate was estimated to fall from 3.5% to 2.0% between the two samples. Often the search for yield is connected to a boom in asset prices generally. We estimated that the average real annualized monthly returns to the S&P fell to 5.9% post-2003 compared to 8.6% previously, and the standard deviation remained largely unchanged (to 15.2 pp from 16.2pp).

1. underlying changes in financial speculators' preferences and resources have led to a much greater participation of financial players, and has raised oil price levels (Section 6.1);

2. because of financialization, less inventory is held and price differentials are wider (Section 6.2);

3. financialization has made spot oil prices more unpredictable (Section 6.3);

4. compensation is needed to keep consumers' utility at the same level as that without financialization (Section 7);

5. financialization can make the welfare of final consumers more sensitive to shocks (Section 7).

This last aspect is what we think goes closest to the heart of public concerns: not so much whether welfare is affected by greater financialization directly but whether financialization has exposed final consumers brutally to the vagaries of political shocks, to oil spills, and to other uncertainties associated with oil.

6 Results

6.1 The Long Futures Position and the Oil Price

The first financialization sub-hypothesis is that underlying changes associated with greater participation of financial players has raised oil price levels. Formally we write this as:

$$\text{Greater financialization } \Rightarrow \frac{\alpha_{s,1}W_s}{F_0^1} \uparrow \ \& \ P_0, \mathbb{E}_0[P_1], F_0^1 \uparrow$$

Table 2: Effect of Greater Financialization on the Long Futures Position and Oil Price Levels

Shift in ↓ Effect on → Baseline value →	$\frac{\alpha_{s,1}W_{s,0}}{F_0^1}$ 0.87	Hypothesis prediction	P_0 Baseline value	$\mathbb{E}_0[P_1]$ 1.03 of P_0	F_0^1 0.91 of P_0	Hypothesis prediction
Greater Financialization			% diff. from baseline			
Financial speculators' risk aversion τ_s: 2 to 1.5	1.9	+ve	0.6	-0.6	0.8	+ve
Financial speculators' wealth $W_{s,0}$: 25% increase	1.6	+ve	0.5	-0.5	0.7	+ve
Supply and Demand Shifts			% diff. from baseline			
Supply news $\mu_{g,1}$: 5% loosening	-16.5		-10.8	-2.5	-1.4	
Supply volatility σ_g: 8.0pp to 9.3pp	2.7		0.1	1.3	-1.8	

Table 2 puts this to the test. In the first row, we see the effect of a lower risk aversion on the amount of money dedicated by financial speculators to oil contracts, the current spot price, its expected level, and the futures price. Lowering financial players' risk aversion from 2 to 1.5 does indeed raise their stake (by 1.9%). A 25% rise in assets at their disposal also raises their oil futures' investment by a similar proportion. These effects seem quite small compared to secular trends, shifts, and volatilities in gross measures of financial participation.

The last two rows describe the effect of changes to the physical layer: a more abundant expected future supply and a rise in the uncertainty surrounding that expectation. These changes are shown to have the potential to create large shifts in financial players' long positions. This is simply because the counterpart to the financial players' speculations are the physical investors' hedging needs. When the risk and return to physical oil changes, the demand for hedging will shift to alter the positions of financial speculators. In our model, a 5% expected loosening in supply implies a potential loss for physical speculators and diminishes their appetite to hedge, such that participation is lowered by 17%. While the small rise in supply uncertainty raises the demand for hedging but at the same time raises the risk to financial speculators of providing that service. In net, it implies a 2.7% rise in financial players' investments.[20]

In terms of price levels, the prediction of the hypothesis is that these should rise following financialization, and indeed this is what we observe. But the effects are small in scale: about half a percent point of the spot price. Could a larger financialization shift imply an effect on the price closer to what we observed? Simulations indicate that even if wealth were to increase by 50 times its baseline value, the price level would only rise by 4%. As the oil price level post-financialization was very roughly double its pre-financialization price, Thus it does not seem likely that much of the oil price rise was due to greater financialization.

Note also that the expected spot price falls by the same extent as the rise in the current spot price following greater financialization: there is a twist to the term structure. As we explained in Section 3.1, this is a general characteristic of any change in the financial layer: the expected price and the spot price must move in opposite directions. As we shall see later on, this limits the effect of financialization changes on welfare.

In contrast, supply and demand can have the kind of large effects on the oil price that we observe in the data. The 5% expected increase in net supply lowers the spot price by just over

[20] The sign of this response is the least robust feature of our simulations but is not important in explaining our results.

11%. As less inventory is carried over, there is also a fall in the expected spot price level of nearly 3% and the futures price by 1%. And even the modest rise in net supply volatility raises both the current and especially the expected spot price.

Where does this leave the empirical literature on financialization that links the large rise in net positions of non-commercial players to the oil price? We have shown that financialization shifts are unlikely to explain the large shifts in the oil price level. Instead these can more plausibly be due to expectational shifts in the demand and supply for spot oil. The net positions of non-commercial players need not only be due to shifts in financial players' preferences and constraints, financial investment volumes themselves depend on expected changes in the physical layer. Thus a correlation between a greater volume of financial flows and higher oil prices is not conclusive evidence of the financialization hypothesis.

6.2 Carry over and Spreads

The next sub-hypothesis that inventory has become less effective in its role of smoothing price differentials and thus that financialization has dislocated oil markets intertemporally is formalized as:[21]

$$\text{Greater financialization } \Rightarrow Q_0 \downarrow \;\&\; \left|\frac{\mathbb{E}_0[P_1]}{P_0} - 1\right| \uparrow \;\&\; \left|\frac{P_0}{F_0^1} - 1 \uparrow\right| \;\&\; \left|\frac{\mathbb{E}_0[P_1]}{F_0^1} - 1\right| \uparrow$$

where $X|_{p,1}$ is the effect of a shock in the physical layer which is expected to occur in period 1 on the elasticity X.

[21] The mechanics of this relate to a famous paper by French (1986). He showed that if the marginal costs of holding inventory are large, then futures prices are very insensitive to shifts in the current period, as there is little response of carry over. In the extreme, prices become dislocated across time — analogously to the intertemporal prices of goods which spoil quickly. The relationship between inventory cost and price differentials is tested empirically across commodities by Fama and French (1987).

Table 3: Effect of Greater Financialization on Total Carry Over and Spreads

Shift in ↓ Effect on →	Q_0	Hypothesis	$\frac{\mathbb{E}_0[P_1]}{P_0}$	$\frac{P_0}{F_0^1}$	$\frac{\mathbb{E}_0[P_1]}{F_0^1}$	Hypothesis
Baseline value →	1.00	prediction	1.03	1.10	1.13	prediction
Greater Financialization	% diff. from baseline					
Financial speculators' risk aversion τ_s: 2 to 1.5	0.2	-ve	-1.3	-0.2	-1.4	+ve
Financial speculators' wealth $W_{s,0}$: 25% increase	0.2	-ve	-1.1	-0.1	-1.2	+ve
Supply and Demand Shifts	% diff. from baseline					
Supply news $\mu_{g,1}$: 5% restriction	-3.6		9.3	-9.6	-1.2	
Supply volatility σ_g: 8.0pp to 9.3pp	0.0		1.2	1.9	3.2	

Greater financialization — whether due to lower risk aversion or more wealth — is predicted to *raise* the amount of carry over, contradicting the financialization hypothesis.[22] Moreover, the spreads, the inverse basis, the risk premium and expected appreciation, all narrow as a greater propensity to bear risk by financial speculators and an expansion of the resources at their disposal enhances their ability to bear risk.

In Section 3.1, we predicted that a shift in the financial layer could only lead to a large rise in current spot price levels if it also implies a large differential reaction between the risk premium and the basis, such that the gap between the two becomes more negative. According to Table 3, the gap shifts by just over 1pp following the two financialization shifts. In Section 3.1 imply that this would be consistent with a small rise in the current price level (of about half a percent) in either case. And indeed, this is very close to the reactions reported in Table 2, showing that these reactions are consistent with the small effects predicted on the price level.

In contrast, news of more net supply in the future lowers carry over to a significant extent — a 5% expected increase in supply lowers carry over by 3.6%. Crucially, only the expected loosening comes close to reproducing the effects on the basis estimated in Table 1 to have taken place. With a 5% loosening in expected net supply, the inverse basis falls by 9.6pp, as there is a lower convenience yield. This is consistent with the view that the excess supply was eliminated from mid-2008 with an approximately 3.9% loosening, based on the calculation of a 7.5pp fall in the inverse basis in Table 1: $(3.9 = \frac{7.5}{9.6} \times 5)$. The loosening in expected net supply can also generate a small fall in the risk premium and a large rise in expected appreciation. The financialization shifts imply that a fall in the risk premium would happen when current spot prices are rising, which seems at odds with what we would expect. Thus supply and demand shifts yield results which are qualitatively more consistent with what we would expect, although

[22]This is in line with Acharya et al. (2011)'s qualitative findings.

matching the timing and size of shifts in the risk premium and appreciation is more difficult than with the basis, as they are not as easily inferable. The last row shows that any accompanying extra supply uncertainty would have raised the risk in holding inventory, and thus raised all spreads, without affecting carry over.

Thus if the evidence is that the inverse basis and financial participation both fell in mid-2008, it seems more plausible that the realization of a glut could have been responsible rather than any change in financialization. Anticipations of physical layer developments are also uniquely capable of explaining the subsequent recovery in the basis (Chart 2).

It is perhaps more surprising that the effects of financialization are small in size. The explanation builds on the interpretation of the model in terms of the demand and supply for storage services in Section 3.2. Note first that the price elasticities of the demand and supply of storage services (21 and 22 respectively) are not independent: the crucial parameter in both is $\eta \equiv \frac{1-\varsigma}{\theta+\omega\varsigma}$, the inverse of the demand and supply elasticities. This is because the supply of storage is chosen as a nominal value — a financial asset — by physical speculators and therefore the spot price elasticities affect the implied real volume of carry over. Thus, the high baseline value of η (= 3.14) implies that the supply of, as well as the demand for, storage is relatively insensitive to price.

Financialization changes affect the supply of storage and thus the amount of carry over (equation 22) with the same elasticity as does expected appreciation. Thus the notoriously low supply and demand elasticities for oil must be one part of the reason why financialization has weak effects on inventory. But another crucial mechanism must be that financialization (here summarized in κ) does not drive large wedges in the risk premium (Table 3). This is because physical speculators can absorb the effect of these changes through shifting the mix of hedged and unhedged inventory, and financial speculators can accept some of the risk to the extent they can diversify through other investments, as discussed in Section 3.1.

Further intuition is provided by considering the hedged component of carry over. We can infer this by referring back to the first column of Table 2 which reports the futures positions of financial speculators, which should move proportionately with the hedged carry over of physical speculators (as $\frac{\alpha_{s,1}W_{s,0}}{F_0^1} = \alpha_{r,2}W_{r,0}$ and $W_{r,0}$ is held constant). Comparing this to the response of total carry over in the table above confirms there is a larger proportionate response in the hedged carry over than on total carry over; when financial speculators' wealth increases by a quarter, the amount of hedged inventory increases by 1.9%, such that the hedge ratio rises by

$2.1(= 1.9 + 0.2)$ pp. Thus financialization increases hedging.

6.3 Unpredictability

The next sub-hypothesis is that financialization has increased the unpredictability of spot oil prices to make the futures price a worse predictor of next-period spot prices:

$$\text{Greater financialization } \Rightarrow (Var_0[P_1])^{0.5} \uparrow$$

The effect of financialization on the conditional standard deviation of oil prices is explored in Table 4 below.

Table 4: Effect of Greater Financialization on Oil Price Unpredictability

Shift in $\downarrow$ Effect on $\rightarrow$ Baseline value $\rightarrow$	$(Var_0[P_1])^{0.5}$ $(Var_0[P_1])^{0.5} = 0.29\mathbb{E}_0[P_1]$	Hypothesis prediction
Greater Financialization	% diff. from baseline	
Financial speculators' risk aversion τ_s: 2 to 1.5	-0.6	+ve
Financial speculators' wealth W_s: 25% increase	-0.5	+ve
Supply and Demand Shifts	% diff. from baseline	
Supply news $\mu_{g,1}$: 5% restriction	-2.6	
Supply volatility σ_g: 8.0pp to 9.3pp	18.3	

The size of the effect of these changes on the unpredictability of the price level are equal to the proportional reaction of the mean of the price level (see the penultimate column of Table 2). This follows from the properties of a log-normally distributed variable when only the mean of its log is changed: as the scale of the price level is changed, so is its variance. The glaring exception is when there is higher supply volatility, which increases the volatility of the price level by over 18% independently of scale.

It then follows that greater financialization should lower the standard deviation and improve the precision of the price signal. For example a lower risk aversion of financial speculators would improve the ability of the market to absorb risk. Thus, here also, the financialization hypothesis is contradicted. But even then the effects of financialization are less than those of supply and demand shifts. A higher supply volatility in particular has an impact of a much greater magnitude than the changes in financialization. It would seem more plausible to attribute changes in the predictability of spot prices to shifts in fundamental volatility.

It is important though, in this regard, to distinguish between uncertainty caused by supply and demand shocks and uncertainty caused by shifts in parameters. Our results concern the former: we have shown that shock uncertainty is not made worse by more financialization. If greater financialization is concomitant with greater unpredictability in the parameters affecting financial speculators then that might raise volatility by itself. For example if financial players' risk aversion (τ_s) were linked to their leverage as in Acharya et al. (2011), or if we wanted to simulate a squeeze on the market as the domination of single speculator with risk-loving and uncertain preferences, then these results may well be different.

7 Consumer Welfare

In this final section we look at the implications of financialization for welfare. A necessary step is to extend the model to take account of consumers' utility as that will be the basis of our welfare calculations.

7.1 Extending the Model for Consumer Welfare

Consumer welfare is calculated by taking a second-order approximation to consumers' lifetime utility (equation (9)) about the deterministic steady-state for period 1 log consumption, and then taking expectations at time 0:

$$\begin{aligned}
\mathbb{E}_0\Pi_{c,0} &= U(C_{c,0}) + \beta\mathbb{E}_0 U(C_{c,1}) \\
&\approx U(\bar{C}_{c,0}) + \beta U(\bar{C}_{c,1}) + \beta\bar{C}_{c,1}U_1(\bar{C}_{c,1})(\mathbb{E}_0[c_{c,1}] - \ln\bar{C}_{c,1}) \\
&+ \frac{\beta}{2}(\bar{C}_{c,1}U_1(\bar{C}_{c,1}) + (\bar{C}_{c,1})^2 U_2(\bar{C}_{c,1}))(Var_0[c_{c,1}] + (\mathbb{E}_0[c_{c,1}] - \ln\bar{C}_{c,1})^2).
\end{aligned} \tag{24}$$

In order to calculate welfare, we need to solve for the steady-state values of consumption, ($\bar{C}_{c,s}$ for s=[0,1]), the conditional mean of the log of second-period consumption, ($\mathbb{E}_0[c_{c,1}]$), and its conditional variance, ($Var_0[c_{c,1}]$). In Appendix 10.3, we describe how these latter two values can be approximated up to second order.

Welfare is assessed in terms of the known percentage of consumption in all dates that is required to compensate consumers for the structural change so that their utility is as in the baseline. As $\Pi^c_{base} + \frac{(1+\beta)}{1-\chi} = (\Pi^c + \frac{(1+\beta)}{1-\chi})(1+C_w)^{1-\chi} \Rightarrow C_w = 100 \times ((\frac{\Pi^c_{base}+\frac{(1+\beta)}{1-\chi}}{\Pi^c+\frac{(1+\beta)}{1-\chi}})^{\frac{1}{1-\chi}} - 1)$.

The suggestion that financialization worsens the welfare of final consumers is put to the test formally as:

$$\text{Greater financialization } \Rightarrow C_w \uparrow$$

Table 5: Effect of Greater Financialization on Consumer Welfare

Shift in ↓ Effect on →	C_w Compensation relative	Financialization hypothesis
Financialization changes	Diff. from baseline	
Financial speculators' risk aversion τ_s: 2 to 1.5	-0.77	+ve
Financial speculators' wealth W_s:25% increase	-0.64	+ve
Supply and Demand Shifts	Diff. from baseline	
Supply news $\mu_{g,1}$: 5% loosening	-3.04	
Supply volatility σ_g: 8.0pp to 9.3pp	0.35	

The results are in Table 5. A more positive value of an entry (of C_w) implies that welfare is lower than the baseline and positive compensation is required. The simulations reveal that greater financialization arising from either lower risk aversion, more speculator wealth, or a lower risk-free rate will improve welfare (by reducing the welfare compensation). This is due to the benefits of risk-sharing, and is consistent with our previous results. The forecasted 5% loosening in net supply which lowers the expected spot price by 11% has the most powerful effect on improving consumers' welfare in this example, equivalent to 3.04 pp less consumption compensation. Even the mild rise in supply volatility worsens welfare by 0.35pp, which is due to the higher price level under greater uncertainty.[23]

Finally, we explore the sensitivity of consumer welfare to shocks, assessing whether or not this is worsened by financialization:

$$\text{Greater financialization } \Rightarrow \frac{\partial C_w}{\partial P_0} P_0|_{p,1} \uparrow$$

[23] The intuition behind these welfare effects is simply that tighter supply conditions raise the expected level of oil prices and lower the mean of log consumption. Lucas (2003)'s famous calculation of a small effect of uncertainty was based on a model where consumption was log linear. Here consumption is not conditionally log linear, and greater uncertainty can affect the expected value of its log.

Table 6: Effect of Greater Financialization on Consumer Welfare Cost Sensitivity to Supply News

Shift in ↓ Effect on → Baseline value →	$\frac{\partial C_w}{\partial P_0} P_0\|_{p,1}$ 0.35	Financialization hypothesis prediction
Greater Financialization	Diff. from baseline	
Financial speculators' risk aversion τ_s: 2 to 1.5	-1.1×10^2	+ve
Financial speculators' wealth W_s: 25% increase	-5.2×10^3	+ve
Supply and Demand Shifts	Diff. from baseline	
Supply news $\mu_{g,1}$: 5% restriction	0.11	
Supply volatility σ_g: 8.0pp to 9.3pp	0.03	

The results are in Table 6 above. To obtain them, we simulated for a vector of equally spaced negative and positive news about supply within a range around the baseline value. The results shown in Table 6 are the average of the numerical derivatives across these points, with each entry capturing the movements of welfare relative to that of the supply level. The baseline value of the semi-elasticity $\frac{\partial C_w}{\partial P_0} P_0|_{p,1}$ is 0.35 meaning that news of higher future supply that lowers current spot prices by 1% will lower the necessary consumption equivalent welfare compensation by 0.35pp. This confirms that fundamental shocks do indeed matter in the model.

The rest of Table 6 describes what happens to this semi-elasticity following financialization and other changes. In the case of either a lower risk aversion or greater resources, financialization hardly affects the sensitivity of consumers' welfare. The loosening in supply of 5% has the most important impact in raising consumers' exposure; consumers' welfare exposure to supply news will be increased by about 0.11pp. These results reject any deleterious effect on consumer welfare sensitivity of financialization.

8 Allowing for Belief Disagreements

In our analysis so far, financial futures function as a risk-sharing device between the physical and financial speculator. Sismek (2012) has recently demonstrated that there are plausible circumstances when trade in a financial instrument can combine both a risk-sharing and a pure speculation motive. In particular, differences in beliefs between investors naturally lead to pure speculation as each uses the financial trade to bet on their own belief against that of the other. Sismek (2012) shows that in the presence of these disagreements, financial innovation always increases the speculative component of the variance of the net worth of participants. This suggests that we should explore if our rejection of the financialization hypothesis is robust to belief disagreements. It may be the case that when financial trade is not just about risk sharing, greater financialization implies all the effects predicted by the hypothesis.

We introduce a large belief disagreement between financial and physical speculators over the mean of the log of the next period price, such that the physical speculator expects a price on average well (about 20%) below the true mean while the financial speculator expects a price the same distance above. According to Sismek (2012), it matters that the disagreement is large, but it does not necessarily matter whether the disagreement is over the return on the asset on which there is pure speculation (the futures price), or on another return (the expected spot price). We assume there is no disagreement over the variance and that consumers and producers expect the correct price on average; this is what the spot markets clear at.

We replace the expression $\mathbb{E}_0[p_1]$ in equations 4 and 8 with separate expressions for physical and financial speculator's expectations, $\mathbb{E}_0^r[p_1]$ and $\mathbb{E}_0^s[p_1]$ respectively, defined as follows:

$$\mathbb{E}_0^r[p_1] = \mathbb{E}_0[p_1] - \epsilon \text{ and } \mathbb{E}_0^s[p_1] = \mathbb{E}_0[p_1] + \epsilon, \text{ where } \epsilon = 0.2 \tag{25}$$

and solve for the portfolio shares which reflect these disagreements. All other expressions in the model remain as they were. Table 7 reports the differences in terms of the futures position, the oil price, oil price uncertainty and consumer welfare compensation.

Table 7: Effect of Greater Financialization with Pure Speculation

Shift in ↓ Effect on →	$\frac{\alpha_{s,1}W_{s,0}}{F_0^1}$ with pure speculation	$\frac{\alpha_{s,1}W_{s,0}}{F_0^1}$ without	P_0 with	P_0 without	C_w with	C_w without
Baseline value →	0.86	1.05	1.02	1.06		
Greater Financialization	% diff. from baseline				pp. diff. from baseline	
Financial speculators' risk aversion τ_s: 2 to 1.5	5.7	1.9	5.1	0.6	-6.2	-0.6
Financial speculators' wealth W_s: 25% increase	3.4	1.6	2.5	0.5	-3.1	-0.7
Supply and Demand Shifts	% diff. from baseline				pp. diff. from baseline	
Supply news $\mu_{g,1}$: 5% restriction	-2.5	-16.5	-9.3	-10.8	-5.2	-3.0
Supply volatility σ_g: 8.0pp to 9.3pp	-17.1	2.7	-6.8	0.1	9.4	0.4

As explained in Sismek (2012), the large and persistent disagreement engenders a strong pure speculative motive for trade: the amount of futures bought by financial speculators rises from 89% of wealth to 105%, with no change in fundamentals. Thus nearly 20% of their wealth is put to work on betting on this difference.

Interestingly, financialization has greater effects in the presence of pure speculation. For example the link between the underlying shifts in financialization and financial participation become stronger (first column), roughly double their effect without financialization. And more importantly, the fall in risk aversion and the 25% rise in wealth affect the oil price by about 5.1% and 2.5% respectively. This is roughly five to eight times the effect without pure speculation. As intriguing as these results are, they still leave us some way short of explaining a major contribution to the total rise in the oil price.[24]

And the effects on the oil price of financialization are still less than that of a 5% increase in net supply, which is expected to lower the current price by nearly 9%. The effect of a lower supply on financial participation under pure speculation is much weaker than without it, as more of the participation reflects the bet on the belief disagreement, which we assume is unaffected by the lower supply and so more resistent to news.

Financialization is shown to be still not harmful for consumer welfare even under pure speculation. We have seen that, following a bout of financialization without speculation, consumers are in general slightly better off. In the presence of speculation, greater financialization is shown to be even more beneficial, representing a lower compensation of about 6 and 3% in the case of our two financialization shifts. Indeed financialization lowers the underpredictability of oil prices by more than without the pure speculative motive. While financial expansion allows specialist investors to bet more, it also shields consumers from that persistent disagreement.

In conclusion, after allowing for pure speculation, by permitting a departure from the assumption that expectations of the oil price converge on the true moments of uncertainty, we find that financialization can have stronger effects on the oil price and financial participation. However the main thrust of our results are preserved.

9 Conclusion

We find no support for the various strands of the financialization hypothesis. Financialization has little effect on oil market variables and final consumers' welfare. We show that there are general limits on the ability of financialization shocks to shift the expected spot price term structure. And also inventory managers can manipulate the margin between hedged and unhedged inventory to shield final consumers. In contrast, anticipations of net supply shifts and changes in net supply volatility have important impacts on spreads, welfare, and even on

[24]Experiments with very large increases in financial wealth did not imply a rise in the current oil price of greater than 10% even under pure speculation.

financial market participation. Those papers that purport to have found a significant impact of financialization without considering the reverse causality are vulnerable to poor identification.

Markets are not complete in our model and we have re-examined our findings in the context of pure speculation over a large and persistent belief disagreement. But we have not allowed for all the frictions displayed in real world financial markets. For example, financial speculators in our paper are not leveraged, and maximize objectives that are broadly consistent with low systemic risk. We have disregarded the possibility of noise traders who experience an average loss, herding behaviour or bubbles (Jovanovic (2013)). Nor do we allow for differences in information between participants, which then would, as in Danthine (1978) or Stein (1987), explain how oil prices transmit information to participants, reducing their risk. Then we also ignore the tack taken by Williams (1987) who argued that the cash or forward sale of oil requires uncertain transaction costs, because of matching. As these costs are uncertain, the outcome is similar to risk aversion in that future prices can be below spot prices, but the explanation lies in the matching process and how that is facilitated by a futures market.

If we were to depart from our assumptions along these directions then we might find a more significant effect of financialization. But even then, these fundamental market failures would elicit their own specific policy solutions or require more careful empirical support. For example, if it were found that the entrance of highly leveraged financial speculators with socially suboptimal objectives disrupts oil markets, the implication is that macro and microprudential regulation should be employed. Thus, policies designed to correct for failures in other financial markets may not be appropriate for oil. Finally our paper shows that it is crucial in the first instance to identify the channels through which financialization can result in market failure.

10 Appendix

10.1 Solving for Speculators' Portfolios

The budget constraint of physical speculators (equation 1) can be written in log terms as:

$$(26) \qquad w_{r,1} = w_{r,0} + \ln((1 - \alpha_{r1,0} - \alpha_{r2,0})(1 + r_f) + \alpha_{r1,0}\frac{P_1 C_{q1,1}}{P_0} + \alpha_{r2,0}\frac{F_0^1 C_{q2,1}}{P_0})$$

$$\Rightarrow w_{r,1} \approx w_{r,0} + r_{rp,1}$$

where:

$$r_{rp,1} \equiv r_f + \ln(1 + \alpha_{r1,0}(e^{p_1 - p_0 + c_{q1,1} - r_f} - 1) + \alpha_{r2,0}(e^{f_0^1 - p_0 + c_{q2,1} - r_f} - 1))$$

is the log portfolio return of the physical speculators. Consider a second-order approximation of $r_{rp,1}$ with respect to $\mathbf{r}_{rs,1}$ (as defined in the main text) about $r_f\boldsymbol{\iota}$):

$$(27) \qquad r_{rp,1} \approx r_f + (\mathbf{r}_{rs,1} - r_f\boldsymbol{\iota})\boldsymbol{\alpha}_{r,0} + \frac{1}{2}diag([\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}]^T)\boldsymbol{\alpha}_{r,0}$$
$$- \frac{1}{2}\boldsymbol{\alpha}_{r,0}^T[\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}]^T\boldsymbol{\alpha}_{r,0}$$

Taking expectations conditional on period 0 information:

$$(28) \qquad \mathbb{E}_0[r_{rp,1}] \approx r_f + (\mathbb{E}_0\mathbf{r}_{rs,1} - r_f\boldsymbol{\iota})\boldsymbol{\alpha}_{r,0}$$
$$+ \frac{1}{2}diag(\mathbf{Var}_0[\mathbf{r}_{rs,1}])\boldsymbol{\alpha}_{r,0} + \frac{1}{2}diag([\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}]^T)\boldsymbol{\alpha}_{r,0}$$
$$- \frac{1}{2}\boldsymbol{\alpha}_{r,0}^T\mathbf{Var}_0[\mathbf{r}_{rs,1}]\boldsymbol{\alpha}_{r,0} - \frac{1}{2}\boldsymbol{\alpha}_{r,0}^T[\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}]^T\boldsymbol{\alpha}_{r,0}$$

and

$$(29) \qquad Var_0[r_{rp,1}] \approx \boldsymbol{\alpha}_{r,0}^T\mathbf{Var}_0[\mathbf{r}_{rs,1}]\boldsymbol{\alpha}_{r,0}$$

Hence, $W_{r,1}^{1-\tau_r}$ is conditionally log-normal such that:

$$(30) \qquad \ln \mathbb{E}_0 W_{r,1}^{1-\tau_r} = (1 - \tau_r)w_{r,0} + (1 - \tau_r)\mathbb{E}_0[r_{rp,1}] + \frac{1}{2}(1 - \tau_r)^2 Var_0[r_{rp,1}]$$

Thus maximizing 1 is equivalent to maximizing the following expression:

(31)

$$\frac{\ln \mathbb{E}_0 W_{r,1}^{1-\tau_r} - (1-\tau_r)w_{r,0}}{1-\tau_r} = r_f + (\mathbb{E}_0\mathbf{r}_{rs,1} - r_f\boldsymbol{\iota})\boldsymbol{\alpha}_{r,0} + \frac{1}{2}diag(\mathbf{Var}_0[\mathbf{r}_{rs,1}])\boldsymbol{\alpha}_{r,0}$$
$$+ \frac{1}{2}diag([\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}]^T)\boldsymbol{\alpha}_{r,0}$$
$$- \frac{1}{2}\boldsymbol{\alpha}_{r,0}^T diag([\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{rs,1}] - r_f\boldsymbol{\iota}]^T)\boldsymbol{\alpha}_{r,0} - \frac{\tau_r}{2}\boldsymbol{\alpha}_{r,0}^T\mathbf{Var}_0[\mathbf{r}_{rs,1}]\boldsymbol{\alpha}_{r,0}$$

by choice of $\boldsymbol{\alpha}_{r,0}$ for which the first-order condition is in the main text.

In the case of financial speculators, we write the budget constraint (7) as:

$$w_{s,1} \approx w_{s,0} + r_{sp,1}$$

with:

$$r_{sp,1} \equiv r_f + \ln(1 + \alpha_{s1,0}(e^{p_1+c_{g,1}-f_0^1-r_f}) + \alpha_{s2,0}(e^{r_{e,1}-r_f} - 1))$$

Taking a second-order approximation of $r_{sp,1}$ with respect to $\mathbf{r}_{ss,1}$ about $\mathbf{0}$ we have:

$$r_{sp,1} \approx r_f + \frac{1}{1+\alpha_{s1,0}}(\mathbf{r}_{ss,1} - r_f\boldsymbol{\iota})\boldsymbol{\alpha}_{s,0} + \frac{1}{2(1+\alpha_{s1,0})^2}diag([\mathbb{E}_0[\mathbf{r}_{ss,1}] \tag{32}$$
$$- r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota}]^T)\boldsymbol{\alpha}_{s,0}$$
$$- \frac{1}{2(1+\alpha_{s1,0})^2}\boldsymbol{\alpha}_{s,0}^T[\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota}]^T\boldsymbol{\alpha}_{s,0}$$

such that:

(33)

$$\mathbb{E}_0[r_{sp,1}] \approx r_f + \frac{1}{(1+\alpha_{s1,0})}(\mathbb{E}_0\mathbf{r}_{ss,1} - r_f\boldsymbol{\iota})\boldsymbol{\alpha}_{s,0}$$
$$+ \frac{1}{2(1+\alpha_{s1,0})}diag(\mathbf{Var}_0[\mathbf{r}_{ss,1}])\boldsymbol{\alpha}_{s,0} + \frac{1}{2(1+\alpha_{s1,0})}diag([\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota}]^T)\boldsymbol{\alpha}_{s,0}$$
$$- \frac{1}{2(1+\alpha_{s1,0})^2}\boldsymbol{\alpha}_{s,0}^T\mathbf{Var}_0[\mathbf{r}_{ss,1}]\boldsymbol{\alpha}_{s,0} - \frac{1}{2(1+\alpha_{s1,0})^2}\boldsymbol{\alpha}_{s,0}^T[\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota}][\mathbb{E}_0[\mathbf{r}_{ss,1}] - r_f\boldsymbol{\iota}]^T\boldsymbol{\alpha}_{s,0}$$

and

$$Var_0[r_{sp,1}] \approx \frac{1}{(1+\alpha_{s1,0})^2}\boldsymbol{\alpha}_{s,0}^T\mathbf{Var}_0[\mathbf{r}_{ss,1}]\boldsymbol{\alpha}_{s,0} \tag{34}$$

The rest of the steps towards the first-order solution are as in the case of the physical speculators.

10.2 Useful Expressions

NOTE FOR EDITOR: THIS APPENDIX IS TO HELP THE REFEREE AND CAN BE REMOVED FOR PUBLICATION In order to solve for the model numerically, the following expressions are useful:

$$
\begin{aligned}
&\mathbb{E}_0[P_1] = A_1 Q_0^{-\eta} v_{1,0} \\
&\mathbb{E}_0[R_{e,1}] = v_{2,0} \\
&Var_0[P_1] = A_1^2 Q_0^{-2\eta} v_{11,0} \\
&Var_0[R_{e,1}] = v_{22,0} \\
&Cov_0[P_1, R_{e,1}] = A_1 Q_0^{-\eta} v_{12,0} \\
&Corr_0[P_1, R_{e,1}] = \frac{(e^{\sigma_{pre}} - 1)}{((e^{\sigma_{re}^2} - 1)(e^{\sigma^2} - 1))^{0.5}}
\end{aligned}
$$

where:

$$
\begin{aligned}
&v_{1,0} \equiv e^{\mu_1 + \frac{\sigma^2}{2}} \\
&v_{2,0} \equiv e^{(1-\rho_{re})\mu_{re,1} + \rho_{re} r_{e,0} + \frac{\sigma_{re}^2}{2}} \\
&v_{11,0} \equiv e^{2\mu_1 + \sigma^2}(e^{\sigma^2} - 1) \\
&v_{12,0} \equiv e^{\mu_1 + (1-\rho_{re})\mu_{re,1} + \rho_{re} r_{e,0} + \frac{\sigma^2}{2} + \frac{\sigma_{re}^2}{2}}(e^{\sigma_{pre}} - 1) \\
&v_{22,0} \equiv e^{2(1-\rho_{r,e})\mu_{re,1} + 2\rho_{r,e} r_{e,0} + \sigma_{re}^2}(e^{\sigma_{re}^2} - 1)
\end{aligned}
$$

and:

$$
\begin{aligned}
&\mu_1 \equiv -\frac{(1-\rho_g)\mu_{g,1} + \rho_g g_0}{\theta + \omega\varsigma} + \frac{\varsigma((1-\rho_y)\mu_{y,1} + \rho_y y_0)}{\theta + \omega\varsigma} \\
&\sigma^2 \equiv (\theta + \omega\varsigma)^{-2}\sigma_g^2 + (\frac{\varsigma}{\theta + \omega\varsigma})^2 \sigma_y^2 \\
&\sigma_{pre} \equiv -\frac{\sigma_{gre}}{\theta + \omega\varsigma} + \frac{\varsigma\sigma_{yre}}{\theta + \omega\varsigma}
\end{aligned}
$$

Also:

$$
\begin{aligned}
&\mathbb{E}_0[p_1] = \frac{\varsigma}{\theta+\omega\varsigma}\gamma_1 - \eta q_0 + \mu_1 \\
&\mathbb{E}_0[y_1] = \rho_y \ln y_0 + (1-\rho_y)\mu_{y,1} \\
&\mathbb{E}_0[x_1] = \gamma_1 + \mathbb{E}_0[y_1] - \omega\mathbb{E}_0[p_1] \\
&Var_0[p_1] = \sigma^2 \\
&Cov_0[y_1, p_1] = \frac{\varsigma}{\theta+\omega\varsigma}\sigma_y^2 \\
&Var_0[x_1] = \sigma_y^2 + \omega^2\sigma^2 - 2\omega Cov_0[y_1, p_1] \\
&Cov_0[x_1, p_1] = Cov_0[y_1, p_1] - \omega\sigma^2 \\
&\text{ and } Cov_0[x_1, y_1] = \sigma_y^2 - \omega Cov_0[y_1, p_1]
\end{aligned}
$$

We can derive similar expressions for X_0, D_0, $\mathbb{E}_0[X_1]$,and $Var_0[X_1]$:

$$
\begin{aligned}
&X_0 = Y_0 \Gamma P_0^{-\omega} \\
&D_0 = Y_0^{\varsigma} \Gamma^{\varsigma} P_0^{-\omega\varsigma} Q_0^{1-\varsigma}
\end{aligned}
$$

and:

$$
\begin{aligned}
&\mathbb{E}_0[X_1] = \Gamma^{1-\frac{\omega\varsigma}{\theta+\omega\varsigma}} e^{(1-\rho_y)\mu_{y,1}+\rho_y y_0 - \omega\mu_1 + (\frac{\omega}{(\theta+\omega\varsigma)})^2\frac{\sigma_g^2}{2} + (\frac{\omega\varsigma}{\theta+\omega\varsigma})^2\frac{\sigma_y^2}{2}} \\
&\mathbb{E}_0[D_1] = (Q_0)^{-(1-\varsigma)}\Gamma^{\varsigma(1-\frac{\omega\varsigma}{\theta+\omega\varsigma})} e^{\varsigma((1-\rho_y)\mu_{y,1}+\rho_y y_0) - \varsigma\omega\mu_1 + (\frac{\varsigma\omega}{(\theta+\omega\varsigma)})^2\frac{\sigma_g^2}{2} + (\frac{\omega\varsigma^2}{\theta+\omega\varsigma})^2\frac{\sigma_y^2}{2}} \\
&Var_0[X_1] = \Gamma^{2(1-\frac{\omega\varsigma}{\theta+\omega\varsigma})} e^{2(1-\rho_y)\mu_{y,1}+2\rho_y y_0 - 2\omega\mu_1 + (\frac{\omega}{(\theta+\omega\varsigma)})^2\sigma_g^2 + (\frac{\omega\varsigma}{\theta+\omega\varsigma})^2\sigma_y^2} (e^{(\frac{\omega}{(\theta+\omega\varsigma)})^2\sigma_g^2 + (\frac{\omega\varsigma}{\theta+\omega\varsigma})^2\sigma_y^2} - 1)
\end{aligned}
$$

10.3 The Distribution of Next-period Consumption

Following Kmenta (1967), a second-order approximation to the log of aggregate consumption (equation 11) about $\omega = 1$ is:

$$
c_{c,1} \approx (\frac{\Gamma^{\frac{1}{\omega}}}{1+\Gamma^{\frac{1}{\omega}}})x_1 + (\frac{1}{1+\Gamma^{\frac{1}{\omega}}})y_1 - \frac{1}{2}\frac{1-\omega}{\omega}\frac{\Gamma^{\frac{1}{\omega}}}{(1+\Gamma^{\frac{1}{\omega}})^2}(x_1 - y_1)^2 \tag{35}
$$

As $x_1 - y_1$ is normally distributed with conditional mean $\gamma - \omega\mathbb{E}_0[p_1]$ and conditional variance $\omega^2 Var_0[p_1]$, then $\frac{(x_1-y_1)^2}{\omega^2 Var_0[p_1]}$ follows a non-central chisquared distribution with conditional mean $1+\frac{(\mathbb{E}_0[x_1-y_1])^2}{Var_0[x_1-y_1]}=1+\frac{(\gamma-\omega\mathbb{E}_0 p_1)^2}{\omega^2 Var_0[p_1]}$ and conditional variance $2(1+2(\frac{(\mathbb{E}_0[x_1-y_1])^2}{Var_0[x_1-y_1]}))=2(1+2(\frac{(\gamma-\omega\mathbb{E}_0 p_1)^2}{\omega^2 Var_0[p_1]}))$. To calculate the conditional covariances of $(x_1-y_1)^2$ with x_1 and y_1, we note that by Stein's lemma, if x_1 and x_1-y_1 are (conditionally) jointly normally distributed and $\|2(x_1-y_1)\|<\infty$, then:

$$Cov_0[x_1,(x_1-y_1)^2]=2\mathbb{E}_0[x_1-y_1]Cov_0[x_1,x_1-y_1]$$

and similarly for x_1 and x_1-y_1.

Therefore:

$$\begin{aligned}\mathbb{E}_0[c_1^c]&=(\frac{\Gamma^{\frac{1}{\omega}}}{1+\Gamma^{\frac{1}{\omega}}})\mathbb{E}_0[x_1]+(\frac{1}{1+\Gamma^{\frac{1}{\omega}}})\mathbb{E}_0[y_1]\\&-\frac{1}{2}\frac{1-\omega}{\omega}\frac{\Gamma^{\frac{1}{\omega}}}{(1+\Gamma^{\frac{1}{\omega}})^2}(\mathbb{E}_0[(x_1-y_1)^2])\\&\text{and } Var_0[c_1^c]=\mathbf{V}_1\mathbf{V}_2\mathbf{V}_1^T\end{aligned}\tag{36}$$

where:

$$\mathbf{V}_2\equiv\mathbb{E}_0[\mathbf{z}_1\mathbf{z}_1^T-\mathbb{E}_0[\mathbf{z}_1]\mathbb{E}_0[\mathbf{z}_1]^T]$$

$$\mathbf{V}_1=\begin{bmatrix}(\frac{\Gamma^{\frac{1}{\omega}}}{1+\Gamma^{\frac{1}{\omega}}}) & (\frac{1}{1+\Gamma^{\frac{1}{\omega}}}) & -\frac{(1-\omega)}{2\omega}\frac{\Gamma^{\frac{1}{\omega}}}{(1+\Gamma^{\frac{1}{\omega}})^2}\end{bmatrix}$$

and:

$$\mathbf{z}_1\equiv[x_1,y_1,(x_1-y_1)^2]$$

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