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Speculative Pricing in the Liverpool Cotton Futures Market. A Nonlinear Tale of Noise Traders and Fundamentalists from the 1920s

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Dear Professor Diebolt,

Following the suggestions of the referee, we added the graphs of squared returns to provide evidence in favour of volatility clustering.

In particular, we modified figures 1, 2 and 3 (pages 15-17 in the current version of the paper) and added the appropriate comments.

We take the occasion to thank you for your continuous encouragement and support.

With king regards,

Giulio Cifarelli

Paolo Paesani

Speculative Pricing in the Liverpool Cotton Futures Market. A Nonlinear Tale of Noise Traders and Fundamentalists from the 1920s.

Giulio Cifarelli[+] and Paolo Paesani*

Abstract

In the 1920s and 1930s, empirical studies of cotton futures pricing tend to attribute market fluctuations to shifts in fundamentals. In this paper we qualify this view focusing on the role of speculation. Our research is based on a nonlinear heterogeneous agents model which posits the existence of two categories of speculators, feedback traders and fundamentalists, who react (differently) to deviations of market prices from their fundamental value. The analysis is based on original data drawn from the online archives of *The Times* and on an historical description of the working of a staple commodity market. The empirical findings allow us to conclude that whereas feedback traders tend to herd, fundamentalists are more affected by risk aversion and react but slowly to the underpricing/overpricing of the cotton contracts. As expected, the presence of fundamentalists stabilizes the market even if, at least in the time period under investigation, the behavior of feedback traders is the major driver of short-run price dynamics.

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Introduction

The paper investigates the role of speculation in the Liverpool cotton futures market between 1921 and 1929. This sample is interesting for two main reasons. First, in the 1920s market forces, rather than cartels and governments, determine prices in a context characterized by the post-war resumption of free trade and by the gradual reintegration of international commodity markets, which would come to an end with the onset of the Great Depression (on this see Hynes et al. 2012). Second, the prices of staple commodities, such as cotton, exhibit high volatility in a period of free international capital movements and shifting exchange rate regimes, conditions not too dissimilar from those observed over the past two decades and propitious to speculation.

Our analysis is based on historical descriptions of the working of speculation in the cotton futures market and focuses on the price determination process, which is found to be nonlinear. A rapidly expanding literature suggests that agent heterogeneity may cause nonlinear mean reversion in the asset pricing mechanism. Brock and Hommes (1997, 1998) and Westerhoff (2004), among many others, assume that different groups of agents condition their behavior on differing types of information. The resulting market price is a weighted average of the expectations of these different groups. The basic intuition here is that the weights given to the various strategies shift over time as agents react to their performance.

A related strand of research, building on Frankel and Froot (1986), Cutler et al. (1990), De Long et al. (1990) among others, focuses on the interaction between noise traders and fundamentalist speculators, considered a major determinant of short term price dynamics. Here too the behavior of agents depends on past profit and the price is driven by an endogenous nonlinear law of motion.

As shown in Cifarelli and Paesani (2012), in the time period under investigation, cotton futures markets are not informationally efficient in the sense of Fama (1970) and cotton price rates of change are serially correlated. Taking this into account, the present study posits that prices do not react only to exogenous news but have also a relevant endogenous driver which is attributed to the interaction of two groups of speculators, noise traders and fundamentalists. Noise traders, prone to "overenthusiasm" and "overtrading", extrapolate past price changes and as such follow a positive feedback trading strategy.[1] Fundamentalists expect prices to return toward their long-run equilibrium value. Whereas the former may destabilize the market, the latter tend to smooth price fluctuations.

Focusing on a period such as the 1920s, where market forces play a predominant role in determining prices, is essential for this model to provide a realistic interpretation of the data. Indeed, observed price patterns, including a large upswing between 1923 and 1925, suggest a relevant impact of destabilizing speculation.

Our approach to the study of this phenomenon differs from previous studies by Westerhoff and Reitz (2005) and Reitz and Westerhoff (2007) in that the strength of both feedback and fundamentalist trading varies over time as speculators react – with differing dynamics – to the same information set, viz. to deviations of the previous period's price from its normal long run value. The empirical findings are satisfactory and provide an informative insight in a time period and in a market that received but scant scholarly attention.

The paper improves upon previous research for the following reasons.

First, it provides – to the best of our knowledge – the first nonlinear dynamic analysis of commodity futures speculation in the 1920s, a period in which sophisticated financial operators had to cope with the volatility of market prices using but limited (by our standards) technical and statistical tools. The analysis is based on original data drawn from the online archives of *The Times.*

[1] For a discussion of the effects of overenthusiam and overtrading, both typical of noise trading, in the cotton market in the 1920s see Hubbard (1923, p. 435-441). On the relationship between noise trading, overconfidence and feedback trading see the analysis of "investor sentiment" in Shleifer and Summers (1990).

Second, it introduces a realistic model which posits that both feedback traders and fundamentalists react (differently) to the same information set, viz. to the deviation of the previous week's market price from its fundamental value, proxied by a three-month price moving average. The former extrapolate price changes and the latter adopt a contrarian behavior. Interestingly, this characterization of speculative activity seems to be consistent with the observations of expert witnesses of those times.

Third, it identifies a clear-cut difference between the reaction of feedback traders, that tend to herd as they react rapidly and simultaneously to price deviations from their normal values, and fundamentalists. The former may destabilize the market while the latter react more slowly, are risk averse, and bring about stabilizing price adjustments that dampen the short term impact of noise trading. On balance, the relatively weak mean reversion provides leeway to destabilizing speculation which seems to replicate some characteristics of contemporary commodity pricing.

Based on these considerations, the rest of the paper is organised as follows. Section 1 discusses the Liverpool cotton futures market in the 1920s and defines the historical and institutional background of the analysis. Section 2 constructs a heterogeneous agent model of cotton price fluctuations. Section 3 contains the statistical analysis of the data. Section 4 investigates the main differences in the trading strategies of fundamentalists and noise-traders. Section 5 concludes the paper.

1. Historical and institutional background

In the second half of the nineteenth century, organised futures markets were created for the main commodities, including cotton. Developments in communication (e.g. the laying of the Trans-Atlantic cable in 1866) enabled merchants to anticipate market movements, trading in advance of delivery. Extended use of warrants and warehouse receipts made it easier to transfer ownership without transferring the assets that underlied the futures contracts and facilitated the advances of capital against the goods held. The establishment of official grading systems permitted to write contracts for the delivery, within a specified future period of time, of given quantities of standard-grade commodities which did not exist until the time of delivery. Codification of rules on weighing, warehousing, inspection, delivery, centralisation of trading, and the establishment of clearing houses transformed the conventional practice of forward sales of goods "to arrive" into fully fledged futures trading (on this see Williams 1982 and the reference cited therein). The creation of organised futures markets extended the scope of speculation. "Without a system of grades and receipts there could be no short-selling, and without short-selling there could be no operations […] in which the dealer seeks to secure profit by selling for forward delivery at one price and by making the delivery with goods bought later at a lower price. Under the old methods 'bull' speculation alone was possible; the speculative market is not complete till the machinery for bear 'speculation' is added" (Emery 1896, p. 39).

In the 1920s, there were eight cotton futures markets in the world; three were located in the USA (New York, New Orleans and Chicago), three in Europe (Liverpool, Bremen, Havre), one in Egypt (Alexandria) and one in India (Bombay). As a result of rapid communication and of the activity of arbitrageurs, "The price of American cotton tends to be a world price. It is made primarily in the futures markets of the world, which are based on American cotton, because the American crop is the most highly standardized and the most liquid [...]. The futures markets are the clearing houses for all information which affects either the supply of cotton or the demand for it" (Cox 1927, p. 176). Among these markets, Liverpool played a very prominent role.

1.1 British cotton trade and the Liverpool market

Until the early nineteenth century British cotton imports came mainly from the British West Indies (75% in 1786-90) and from Mediterranean countries (19% in 1786-90). At the beginning of the twentieth century the situation had dramatically changed and Britain mainly depended on imports of American cotton (77% in 1901-1904, against less than 1% in 1786-90).[2]

The development of organized cotton markets started in late eighteenth century, when British cotton trade began to grow quickly in volume, importance, and technical organization and when cultivation of cotton was first attempted in North America, soon leading the USA to become the most important producer in the world (Cristiano and Naldi 2013).

In the 1920s, Europe as a whole imported approximately 50 percent of the American crop yearly and Britain took up more than all other European countries put together, with the exception of Germany. British imports of American cotton were mostly handled in Liverpool, the largest port closest to the Manchester mills. The Liverpool cotton futures market had been formally organized in 1882 by the Liverpool Cotton Association, twelve years after the New York cotton futures exchange (the largest in the world) and two years after New Orleans (Baffes and Kaltsas 2004).[3]

It hosted different categories of merchants including: importing houses, selling brokers (assisting importers in reselling the cotton after its arrival in Liverpool), spinners' buying brokers (buying cotton on behalf of mills), merchant brokers (who imported and sold cotton to their own spinners). Merchants were divided into two groups: full members, who set the policies of the Association, and associate members. Full membership was limited to 600 and reserved to British citizens. There were no fixed limits for associate members, who were divided in seven distinct categories.

As Cox (1927) observes, before World War I Liverpool was known for making cotton standards for Europe and virtually for the whole world as it was the only market where futures on both American and non American cotton were

[2] Source Chapman and McFarlane (1907). On early Liverpool cotton imports and the organization of the cotton market in the XVIII century see Dumbell (1923).

[3] As Williams (1982, p. 306) recalls, although the year 1869 has been given as the earliest date for written rules in Liverpool, the minutes of the Liverpool Cotton Brokers Association for 19 April and 17 June 1864 mention the voting into force of rules for cotton 'to arrive'. For an early account of the creation of the Liverpool Cotton Market and of the Liverpool Broker's Association see also Ellison (1886).

traded. Most cotton bought and sold in Europe, was traded and sold on Liverpool contract forms and according to Liverpool rules. Settlement disputes were nearly always referred to Liverpool for arbitration. Much of the international business of Liverpool was lost during and after World War I due to exchange rate instability and to a more aggressive policy on the part of the American markets, New York in particular.

1.2 Speculation and pricing in cotton futures markets in the 1920s

In the 1920s, the study of the relationship between futures markets and speculation was in its early stages. Emery (1896) contains one of the first systematic treatments of the subject. After relating the emergence of speculation (the operation of *buying and selling commodities, or securities or other property, in the hope of a profit from anticipated changes of value*), Emery clarifies that professional speculation plays two main roles in the economy: it promotes efficient allocation over time and space through its influence on prices, it relieves producers and traders of ordinary business risks. Speculators' activity is mainly based on the intelligent examination of market fundamentals. Speculators discount all relevant news and are as successful as rapid and accurate their forecasts are.

On the whole, the presence of professional speculators tends to reduce price volatility and to moderate the size if not the frequency of price changes. At times, however, prices may deviate from fundamentals either because of the public reacting to unpredictable excitement or panic or as a consequence of manipulation (e.g. through corners, squeezes, spreading of false rumors) but these episodes tend to be short-lived.

Building (among many others) on Emery, Hubbard (1923) investigates the cotton industry and cotton futures market both in the USA and in Britain. Hubbard coincides with Emery in seeing cotton prices as mainly determined by fundamentals and in expecting deviations from them to be short-lived. "There exists in the cotton market no such thing as a good 'tip' and no such thing as 'inside information'. When all is said and done, prices move according to supply and demand. Sometimes the momentary demand may prove to be merely excited speculative buying and not real demand from consumers; sometimes the selling may be mere liquidation and not the actual pressure of cotton. In either case the force in the market is purely temporary and not to be seriously considered as a reason for permanent change in prices. […] It is always the supply of cotton and the demand for cotton which are the real fundamentals of the market" (Hubbard 1923, p. 436–437).[4] Similarly, Howell notes that spot and futures prices move together because they are both "determined largely by the aggregate of present and anticipated future conditions of demand and supply" (Howell 1939, p. 50). As to this, Smith (1928) identifies eight main supply and demand factors and quantifies their interrelationship with cotton prices.[5]

Against this background, Hubbard discusses the specific role of speculation on pricing and identifies two types of speculators: competent and incompetent. Competent speculators operate on the basis of market fundamentals to whose investigation they devote *much reasoning taking the form of prolonged and systematic analysis*. *Competent speculators are calm and patient. When they reverse their positions (…) they do so gradually.* Their presence contributes to stabilizing the market. Incompetent speculators, instead, constantly shift their position, often reversing it when they incur losses. They tend to be *convinced by the force of the market itself*, are prone to over-enthusiasm and over-trading. Over-trading, in particular, is

[4] Killough and Killough (1926, p. 47-48) agree with Hubbard (and Emery) when they write "The speculator uses the futures market as a place to pit his judgment of supply, demand, and price movements against the judgments, better or worse, of other speculators. His function is to bring together all the available facts, to act upon them, and thus to turn the balance of influence toward the maintenance of a fair competitive price".

[5] The list of supply and demand factors provided by Smith (1928, p. 9-10) reads as follows: "(A)ctual supply of cotton in the United States at the beginning of the month. […] "(P)otential" supply, or estimated size of the crop. […] Accumulated domestic consumption, by months. Accumulated exports, for foreign consumption, by months. […] Accumulated rates of change in general price level. Average price of industrial stocks. […] Series representing the years from 1903 to 1924 and indicating yearly changes, or trend, in demand and other trend factors. Series representing the months of the crop year, beginning June, and indicating seasonal changes not otherwise taken care of".

responsible for the confusing upward and downward zigzag patterns which can be observed on price charts.

Hubbard's observations confirm those of Chapman and Knoop (1906) as to the existence of expert and inexpert speculators in the Liverpool cotton futures market, with the former having a stabilizing influence on prices whereas the presence of the latter, possibly concomitant with market manipulation, could have destabilizing if short-lived effects on prices.[6]

In the same vein, Howell observes "Trading by speculators tends to increase the breadth and liquidity of the market (…) On the other hand, the manipulation by speculative transactions may at times decrease the usefulness of futures as hedges and result in other disadvantages to growers, merchants, and manufacturers" (Howell 1939, p. 47).

2. Heterogeneous agent model of cotton price fluctuations

The hypothesis that different types of speculators play a crucial role in determining short term cotton price dynamics can be empirically investigated using appropriate modeling and econometric techniques. Our approach to this extends the chartist-fundamentalist interaction set out by Reitz and Westerhoff (2003) which, in turn, relies on previous analyses by Day and Huang (1990) and Lux and Marchesi (2000), among others. In line with the heterogeneous agents models' rationale, it is assumed that both fundamentalists and feedback traders react – admittedly in a highly differing way – to a perception of market mispricing.

Feedback traders extrapolate the existing price trend and, introducing a positive feedback loop in the dynamics, raise price volatility. Fundamentalist contrarian behavior usually reduces price deviations from their normal

[6] Chapman and Knoop define inexpert speculators as follows "the public apt to be influenced as a crowd, to give way to panic or become unduly sanguine ... and easily misguided by bulling and bearing operations" (Chapman and Knoop 1906, p. 324–325).

(equilibrium) value and dampens market variability.[7] Different types of market configurations are possible, depending on the relative number of feedback traders and fundamentalists. Transition among these configurations can be modeled with a regime-shift procedure.

Based on this intuition, this paper relies on the STAR methodology originally set out in Teräsvirta and Anderson (1992) and Teräsvirta (1994). This approach posits a smooth transition between two (or more) regimes with differing dynamic characteristics, driven by the behavior of a given indicator variable or set of variables. In our case, the deviation of prices from their normal (fundamental) value triggers the transition from one regime to the other.

Prices are set in an order driven market. Every period traders revise their long/short positions; price changes from *t* to *t+1* are a function of their excess demands and can be parameterized by the following log-linear function

$$p_{t+1} = p_t + a(D_t^N + D_t^F) + e_{t+1} \qquad (1)$$

where p_t is the logarithm of the cotton spot/futures price, a is a positive market reaction coefficient and D_t^N and D_t^F denote the demand of feedback traders and fundamentalists. The residual e_{t+1} accounts for additional agents that may impact on prices, such as hedgers, consumers and producers. The demand of feedback traders at time t is given by

$$D_t^N = a_1 S_{1it}(p_t - p_{t-1}) \qquad (2)$$

[7] Assuming that the two groups of speculators partially overlap allows us to take into account the possibility that the same speculator shifts from one behavior to the other according to the size of market disequilibrium.

where coefficient a_1 is positive as feedback traders expect the existing price trend to persist in the subsequent time period. They will buy the commodity if Δp_t is positive and sell it if Δp_t is negative. Their overall impact is nonlinear and is given by $a_1 S_{1it}$ where S_{1it} is assumed to measure the fraction of the set of feedback traders entering the market at time *t*, fraction which, in turn, will depend upon market conditions.

It is parameterized by the following logistic function

$$S_{1it} = \left[1 + \exp\left\{-\gamma_1 \left(\left|N - p_{t-i}\right| / \sigma_{t-i}\right)\right\}\right]^{-1} \qquad i = 0, ..., l$$

(3)

N is the normal (equilibrium) price of the commodity spot/futures contract.

It is defined as the following M-periods moving average of the logarithms of current and past commodity prices $N = \sum_{r=0}^{M-1} p_{t-r} / M$. Following Schwartz and Smith (2000) and Ellen ter and Zwinkels (2010) we posit that the cotton price can be treated as the algebraic sum of two stochastic components: an equilibrium level *N* and a temporary deviation (N-p_t). The value of the delay parameter *i* is determined empirically as it depends upon observed nonlinearities which in turn reflect the physical and institutional characteristics of the Liverpool cotton pricing system.

The component $\left|N - p_{t-i}\right| / \sigma_{t-i}$ is a signal to noise ratio. The larger the deviation of p_{t-i} from N, the stronger the perception of market disequilibrium and the larger the fraction of feedback traders that will post orders on the market. The denominator, σ_{t-i}, is an index of price variability. It accounts for the impact of risk. A higher (lower) risk associated with higher (lower) price volatility will reduce (increase), for a given perception of market disequilibrium, the willingness of speculators to enter the market. As in Reitz and Slopek (2009) S_{1it} can take any value in the [0.5-1] interval as $| N - p_{t-i} |$ ranges from 0 (when $N = p_{t-i}$) to $+\infty$. It is assumed thus that at least 50 percent of potential feedback traders operate in the market at any time t. Coefficient γ_1 is positive and captures the dynamics of the nonlinear behavior. The higher the synchronization of traders' reaction to price deviations from their normal level (a symptom of herding behavior), the larger the value of γ_1. On the contrary, a low absolute value of γ_1 will reflect idiosyncratic reactions of traders to price disequilibria, possibly due to differing degrees of risk aversion. The demand of fundamentalist speculators reads as

$$D_t^F = a_2 S_{2jt}(N - p_t) \quad (4)$$

where a_2 is a positive reaction coefficient. Fundamentalists posit that cotton prices are mean reverting i.e. that any deviation from their normal value N will but be temporary. They will buy cotton contracts whenever they deem them underpriced ($(N - p_t) > 0$) and sell if they believe them to be overvalued ($(N - p_t) < 0$), dampening in this way price fluctuations. Also the overall stabilizing impact of fundamentalists $a_2 S_{2jt}$ is assumed to be nonlinear. S_{2jt} measures the time varying fraction of the set of fundamentalist speculators that will enter the market at time t. It is parameterized by the following logistic function

$$S_{2jt} = \left[1 + \exp\left\{-\gamma_2 \left(\left|N - p_{t-j}\right| / \sigma_{t-j}\right)\right\}\right]^{-1} \qquad j = 0,...,m$$

(5)

which has the same properties of equation (3) above. Coefficient γ_2, however, reflects the dynamics of the fundamentalists' reaction to price deviations from N, which, as shall be seen in the empirical analysis, differs significantly from that of feedback traders. Here too we assume that at least 50 percent of potential fundamentalist speculators are active in the market at any time t.[8] Combining equations (1) to (5) the impact of noise trader and fundamentalist speculators on cotton spot/futures trading is parameterized by the following nonlinear relationship

$$\Delta p_{t+1} = \frac{c_1}{1+\exp\left\{-\gamma_1 \left(\left|N - p_{t-i}\right| / \sigma_{t-i}\right)\right\}} \Delta p_t + \frac{c_2}{1+\exp\left\{-\gamma_2 \left(\left|N - p_{t-j}\right| / \sigma_{t-j}\right)\right\}} (N - p_t) + e_{t+1} \qquad (6)$$

where $c_1 = aa_1 > 0$, $c_2 = aa_2 > 0$, $i = 0,...,l$, and $j = 0,...,m$.

The selection of the smooth transmission parameterization of equations (3), (5) and (6) is justified, according to Teräsvirta (1994), by the plurality of the agents that are involved in the decision process. Even if the single speculator takes a dichotomous decision, it is unlikely that all agents act simultaneously. Since the price series provide information on the aggregate decision process only, the overall impact will be smooth rather than discrete.

3. Statistical analysis of cotton price dynamics

3.1 Empirical specification of the model

Cotton spot and futures prices are sampled with a weekly frequency and found to be heteroskedastic. A GARCH procedure is therefore used – following Lundberg and Teräsvirta (1998) – in order to estimate the second moments of the model. The following system is used in the empirical investigation, where the specification of the conditional mean of the spot/futures cotton price rates of change is given by equation (6′), while the

[8] Alternative switching rules, in which it is assumed either that the number of potential noise trader/fundamentalist speculators operating in the market varies from 0 to 100 percent, or that $S_{2jt} = (1 - S_{1it})$, i.e. that the number of fundamentalists rises as the number of active feedback traders declines, were tested and rejected in the empirical investigation.

corresponding conditional second moments are parameterized as a GARCH(1,1) relationship

$$\Delta p_t = c_0 + \frac{c_1}{1+\exp\left\{-\gamma_1\left(\left|N - p_{t-1-i}\right| / h_{t-1-i}\right)\right\}}\Delta p_{t-1}$$

$$+\frac{c_2}{1+\exp\left\{-\gamma_2\left(\left|N - p_{t-1-j}\right| / h_{t-1-j}\right)\right\}}(N - p_{t-1}) + e_t \quad i = 0,\ldots,l\ ,\ j = 0,\ldots,m \qquad (6')$$

where $e_t = \nu_t\sqrt{h_t^2}$, $\nu_t \sim IIDN(0,1)$

$$h_t^2 = \omega + \alpha e_{t-1}^2 + \beta h_{t-1}^2 \qquad (7)$$

It is assumed throughout that $N = \sum_{r=0}^{11} p_{t-r} / 12$, i.e. that both fundamentalists and feedback traders base their assessment of the normal equilibrium price on past observations up to three months.

3.2 Preliminary Statistical Analysis

We employ weekly data on spot, one month and three months futures prices for cotton, observed over the 7 January 1921 – 31 December 1929 time period. Weekly prices are Friday closing prices as recorded the following day.[9] The prices come from the online archives of *The Times* (Section: home commercial markets).[10] They refer to the Liverpool American Future Contract.

[9] The choice of a weekly frequency can be justified on the basis of two considerations. First, the use of a daily frequency would imply a large and potentially confusing number of lags in the dynamic parameterization of the pricing equation, given the observed reduced informational efficiency of the cotton market. Second, we use the very frequency and dating patterns adopted by the International Institute of Agriculture in its "International Yearbook of Agricultural Statistics" (for more details see Hynes et al. 2012). As pointed out by Hubbard (1923, p. 294) tenders on futures contracts in Liverpool were held on Mondays, Wednesdays and Fridays.

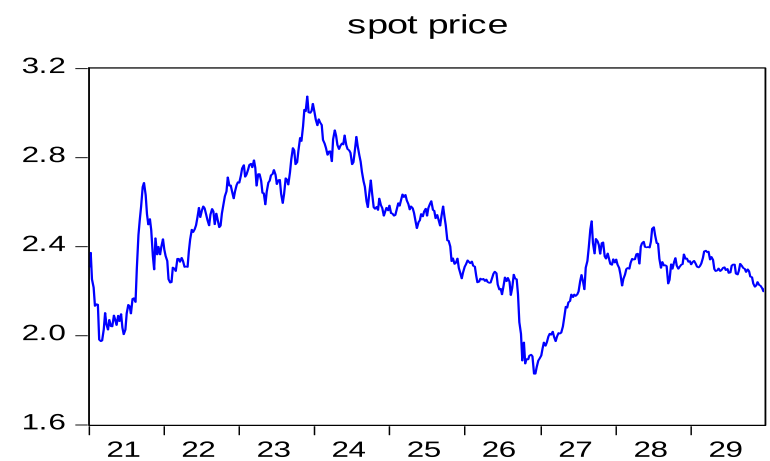
[10] We use as spot price the price of the futures contract closer to delivery, that is with maturity in the current month.

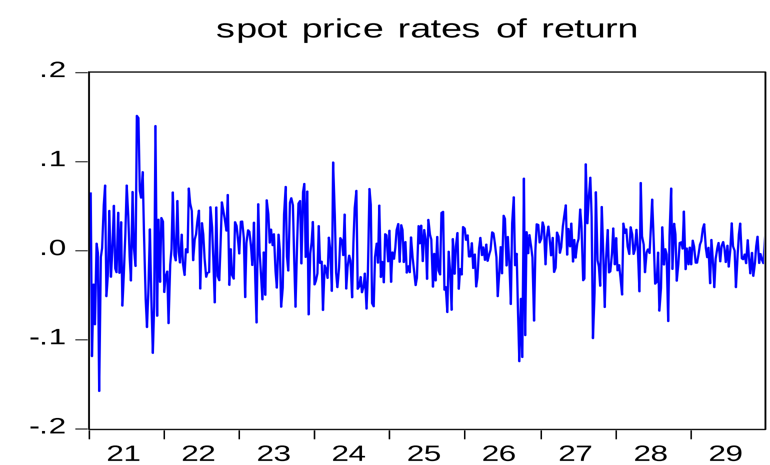
In the period which our analysis refers to (1921 – 1929), the futures contract prescribed the delivery of 100 bales of American Cotton net weight (equivalent to 48,000 pounds) of Fully Middling Cotton or of any grade not lower than Low Middling (Liverpool classification standards), "with additions or deductions on the agreed price for such qualities as are within the contract according to their value as compared with the spot value of fully middling […] on the day the cotton is tendered" (Hubbard 1923, p. 290). Delivery was possible in every month of the year.[11] The price was made in Liverpool points. "A Liverpool 'point' is one-hundredth of an English penny per pound of cotton" (Hubbard 1923, p. 291). The farthest ahead a contract could specify was one year and one month ahead. Contracts bore an interest calculated as the difference between the agreed price and the price set by the Future Committee at 11 A.M. on the first Monday following the transaction. Interests were settled weekly (on Thursdays) through the Cotton Bank, a clearing institution managed by the Bank of England (on this see Hubbard 1923, p. 293–294).

As can be seen from the graphs set out in the upper panels of Figures 1, 2 and 3, prices – set out in logs – exhibit a cyclical behaviour. Three main phases can be identified: a surge in prices between 1921 and 1924, a correspondingly sharp decline ending in mid-1926 and a partial recovery followed by relative stability from 1927 to the end of the sample. These gyrations are accompanied by uneven bouts of volatility clustering in the price rates of return (central panels of Figures 1, 2 and 3). Spikes in variability, quantified by the squared rates of return set out in the lower panels of Figures 1, 2 and 3, correspond to periods of market stress which seem to be particularly relevant during the first of the three phases mentioned above. Whenever feedback traders enter the market, we expect price volatility to rise, whilst fundamentalist dominance is likely to exert a dampening pressure.

[11] For a description of cotton futures contracts prior to the 1919 reform see Chapman and Knoop (1904) and Hubbard (1923), Ch. XXV.

Figure 1. Spot prices, 1921 – 1929





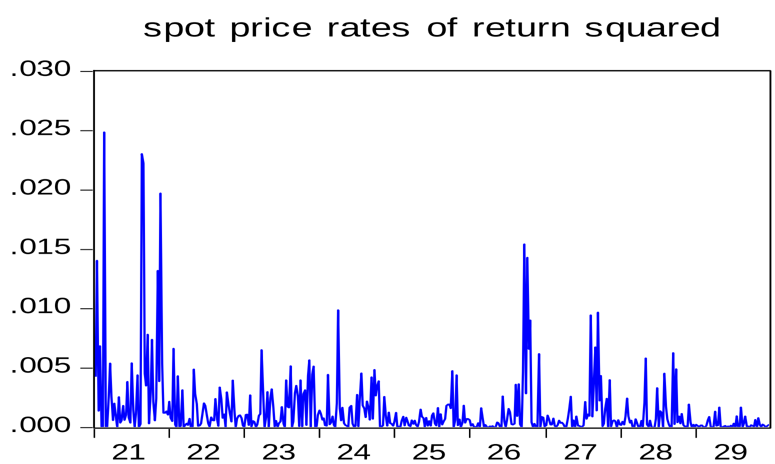


Figure 2. One month to maturity futures prices, 1921 – 1929

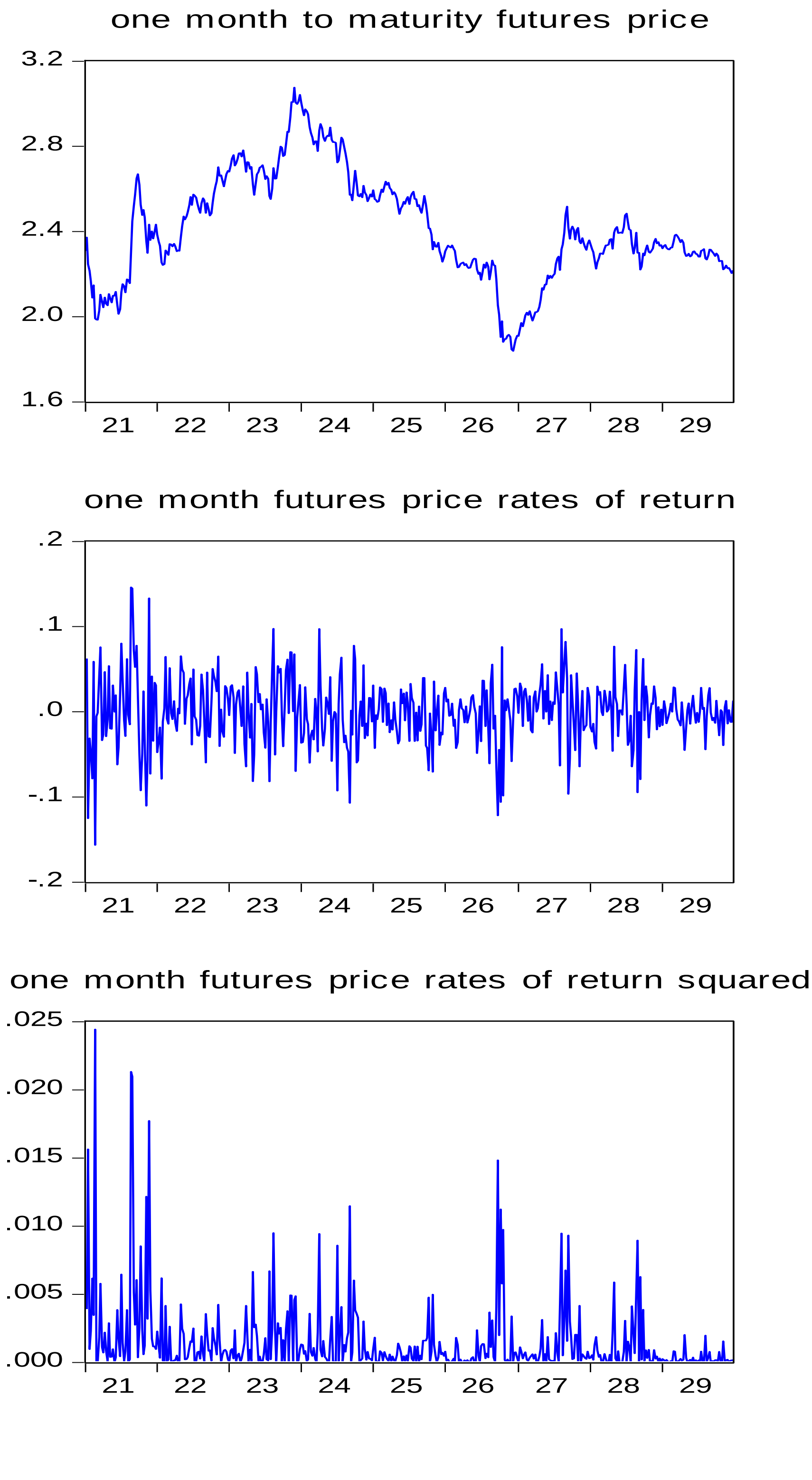
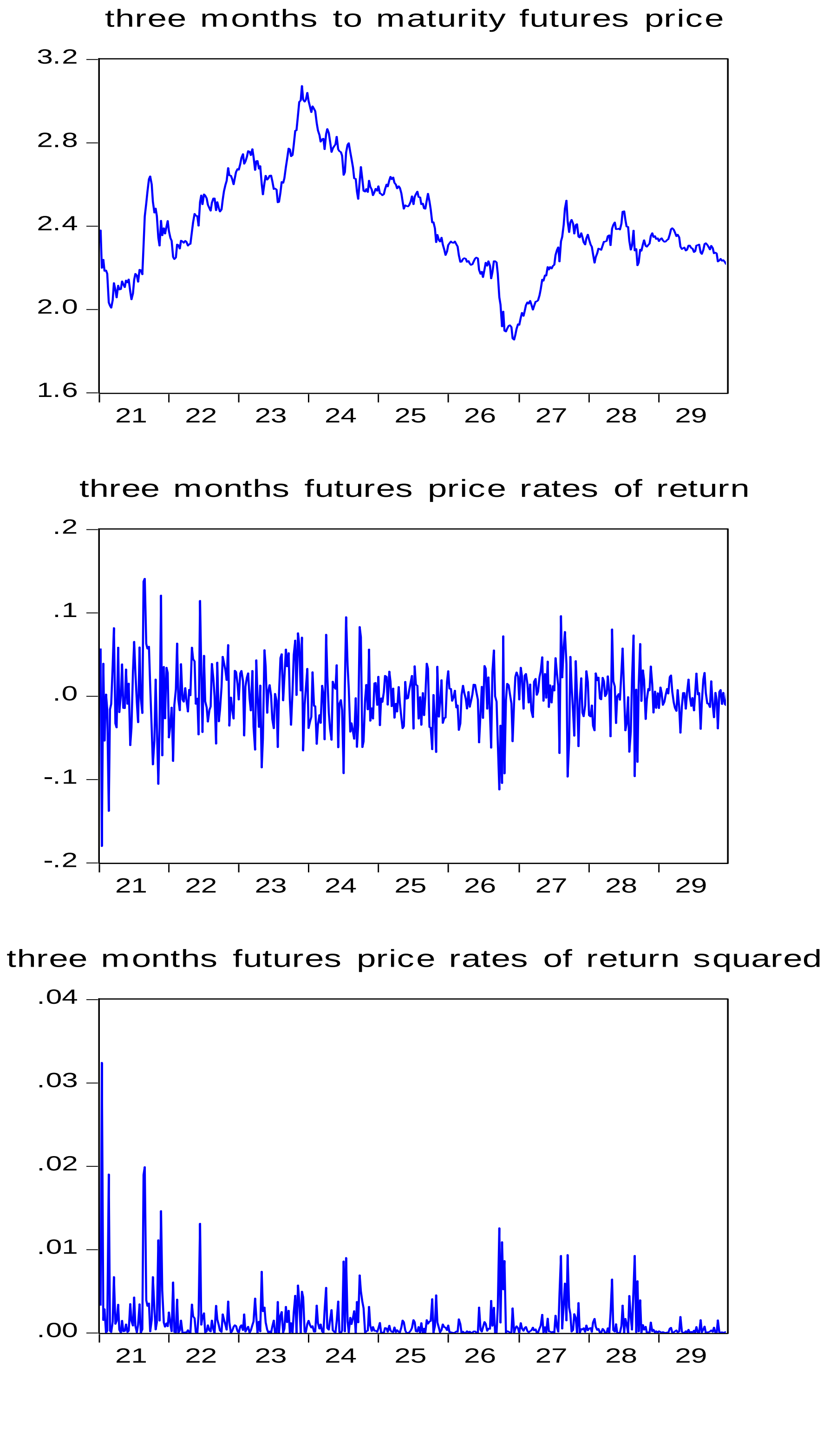
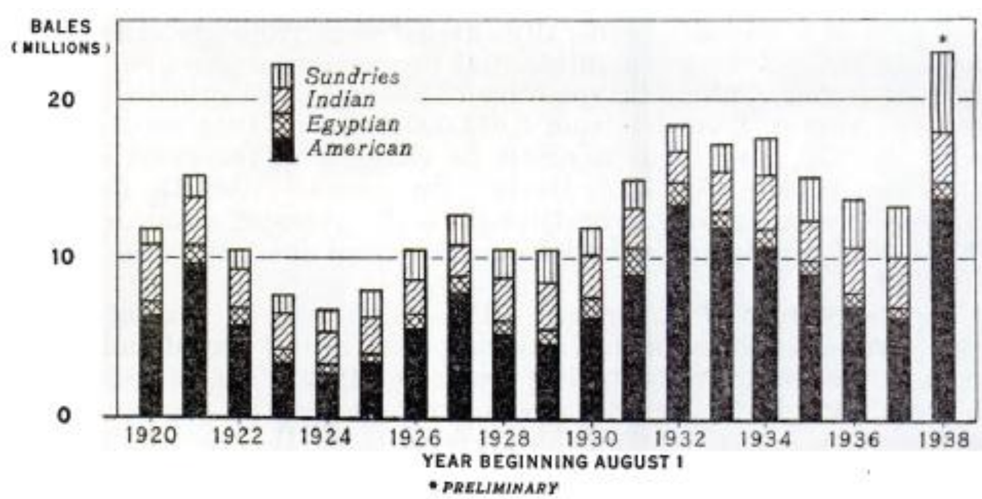


Figure 3. Three months to maturity futures prices, 1921 – 1929



Stocks carried over from one season to the next synthesize the interplay of demand and supply and, as such, provide information on excess demand, useful to interpret price variations. Figure 4 shows the world carry-over of cotton of specified growths, distinguishing among American, Egyptian, Indian and other producers. Stocks of American cotton vary significantly over time and, given their size, impact on overall stocks dynamics. Between 1921 and 1924, a period of high price variability, stocks of American cotton fell from approximately 10 million bales to less than 5. Total supply declined from 20 million bales in 1920 to almost 15 million bales in 1923, partly as a result of a heavy boll weevil infestation (see Howell 1939, Figures 2 and 4, p. 4 and p. 5). Meanwhile, mill consumption showed a mildly positive trend, increasing from approximately 12 million bales in 1922 to about 15 million in 1926 (see Howell 1939, Figure 11, p. 16), reflecting improved business conditions. In 1924, production picked up again and kept increasing until 1926.

Figure 4. World carry-over of cotton of specified growths, by years 1920 – 1938



Source Howell (1939, p. 4)

This led to lower prices and increasing stocks, in spite of sustained consumption. Finally, a small crop in 1927 and average crops in 1928 and 1929 contributed to the contraction of stocks and to the recovery and subsequent stabilisation of prices observed from 1927 until the end of the sample.[12] Summary statistics of returns on spot and futures contracts are presented in Table 1. Returns are computed as first differences of the logarithms of the price levels. The time series distributions are asymmetric and leptokurtic.

Table 1. Descriptive statistics

1921 – 1929			
	Δs_t	Δf_t^1	Δf_t^3
Mean	0.0004	0.0004	0.0004
Std.dev.	0.0374	0.0376	0.0364
Skew	0.2027	0.0926	0.1478
E.Kurt	1.3729	1.2606	2.2163
JB	39.1098 [<0.0001]	30.9797 [<0.0001]	29.8999 [<0.0001]
AR(1)	0.133	0.102	0.086
Auto(1)	8.6581 [0.0030]	7.0993 [0.0080]	6.1570 [0.0130]
AR(3)	0.012	0.005	0.017
Auto(3)	9.4981 [0.0230]	7.5765 [0.0560]	7.6078 [0.0550]
AR(6)	-0.066	-0.067	-0.028
Auto(6)	13.071 [0.042]	7.7262 [0.259]	4.6458 [0.590]
AR(12)	-0.011	-0.023	-0.042
Auto(12)	16.755 [0.159]	12.733 [0.389]	10.919 [0.536]
ARCH(1)	51.5140 [<0.0001]	40.9950 [<0.0001]	34.358 [<0.0001]
ARCH(3)	103.810 [<0.0001]	81.6560 [<0.0001]	69.6120 [<0.0001]
JTA	36.8115 [<0.0001]	41.5863 [<0.0001]	25.9199 [<0.0001]

Notes. Probability values in square brackets; Skew: Skewness; E.Kurt: Excess Kurtosis; JB: Jarque-Bera normality test; AR(n): n-th order autocorrelation coefficient; Auto(n): Ljung-Box test statistic for n-th order serial correlation; ARCH(n): Ljung-Box test statistic for n-th order serial correlation of the squared time series; JTA: Joint Wald test of the null hypothesis of no asymmetry distributed as χ^2 with 3 degrees of freedom (Engle and Ng, 1993). The data have a weekly frequency over the sample period 7 January 1921–31 December 1929.

[12] On this see also Rowe (1936, p. 102-103) and the section devoted to cotton in The *Special Memoranda on stocks of staple commodities*, written by J.M. Keynes for the London and Cambridge Economic Service (Keynes 1983) Appendix 1.

Intertemporal dependency seems to be stronger for cash than for futures weekly returns. The three time series seem to be mostly affected by first-order serial correlation, higher-order correlations being much less relevant. As expected from visual inspection of the return time series (Figure 1, 2 and 3), volatility clustering affects the time series, as shown by the significant serial correlation of the squared weekly returns.

This finding supports the choice of a GARCH parameterization of the conditional second moments.[13]

3.3 Quasi-Maximum Likelihood (ML) model estimates

Parsimonious ML estimates of the nonlinear model, equations (6′) – (7) are set out in Table 2. The specification of the system is justified by an accurate preliminary investigation which follows the procedure suggested by Teräsvirta (1994). At first the order of the cash/spot return autocorrelations is selected on the basis of the Akaike Information Criterion; a one week lag provides uniformly the best fit.[14] A test of linearity against the nonlinear parameterization of equation (6′) is then performed adopting the procedure of Luukkonen et al. (1988), as modified by Wan and Kao (2009). The transition functions S_{1it} and S_{2jt} are replaced in equation (6′) by third order Taylor series approximations and the following auxiliary equation is estimated

$$\Delta p_t = \lambda_0 + \lambda_1 \Delta p_{t-1} + \lambda_2 \Delta p_{t-1} w_{t-1-i} + \lambda_3 \Delta p_{t-1} w_{t-1-i}^2 + \lambda_4 \Delta p_{t-1} w_{t-1-i}^3$$

$$+\delta_1 (N - p_{t-1}) + \delta_2 (N - p_{t-1}) w_{t-1-j} + \delta_3 (N - p_{t-1}) w_{t-1-j}^2 + \delta_4 (N - p_{t-1}) w_{t-1-j}^3 + u_t \qquad (8)$$

where $w_{t-k} = (N - p_{t-k})$, $\quad k = i, j$

[13] Howell (1934) identifies an analogous pattern for the New York cotton futures prices. His innovative empirical analysis, over the 1917 to 1933 time period, finds that the extent of the fluctuations in prices of cotton futures contracts, for various maturities, varied directly over time with the level of cotton prices.

[14] As suggested by Teräsvirta (1994, p. 211), using the SBIC order selection critierion in this context sometimes leads "to too parsimonious a model in the sense that the estimated residuals of the selected model are not free from serial correlation".

We test linearity against STAR modeling - for various values of i and j - performing LM tests of the null hypothesis $H_0: \ \lambda_2 = \lambda_3 = \lambda_4 = \delta_2 = \delta_3 = \delta_4 = 0$. When $i = j = 0$, H_0 is uniformly rejected, as can be seen from the F-test statistics set out in the LM-NLT row of Table 2. The nonlinear parameterization is justified by the data. The time-varying fractions of feedback traders and fundamentalists entering the market are thus parameterized in equation (6′) as S_{10t-1} and S_{20t-1}.

The overall quality of fit is satisfactory. The parameters of both the conditional mean and conditional variance relationships have the appropriate signs and are significantly different from zero. The usual misspecification tests suggest that the standardized residuals ν_t are well behaved and that the serial correlation and heteroskedasticity of the original return time series are captured by the model ($E(\nu_t) = 0$, $E(\nu_t^2) = 1$, and both ν_t and ν_t^2 are serially uncorrelated). The estimates of equation (6′) reflect the autocorrelation of the cotton spot and futures return time series; the tenets of the efficient markets theory do not apply to the cotton market of the 1920s.

The JTA sign bias tests of Engle and Ng (1993) support the choice of a symmetric conditional variance parameterization since the strong asymmetry of the original return time series detected in Table 1 is filtered out by the specification of the conditional means. The conditional normality of the standardized residuals, however, is rejected by the Jarque Bera test statistics. The t-ratios reported in Table 2 are therefore based on the quasi-maximum likelihood estimation procedure of Bollerslev and Wooldridge (1992). Finally, the F-tests for no remaining nonlinearity, set out in the LM-RNLT row (see Eitrheim and Teräsvirta, 1996, p. 63-65), suggest that the model accounts for the nonlinearities of the data.

The conditional mean estimates support the nonlinear parameterization of the noise trader/fundamentalist behavior, especially in the case of the

Table 2. Estimates of the nonlinear model: equations (6') – (7)

	Spot price i=0, j=0	One month futures price i=0, j=0	Three months futures price i=0, j=0
c_0	0.0002 (0.1305)	-0.0001 (-0.0987)	-0.0003 (-0.2241)
c_1	0.1777 (3.3157)	0.1813 (3.7764)	0.1563 (2.7812)
c_2	0.0933 (2.2487)	0.0937 (5.1898)	0.0689 (2.4154)
γ_1	3.3619 (2.0544)	2.4714 (2.0212)	1.6553 (2.0356)
γ_2	0.2153 (2.9473)	0.2480 (2.6484)	0.2787 (2.7919)
ω	0.58e10-5 (2.1022)	0.68e10-5 (2.0707)	0.76e10-5 (3.0610)
α	0.1920 (5.1078)	0.2021 (5.0730)	0.2200 (6.3950)
β	0.7729 (18.7141)	0.7589 (17.6260)	0.7358 (18.1371)
LLF	898.0678	889.4270	904.7378
Standardized residuals diagnostics			
$E(\nu_t)$	0.0046	0.0065	0.0085
$E(\nu_t^2)$	0.9730	0.9684	0.9683
Skew	0.1489	-0.0308	0.02400
E.Kurt	0.6934	0.8564	1.0112
Auto(1)	0.9450 [0.3310]	0.5640 [0.4527]	0.8430 [0.3586]
Auto(3)	3.4770 [0.3237]	1.3370 [0.7205]	2.4240 [0.4893]
ARCH(1)	0.1089 [0.7414]	0.3971 [0.5286]	0.3351 [0.5627]
ARCH(3)	3.5247 [0.3176]	6.8239 [0.0777]	2.1407 [0.5437]
JTA	7.7999 [0.0503]	7.6157 [0.0547]	4.1759 [0.2431]
JB	11.1287 [0.0038]	14.4085 [0.0007]	20.0258 [<0.0001]
LM-NLT	4.4227 [0.0002]	4.1432 [0.0004]	4.2941 [0.0003]
LM-RNLT	1.6404 [0.1343]	0.6278 [0.7081]	0.5991 [0.7317]
LRT($c_1=\gamma_1=c_2=\gamma_2=0$)	9.6776[0.0462]	9.4001[0.0497]	7.4756[0.1127]

Notes. t-ratios in parentheses and probability values in square brackets; LLF: Log Likelihood value; Skew: Skewness; E.Kurt: Excess Kurtosis; JB: Jarque-Bera normality test; Auto(n): Ljung-Box test statistic for n-th order serial correlation; ARCH(n): Ljung-Box test statistic for n-th order serial correlation of the squared time series; JTA: Joint Wald test of the null hypothesis of no asymmetry; LM-NLT: LM non-linearity test; LM-RNLT: residual non-linearity test; LRT(x=0): likelihood ratio test of the null hypothesis x=0. The data have a weekly frequency over the sample period 7 January 1921 – 31 December 1929. The sample includes 469 observations.

spot/cash and one month to maturity futures contracts. The coefficients, as shall be shown below, identify a nonlinear dynamic reaction to price deviations from their normal value.[15] The coefficients of the three month to maturity contracts are smaller in absolute value and detect a systematic reduction in the speed of market reaction to price movements. Trading seems to become less frequent and the impact on pricing of both feedback traders and fundamentalists decreases with the maturity of the futures contracts.

4. Fundamentalist and feedback traders' pricing dynamics

The value of the speed of adjustment coefficients differs according both to the nature of the speculator and to the type of contract. The value of γ_1 is always larger than that of γ_2, denoting a striking difference in the reaction to the same amount of information, i.e. to deviations of past period's prices from their normal value $(N - p_{t-1})$. As shown in Table 3, the value of the means, medians and standard deviations relative to (incompetent) feedback traders exceed those of (competent) fundamentalists, over the three contracts. As the maturity of the contract rises the fraction of feedback traders entering the market tends to decline, whilst the fraction of fundamentalists tends to rise; destabilizing speculation seems to focus on the spot and on the one month to maturity futures sections of the cotton market. The first order autocorrelation of the S_{10t-1} time series (feedback traders entering the market) is smaller than the corresponding autocorrelation of S_{20t-1} (the fraction of fundamentalists that enter the market). Indeed,

[15] The LR tests set out in the LRT row of Table 2 show that, with the exception of the three months to maturity contract, the joint hypothesis that the noise trading and fundamentalist parameters are nil is rejected at the 5 percent level of significance.

Table 3. Descriptive statistics of the S_{10t-1} and S_{20t-1} time series

	Spot/cash prices		One month to expiration futures price		Three months to expiration futures price	
	S_{10t-1}	S_{20t-1}	S_{10t-1}	S_{20t-1}	S_{10t-1}	S_{20t-1}
Mean	0.9013	0.5677	0.8647	0.5755	0.8192	0.5857
Median	0.9768	0.5596	0.9258	0.5630	0.8377	0.5686
Std.dev.	0.1384	0.0491	0.1489	0.0562	0.1475	0.0612
AR(1)	0.2940	0.5870	0.3830	0.5930	0.4710	0.5730
$\rho_{S_{10t-1},S_{20t-1}}$	0.7346 [<0.0001]		0.8085 [<0.0001]		0.9043 [<0.0001]	
$\rho_{S_{h0t-1},(N-p_{t-1})^+}$ $h=1,2$	0.6983 [<0.0001]	0.6874 [<0.0001]	0.7179 [<0.0001]	0.6925 [<0.0001]	0.7593 [<0.0001]	0.7211 [<0.0001]
$\rho_{S_{h0t-1},(N-p_{t-1})^-}$ $h=1,2$	-0.6317 [<0.0001]	-0.6370 [<0.0001]	-0.6572 [<0.0001]	-0.6530 [<0.0001]	-0.6925 [<0.0001]	-0.6675 [<0.0001]

Notes. Probability values in square brackets; Std.dev.: Standard deviation; AR(1): first order autocorrelation coefficient.

feedback traders tend to enter and exit the market frequently, even if, as the time to maturity of the contract rises, regime persistence rises.[16] As a consequence the correlation $\rho_{S_{10t-1},S_{20t-1}}$ between noise trader and fundamentalist reaction to price deviations from their fundamental value too rises with time to maturity.

As shown in the last two rows of Table 3, there is a relevant asymmetric correlation between S_{10t-1} and positive and negative values of $(N-p_{t-1})$, $(N-p_{t-1})^+$ and $(N-p_{t-1})^-$. Feedback traders do not react to both negative and positive price shifts in a similar way. They are more prone to enter the market when $(N-p_{t-1})$ is positive than when it is negative. In the same way the correlation with S_{20t-1} is significantly larger - in absolute value - when $(N-p_{t-1})$ is positive than when it is negative, as fundamentalists seem to

[16] As the maturity of the cotton contracts rises, the absolute value of γ_1 declines, the degree of synchronization of the response of feedback traders to price deviations from their normal value declines and the persistence and (first order) autocorrelation of the S_{10t-1} time series rises. Ellen ter and Zwinkels (2010) follow De Jong et al. (2009) and attribute strategy persistence to a relevant status quo bias.

react more to under-pricing (going long) than to overpricing of the cotton contracts (going short).

In Figure 5 are set forth scatter plots of the transition functions of noise trader and fundamentalist speculators against deviations of cotton spot/cash and futures prices from their fundamental value. We have interpolated the scatter plots using local first order polynomial regressions with bandwidth based on the nearest neighbor approach.[17]

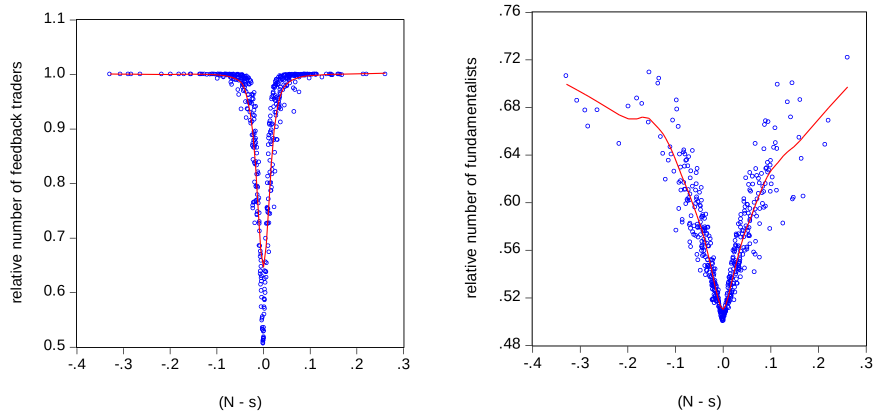
The shape of the nearest neighbor fit is highly informative and reflects the differing values of the transition parameters γ_1 and γ_2. Feedback traders seem to herd in their reaction to price misalignments; small positive/negative price deviations from their normal (equilibrium) values bring about a large simultaneous increase in their relative number, with a destabilizing impact on pricing.

As expected, simultaneity decreases with the time of expiration of the contracts, since the absolute value of the transition parameter γ_1 declines. The scatter plot of fundamentalist speculation reflects a different reaction to price deviations from their three-month moving average. Whereas the value of S_{10t-1} is close to 1 for values of $(N - p_{t-1})$ that lie in the +/-.1 rate of change band, the corresponding value of S_{20t-1} is much smaller, and varies from 0.64 to 0.70 according to the maturity of the contracts. The relative number of fundamentalists grows but slowly as their stabilizing reaction seems to be affected by a growing degree of risk aversion.

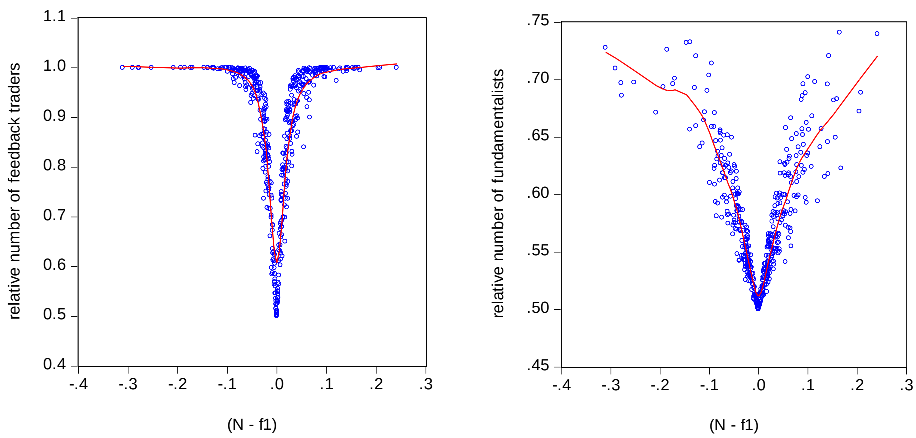
[17] The local regressions are performed on a sub-sample selected according to the Cleveland (1993) procedure and involve about 100 evaluation points. Tricube weights are to be found in the weighted regressions used to minimize the weighted sum of squared residuals. The bandwidth span of each local regression is set to 0.3, which implies a sample of 140 observations for each evaluation point.

Figure 5. Nearest neighbor interpolations of the scatter plots of S_{10t-1}, S_{20t-1}, and price disequilibrium

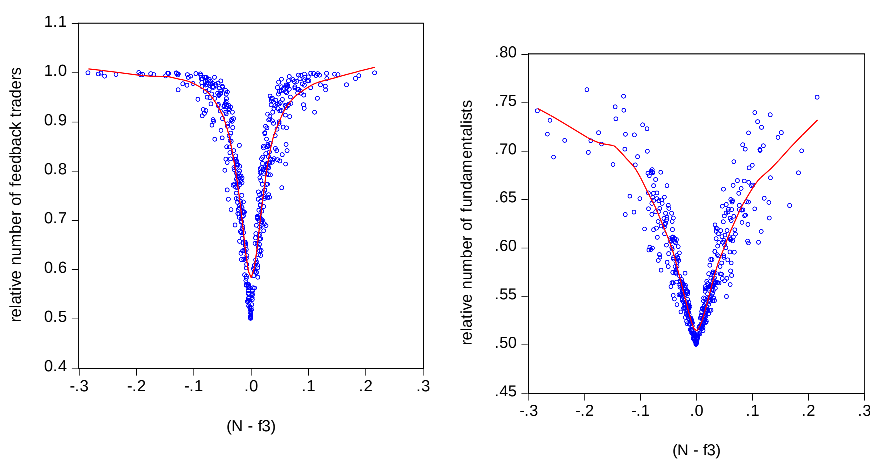
Spot/cash contracts



One month to maturity futures contracts



Three months to maturity futures contracts



Increases in the number of speculative positions are brought about by price deviations from equilibrium that are progressively larger in absolute value and the slope of the nearest neighbor fit of the scatter plot declines as the absolute value of the misalignments rises.

Risk aversion is larger in absolute value for negative than for positive values of $(N - p_{t-1})$, as fundamentalists seem to be more wary to enter the market when the cotton contracts are overpriced than when they are underpriced, a finding that is corroborated by the relative values of the correlation coefficients $\rho_{S_{20t-1},(N-p_{t-1})^{+}}$ and $\rho_{S_{20t-1},(N-p_{t-1})^{-}}$, set out in Table 3.

An intuitive dynamic pattern of the interaction between fundamentalist speculators and feedback traders can be surmised from Table 4. As expected, fundamentalist speculation stabilizes market prices in all cases whereas feedback traders contribute to market stabilization in cases (1) and (4) only.

In order to quantify the overall impact of this nonlinear interaction we perform a dynamic ex post (historical) simulation exercise. First, we simulate the non-linear contribution to the price determination process of feedback traders i.e. $C_X = c_1 \left[1 + \exp\left\{-\gamma_1 (|N - p_{t-1}| / h_{t-1})\right\}\right]^{-1} \Delta p_{t-1}$.

Table 4. Dynamic interaction between fundamentalists and feedback traders

	$\Delta p_{t-1} > 0$		$\Delta p_{t-1} < 0$	
	(1)	(2)	(3)	(4)
	$(N - p_{t-1}) > 0$	$(N - p_{t-1}) < 0$	$(N - p_{t-1}) > 0$	$(N - p_{t-1}) < 0$
Feedback traders	Buy $\Delta p_t > 0$	Buy $\Delta p_t > 0$	Sell $\Delta p_t < 0$	Sell $\Delta p_t < 0$
Fundamentalists	Buy $\Delta p_t > 0$	Sell $\Delta p_t < 0$	Buy $\Delta p_t > 0$	Sell $\Delta p_t < 0$
Price impact	Rapid increase in prices $\Delta p_t >> 0$. The system switches to (2) if $p_t > N$	Fundamentalists take short positions dampening the upward price shifts due to feedback traders' purchases.	Fundamentalists take long positions dampening the downward price shifts due to feedback traders' sales.	Rapid fall in prices $\Delta p_t << 0$. The system switches to (3) if $p_t < N$

Second, we repeat the exercise calculating the combined contribution of both feedback traders and fundamentalists i.e.

$$\begin{aligned} C_X + C_F &= c_1 \left[1 + \exp\left\{-\gamma_1 \left(\left|N - p_{t-1}\right| / h_{t-1}\right)\right\}\right]^{-1} \Delta p_{t-1} \\ &\quad + c_2 \left[1 + \exp\left\{-\gamma_2 \left(\left|N - p_{t-1}\right| / h_{t-1}\right)\right\}\right]^{-1} (N - p_{t-1}) \end{aligned} \tag{9}$$

We then compute the standard errors of the two simulated time series and find that the relative decrease in speculative price variability, due to the market entry of fundamentalists $\left[STD\left(C_X\right) - STD\left(C_X + C_F\right)\right] / STD\left(C_X\right)$, takes the following values: 0.156 in the case of spot prices, 0.161 in the case of one month to maturity futures prices and 0.181 in the case of three months to maturity futures prices. These findings corroborate the hypothesis that fundamentalist speculators bring about stabilizing price adjustment, dampening the short term impact of feedback trading in the context of a model that accommodates for a time varying entry of economic agents into the market that is led by disequilibrium perceptions. Here too the impact of fundamentalists grows with the time to maturity of the contracts.

Finally, it should be noted that the speed of adjustment varies over market regimes since a large (small) number of fundamentalists can be associated with a large (small) number of feedback traders and vice versa depending upon the size of $\left|N - p_{t-1}\right|$. In particular, the system will oscillate between situations in which a large number of feedback traders is associated with a small number of fundamentalists and situations in which large price deviations from equilibrium bring about the entry of a large number of both fundamentalists and feedback traders.

5. Conclusions

Cotton trade has always played a very relevant role in international commodity exchange. During the XIX century, the financial dimension of this trade acquires characteristics that look increasingly similar to those observed today. The diffusion of futures trading, the observation of nonlinear price dynamics and the growing awareness about the role of speculators in determining market prices accompany this evolution.

Building on preliminary historical and institutional reconstruction, our analysis of speculation in the Liverpool cotton futures market validates the choice of applying a model with heterogeneous agents to historical data. This assertion is justified both by the quality of the empirical findings and by their coherence with the main conclusions of qualitative analyses performed in the 1920s and 1930s.

The model we use improves upon previous studies by Westerhoff and Reitz in that it allows the impact on prices of both feedback and fundamentalist speculation to vary over time.

Based on these considerations, our main findings may be summarized as follows. First, the entry into the market of speculators is affected by different reactions to a common perception of market disequilibrium. Feedback traders act as trend-chasers and tend to herd. Fundamentalists instead react more slowly to price disequilibria and stabilize the market. Second, both feedback traders and fundamentalists react asymmetrically to deviations of prices from their fundamental values, more to underpricing than to overpricing of the cotton contracts. Third, the presence of fundamentalists stabilizes the market in all cases whereas the impact of feedback traders on market equilibrium is more nuanced. In case of minor deviations of cotton prices from their equilibrium value, pricing is mostly affected by feedback traders who enter or exit the market in large numbers. As the size of deviations increases, fundamentalists enter the market, offsetting the impact of the actions of feedback traders.

In the 1920s and 1930s, empirical studies of the dynamics of cotton futures prices tend to interpret market fluctuations mostly in terms of supply and demand, that is of fundamental drivers. Our research qualifies this view. In the time period under investigation, we find that feedback trading is a major determinant of price dynamics, at least in the short-run. The interplay of heterogeneous agents and their nonlinear impact seems to be responsible for the pronounced swings in cotton prices of those years.

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