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Financial markets can go mad: evidence of irrational behaviour during the South Sea Bubble[1]

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The volatility of world stock markets in recent years has been the subject of considerable debate. At one extreme there are those who argue that these fluctuations have resulted from shifts in fundamental values, others focus on the actions of rational investors confronted with new, fast-changing information and, at the other extreme, there are those who blame investor irrationality. Thaler suggests that an important conclusion to emerge from the behavioural finance literature is that the resolution of these debates is more likely 'if we learn more about the behavior of people who operate in these markets'.[2] To this end, this paper explores whether investors can be prone to bouts of irrational speculative mania.

Investor behaviour is examined during a period when market prices systematically deviate from fundamental values; that is, during a bubble. Specifically, the paper focuses on one of the most famous bubbles, that associated with the rise and fall of the South Sea Company during 1720. The causes of this bubble have attracted considerable academic debate, since it formed an important part of the first major speculative boom and bust in European stock markets, and its aftermath has had a considerable impact on financial markets. Much of the earlier literature characterizes this bubble as an episode of irrational speculative activity, but more recent explorations have sought to explain it within a rational expectations framework. In this article new evidence is presented, which calls into question these latter contributions and refocuses attention on the central conclusion to emerge from Adam Anderson's original history of the Bubble; namely that it represented an 'unaccountable frenzy', which should serve 'as a warning to after ages'.[3] These findings underline the important role that irrationality may play in stock markets and suggest that today's policymakers may need to counteract the potentially damaging effects of irrational pricing of financial assets.

[1] We are grateful to the anonymous referees for their valuable comments on an earlier draft of this paper.

[2] Thaler, *Behavioral finance*, p. xxi.

[3] Anderson, *Origin of commerce*, p. 123.

The article is arranged as follows. Section I outlines the events surrounding the rise and fall of the South Sea Company in 1720. Section II briefly reviews the literature on the origins of bubbles in general, and section III provides a summary of the debate concerning the causes of the South Sea Bubble. Section IV provides details of the data, and the methodology employed in this study is discussed in section V. Results are presented in section VI and discussed in section VII. Some conclusions follow in section VIII.

I

During 1719, John Law's financial experiment to convert France's debt into stock in the Compagnie d'Occident (the 'Mississippi company') proved a great success, and extraordinary profits were being made by Mississippi investors.[4] The government in England was already exploring means of managing its outstanding debt, and events in France prompted it to explore a scheme similar to Law's Mississippi operation.[5] Following a bidding process between the Bank of England and the South Sea Company, the latter 'won' the right to buy in all outstanding government long annuities, short annuities, and redeemable debts (~£31.5 m) in exchange for its own stock. The government agreed to credit the Company with an increase of £31.5 m in its nominal share capital if all subscribable debts were exchanged, and to pay interest on the debt partly at 4 per cent and partly at 5 per cent until 1727, when a single rate of 4 per cent would be paid. In exchange for these privileges, the South Sea company agreed to pay the government a maximum sum of £7.6 m, assuming full conversion of the government debt.

The South Sea Company refused to set in advance the nominal amount of stock exchangeable for debt, and any rise in the share price above the nominal value (£100) would therefore reduce the amount of stock needed to convert the outstanding government debt. For example, if the share price were £300, the government debt of £31.5 m could be bought in by issuing only £10.5 m (nominal) of stock. The remaining £21 m (nominal) of issuable stock could therefore provide a potential cash flow of £63 m at the prevailing market price (£300), some of which could be used to meet the potential £7.6 m payable to the government.[6] This, together with the desire of South Sea projectors to make a capital gain on their own share holdings, gave the Company an incentive to secure an appreciation in the share price. The largely redundant commercial interests of the South Sea Company offered no outlet for any additional capital raised. However, an appreciation in the share price did provide the Company with the means of raising dividends—albeit, unsustainably—and consequently stimulating even fur-

[4] Murphy, *John Law economic theorist*, pp. 156–65.
[5] Dickson, *Financial revolution in England*, pp. 90–121.
[6] Scott, *Constitution and finance*, p. 307.

Table 1. *Schedule of payments for South Sea money subscriptions (£)*

First Subscription (£s)		*Second Subscription* (£s)		*Third Subscription* (£s)		*Fourth Subscription* (£s)	
14 April 1720	60	(29 April) 1720	40	16 June 1720	100	24 Aug. 1720	200
14 June	30	14 Sept. (24 Aug.)	40	2 Jan. 1721	100	24 Feb. 1721	200
14 Aug.	30	14 Jan. 1721 (24 Dec.)	40	2 July	100	24 Aug.	200
14 Oct.	30	14 May (24 April)	40	2 Jan. 1722	100	24 Feb. 1722	200
14 Dec.	30	14 Sept. (24 Aug.)	40	2 July	100	24 Aug.	200
14 Feb. 1721	30	14 Dec. (24 Dec.)	40	2 Jan. 1723	100		
14 April	30	14 March 1722 (24 April)	40	2 July	100		
14 June	30	14 June (24 Aug.)	40	2 Jan. 1724	100		
14 Aug.	30	14 Sept. (24 Dec.)	40	2 July	100		
		14 Dec. (24 April) 1723	40	2 Jan. 1725	100		
Total	300	Total	400	Total	1,000	Total	1,000

Notes: The sources of data and the method of compilation are discussed in appendix I.

ther rises in the share price. In addition, it emerged later that in their bid to secure the scheme's passage through Parliament, the Company had effectively given 'call options' to key government ministers, to 40–50 members of Parliament, and to those closely connected with the Crown, thereby ensuring that this powerful group also had a strong desire to see the share price rise.

In their implementation of the debt conversion scheme, the Company engaged in what Hutcheson, a sceptical Member of Parliament at the time, described as 'artful management of the spirit of gaming'.[7] A number of devices were employed to issue more stock, while maximizing the South Sea share price. First, four successive share issues were launched on generous subscription terms involving small down payments and extended calls (see table 1 for details of the four subscription issues). Second, the partly paid (and therefore highly leveraged) scrip was designed to be popular with speculators, particularly as it could be transferred using a simple legal assignment. Third, to increase investor liquidity and, consequently, to encourage further demand for its stock, the South Sea Company encouraged investors to borrow from the Company against the security of its shares or subscription receipts. A total of more than £11 m was eventually lent in this way. Fourth, the South Sea Company supported its share price by

[7] Hutcheson, *Collection of calculations*, p. 64.

buying up its own stock. Fifth, the Company raised investors' expectations by carefully orchestrated dividend announcements, it being announced, for example, on the day before the first money subscription that the midsummer dividend would be increased to 10 per cent (from 3 per cent). Lastly, the Company delayed the issue of shares to those who had converted their annuities, and failed to issue receipts for the third and fourth subscriptions. The intention here was to make it more difficult for converting annuitants and subscribers to sell their shares and partly-paid scrip, thereby giving further support to the share price. However, this latter ploy was, at best, only partially successful, since investors could and did trade in subscription receipts before they were delivered out by the company, and there is considerable evidence that such trading was widespread. For example, it was reported that one-sixth of all subscription three receipts were resold within days of the issue, prior to receipts being delivered by the company.[8]

Against this background, South Sea shares, which had already advanced from £130 in February 1720 to over £300 in early April, rose further to £400 (20 May), then to £500 (28 May) before touching £600 on 31 May. This vertical ascent continued into the following month, the share price breaching £700 on 1 June and £800 on 4 June. On 23 June the Company closed its books for two months in order to process the midsummer dividend, so that quoted prices during this period are in fact forward prices 'for the opening of the books'. The highest (forward) price was £1,050, recorded on 25 June, but when the books were reopened the spot price had fallen to £820 (cum dividend). Thereafter South Sea stock weakened dramatically—to £520 in mid-September, £290 at the beginning of October and a low of £170 on 14 October 1720. The bubble had burst.

II

An important distinction is made in the literature between bubbles that result from rational as opposed to irrational behaviour.[9] It has been suggested that, broadly, the former arise from three causes, self-fulfilling expectations ('rational bubbles'), mispricing of fundamentals ('intrinsic bubbles'), and the endowment of irrelevant exogenous variables with asset pricing value ('extrinsic bubbles'). The South Sea Bubble has been attributed to each of these causes.

Rational bubbles occur when asset prices continue to rise because investors believe that they will be able to sell the overvalued asset at a higher price in the future.[10] Investors are aware that a point will be reached when the bubble will burst and, consequently, they require compensation for the risk in the form of higher returns. As the bubble grows, the probability of a price collapse increases and investors require ever increasing compensa-

[8] Dickson, *Financial revolution in England*, p. 129.
[9] Katsaris, *Collapsing speculative bubbles*, pp. 9–10.
[10] Flood and Hodrick, 'Speculative bubbles', p. 86.

tion (returns). This behaviour is associated with spiralling prices, which result, eventually, in the bubble bursting.

Intrinsic rational bubbles occur when investors systematically and persistently misvalue fundamentals.[11] This might arise, for example, during a period of rapid innovation, when even rational investors find it difficult to determine an asset's fundamental value. Zeira demonstrates that intrinsic bubbles can result in prices rising significantly for long periods, and then crashing as a result of informational dynamics.[12] Froot and Obstfeld suggest that empirical evidence for intrinsic bubbles is based on the persistent overreaction that occurs following news of dividends.[13]

It is argued that extrinsic rational bubbles, or 'sunspots', occur when otherwise rational investors, face uncertainty (cf. risk) concerning their environment.[14] In the face of this uncertainty they erroneously endow asset-pricing value to exogenously determined factors which have no impact on fundamental values.[15] When these beliefs are widely shared it may result in asset prices deviating from fundamental values. Support for the existence of extrinsic bubbles comes, for example, from adjustments of asset prices to forecasts from investors who do not hold superior information.

In contrast to the above explanations for bubbles developed within a rational expectations framework, some authors have argued that these bubbles may result from investors being driven by irrationally optimistic expectations, fashion, or fads.[16] Under such conditions investors may develop totally unrealistic expectations about a company's future profitability; as a result the relationship between fundamental values and prices breaks down.[17] These bubbles have been associated with herd behaviour,[18] and it has been suggested that investors may be driven by psychological factors unconnected to fundamental values.[19] For example, when investors are uncertain about the quality of information they hold, they may revert to a simple heuristic of following market trends.[20] If investors use the market in this manner to improve their information set, it can result in a form of herd behaviour or mimetic contagion[21] that displays the typical features of a bubble.

The distinction between bubbles developed from rational or irrational behaviour may not be as clear-cut as the above analysis suggests. For example, investors may mistakenly be convinced that market valuations are

[11] Froot and Obstfeld, 'Intrinsic bubbles', p. 1190.
[12] Zeira, 'Information overshooting', pp. 239–50, 253.
[13] Froot and Obstfeld, 'Intrinsic bubbles', p. 1208.
[14] Azariades, 'Self-fulfilling prophecies', pp. 380–1.
[15] Ibid., p. 395.
[16] Shiller, *Irrational exuberance*, pp. 17–168.
[17] Ofek and Richardson, 'DotCom mania', p. 1134; Perkins and Perkins, *The Internet bubble*, pp. 197–201.
[18] Devenow and Welch, 'Rational herding', p. 605.
[19] Shiller, *Irrational exuberance*, pp. 135–67.
[20] Avery and Zemsky, 'Herd behaviour in financial markets', p. 740.
[21] Lux, 'Herd behaviour', pp. 893–4.

realistic and as a result become participants in an 'irrational' bubble; but the degree of misjudgement that should be classed as irrational is a matter of subjective judgement. Similarly, those who fail to sell assets before the crash of a rational bubble may have misjudged the crash probability. Once again, the degree of misjudgement permitted for an investor to be termed rational is debatable.

III

Those who seek to explain the South Sea Bubble in terms of irrational behaviour rely largely on contemporary anecdotes and quotations. For example, Carswell quotes John Martin, a banker who subscribed to £500 worth of South Sea stock in June 1720 with the comment, 'when the rest of the world are mad, we must imitate them in some measure'.[22] Carswell suggests that it is difficult to explain within a rational expectations framework how investors could have 'believed their [the South Sea Company's] airy structures would not, in the absence of real assets or even prospects, collapse in ruins'.[23] Kindleberger uses the South Sea Bubble as a classic example of speculative mania, where speculation spread to members of the public who had little knowledge of the market.[24] Chancellor identifies three factors which he believes point to irrationality associated with those who purchased shares towards the peak of the bubble; first, that there was considerable public information indicating that the shares were overvalued, second, the risk/reward ratio for these late entrants was very poor, and lastly, the price volatility during 1720 could not be explained by changes in the fundamentals of the South Sea Company.[25] Dickson suggests that in the early eighteenth century even the judgement of experienced businessmen was affected by factors in the social and economic environment, which 'bred an appetite for gain' that 'could and did become uncontrolled'.[26] In summary, the above accounts point to the South Sea Bubble arising from irrational mania.

Recent, more quantitative contributions to the debate have attempted to explain the bubble within a rational expectations framework. Neal, for example, presents evidence to suggest that the rise in the South Sea share price from early February to mid-May was caused by investors re-evaluating the company's fundamentals in the light of the unprecedented financial innovation introduced to convert government debt into stock.[27] However, in retrospect, there appears to have been some mispricing of the fundamentals at this time and, consequently, this phase displays the features of an

[22] Carswell, *The South Sea Bubble*, p. 163.
[23] Ibid., p. 241.
[24] Kindleberger, *Manias, panics, and crashes*, pp. 111–12
[25] Chancellor, *A history of financial speculation*, p. 94.
[26] Dickson, *Financial revolution in England*, p.156.
[27] Neal, *Rise of financial capitalism*, pp. 111–12.

intrinsic bubble. He suggests that the price rises between mid-May and late June resulted from shrewd foreign investors realizing that the South Sea directors were engaged in various forms of price rigging. They therefore believed that they would be able to sell these overvalued shares at even higher prices in the future, and a rational bubble was created. Neal argues that a technical convergence of the forward and spot prices occurred from late June to late August, when the transfer books were closed.[28] Lastly, he suggests that the subsequent collapse was initially caused by a credit squeeze that led to an unwinding of speculative positions, and later by the uncertainty surrounding the proposed reorganization schemes for the Company. Overall, Neal's view is that the South Sea Bubble can be explained in terms of rational behaviour in that it 'appears to be a tale less about the perpetual folly of mankind and more about the continual difficulties of the adjustments of financial markets to an array of innovations'.[29] Carlos, Moyen, and Hill explore whether movements in the share price of a trading organization, the Royal African Company, could be attributed solely to responses to changes in underlying fundamentals during the South Sea Bubble.[30] The evidence they present suggests that 'fundamentals cannot fully explain the market price for the first three quarters of 1720'.[31] However, they conclude that on the whole their results are consistent with investor rationality during this period.

Garber estimates that the market capitalization for the South Sea Company at the end of August 1720 was £164 m; that is around five times the tangible net assets.[32] He argues that speculators, 'working on the basis of the best economic analysis available', believed that the fund of credit which the South Sea Company had accumulated justified the market valuation, since it could be used for commercial expansion.[33] However, it is clear that the Company engaged in no significant trade other than holding government debt, and Garber himself points out that 'anyone projecting commercial returns high enough to justify the higher prices of South Sea shares was probably too optimistic'.[34] Consequently, if, as Garber argues, rises in the South Sea share price can be attributed to rational behaviour, then these can, at best, be attributed to a mispricing of fundamentals (an intrinsic bubble) or to a view amongst investors that some outside factors might improve the Company's prospects (an extrinsic rational bubble). This view to some extent mirrors Scott's more qualitative assessment of the history of the South Sea Company up to the end of May.[35] He argues that the share price was not excessive during this period because investors were not aware

[28] Ibid., p. 111.
[29] Ibid., p. 90.
[30] Carlos, Moyen, and Hill, 'Royal African Company share prices'.
[31] Ibid., p. 80.
[32] Garber, 'Famous first bubbles', p. 52.
[33] Ibid., p. 52.
[34] Ibid., p. 52.
[35] Scott, *Constitution and finance*, pp. 308–20.

of the price rigging and other malpractices of the South Sea directors. The 60 per cent excess in share price over tangible assets (goodwill) at the end of May could, in his view, be accounted for by overoptimism rather than irrationality (an intrinsic bubble).[36] However, his explanation of the rise in prices from June onwards includes references to 'a spirit of wild speculation' and market manipulation[37] that suggest either a rational bubble, an extrinsic bubble (based around a false view that market manipulation might succeed in producing ever higher prices) or even irrational behaviour.

The extent to which the South Sea Bubble can be explained as a rational bubble is debatable, for two reasons associated with bubble theory. First, South Sea trade was effectively dead, and the bulk of the Company's assets consisted of loans to the government earning a known rate of interest. It was therefore essentially an annuity holding company or 'bond', subject to a call option after seven years—when the government was entitled to begin to repay its debt at face value—that is, an asset with known cash flows and terminal values. Bubble theory suggests that such assets cannot be the subject of rational bubbles since, when the 'bond' is repaid, investors face a certain capital loss.[38] Second, the supply of South Sea stock increased significantly with each successive money subscription, and as the price increased, a larger increase in supply became permissible. The connection between the conversion price for government debt and the Company's issuable capital was well publicized, and it is therefore likely that investors understood that a greater volume of shares would come onto the market the higher the share price rose. Bubble theory suggests that in such circumstances a rational bubble is not possible, since the market will be unable to absorb an ever-increasing supply of stock at a price higher than its fundamental value.[39]

As is evident from this brief overview of the literature, there is a great deal of debate concerning the degree of investor rationality during the rise and fall of the share price of the South Sea Company during 1720. On the whole, those authors who employ quantitative analysis favour a rational explanation, and those who employ qualitative analysis conclude that irrationality prevailed. The aim here is to employ new data to explore the behaviour of investors in South Sea stock during 1720, and hence to shed light on the origins of the South Sea Bubble.

IV

The data employed in this study relate to a key source that to date has not been employed in interpretations of the South Sea Bubble. This involves the price performance of South Sea shares in relation to subscription receipts, and the price performance of the four separate subscriptions in

[36] Ibid., p. 313.
[37] Ibid., p. 319.
[38] Katsaris, *Collapsing speculative bubbles*, p. 17.
[39] Tirole, 'Asset bubbles', p. 1521.

relation to each other at each point in time throughout the Bubble period. The analysis is confined to the four 'money' subscriptions, which should be distinguished from the two conversion offers that allowed holders of government annuities to convert the debt into South Sea stock. The successive conversion offers changed the terms of the exchange of government annuities into stock, and it would be difficult to compare the prices of the conversion offers. However, the four 'money' subscriptions do not suffer from this disadvantage, since each subscription simply provided the holder with a means of acquiring stock through a system of staged payments—which varied for each subscription. Having appropriately discounted the staged payments of the four subscriptions, the stock and the 'money' subscriptions are converted into directly substitutable instruments, in that they represent equivalent claims on assets and dividends. Consequently, the adjusted subscription prices can be compared directly with each other, and with the stock price.

The schedule of payments for each of the successive money subscriptions is provided in table 1. Receipts for these subscriptions could be traded through a simple legal assignment, as was made clear in the subscription preambles.[40] The price data employed for South Sea stock and subscriptions is from *Freke's Prices of Stocks etc*, which was published twice per week, each issue covering three days' trading (Wednesday to Friday, and Saturday to Tuesday), there being no trading on Sundays. John Freke published his price list from 1714–22. He collected prices in the morning and until 3.00 pm each afternoon, sometimes recording as many as three daily prices, for both stock and subscription receipts. Where multiple daily prices are quoted, a simple average is used to provide a single price for the day, since no trading volume is available to determine a weighted average.

An alternative data source is John Castaing's *The Course of the Exchange*, which began publication in 1697 and eventually became the official stock-exchange price list. However, Freke's price list is employed because it is the most comprehensive, and as such is uniquely placed to provide the data necessary for a detailed comparison of stock and subscription prices during the South Sea Bubble. For example, subscription prices are quoted by Freke for periods not covered by Castaing and, crucially, for the third and fourth subscriptions Freke, but not Castaing, makes a distinction between 'for money' and forward subscription prices. This allows more direct comparison of stock and subscription prices during the period when these two forms of secondary market for receipts were active, even though the receipts had not been delivered out by the Company.

Scott, in his seminal work on the South Sea Bubble, chose to use Freke's stock prices,[41] but both Dickson[42] and Neal[43] use Castaing's prices, and

[40] House of Lord's Record Office Parchment Collection, Box 157, 1720.
[41] Scott, *Constitution and finance*, pp. 392, 422.
[42] Dickson, *Financial revolution in England*, p. 139.
[43] Neal, *Rise of financial capitalism*, pp. 183–4.

Neal suggests that Castaing is the more reliable source.[44] The grounds for Neal's allegation are not made explicit, but it may be because Freke was known as a supporter of the South Sea Company and its scheme. However, this fact alone is not sufficient to discount Freke's prices, since it is not obvious how a systematic distortion of prices could have helped the South Sea cause. Equally, as a commercial provider of data, Freke would be well aware that any perception that he was distorting the data would have destroyed his business, particularly as he was in close competition with Castaing. In addition, Freke's publication was reportedly aimed at a London readership, and these subscribers would have ready access to Exchange Alley, where trading took place; differences between Freke's reported prices and actual prices would therefore have quickly come to light. Castaing's sheet, on the other hand, may have been intended more for non-London residents, who would have less ready access to the market for subscription receipts.[45] Parsons uses Freke's prices in his study of the behaviour of London stock prices.[46] He compares Freke's prices with a source taken mainly from the *Daily Courant* and finds 'reasonable similarity between the two price series'.[47]

The most complete series of Freke's prices is housed in the British Library (only issue no. 96, covering data for 21–23 May 1720, is missing) and, for the reasons discussed above, this is used to provide a continuous series of South Sea stock and subscription prices from 14 May 1720, when the first listing of a subscription price appears, until 27 September 1720, when the South Sea Bubble had burst.[48] Subscription prices continue to be available during the rest of 1720 but their value for this study is questionable, since towards the end of September the South Sea Company began to consider proposals for remedial action involving retrospective adjustment of the last two subscription prices. The first detailed reports of this appeared in Castaing in early October. A cut-off point of 27 September is used to allow for possible anticipation of such action, which may have led to some distortion in subscription prices.

The first three partly paid subscriptions may be viewed as equivalent to fully paid shares, apart from the phasing of the subscription payments, since they were entitled to the 10 per cent midsummer stock dividend of 1720, and to the cash dividends promised in September.[49] The fourth

[44] Ibid., pp. 183–4.
[45] Ibid., pp. 169–70.
[46] Parsons, *Behaviour of prices*, p. 60.
[47] Ibid., p. 67.
[48] One potential point of confusion with Freke's subscription prices is that he changes his method of quotation. Until 24 June 1720, his prices exclude down payments and calls, which therefore have to be added back to arrive at full market prices. After 24 June 1720, Freke makes clear that his prices are quoted on an inclusive basis (i.e. including down payments and calls) except in those cases—mainly affecting the fourth subscription—where he expressed the price as 'premium' or 'discount' on the amount paid. In contrast, Castaing's subscription prices are quoted throughout the Bubble period on an exclusive basis.
[49] Dale, *The first crash*, p. 162.

subscription was not subject to the 10 per cent stock dividend, and therefore a 10 per cent upward adjustment is made to the sum of quoted prices and discounted calls for the fourth subscription, to put it on a comparable basis with the first three subscriptions and the stock price.

The interpretation of subscription prices is complicated by the fact that the receipts for the subscriptions were not immediately delivered out by the company. Consequently, where receipts had not been delivered, transactions in subscriptions were in effect forward contracts; the (indeterminate) settlement date being the date on which delivery was made to the buyer. Consequently, there were two types of contract in the subscriptions' secondary market: 'forward/forward contracts', where both payment for and delivery of receipts were deferred until the receipts were given out, and 'spot/forward contracts', where buyers paid cash upfront in anticipation of being provided with receipts when they became available. This distinction between contracts for time (forward/forward) and contracts for money (spot/forward) is clearly described in the contemporary pamphlet literature,[50] as well as in litigation relating to South Sea contracts.[51] Contracts for money were risky, since they involved in effect an unsecured loan to the seller of receipts, and they also implied loss of interest to the buyer on the money deposited. Accordingly, the spot/forward (designated by Freke as 'for money') quoted prices are significantly lower than the regular forward/forward prices quoted by Freke.

To handle these issues during the period when subscription receipts had not been delivered out by the company, a number of choices and adjustments in relation to the subscription price data are made. First, where Freke gives separate prices for regular and 'for money' transactions—as in the case of the third and fourth subscriptions—the former are used on the grounds that settlement risk distorts the latter. Second, where no separate prices are given for the two types of transaction it is assumed that the prices quoted relate to forward/forward transactions, since this is consistent with Freke's terminology. Third, in order to calculate a present-value or spot-price equivalent for the subscription receipts, an appropriate discount rate is applied (see below) to the quoted forward price. For this purpose, an assumption has to be made about the expected maturity of the forward transaction; that is, on what date the subscription receipts were expected to be delivered out by the company. It is known that the subscription receipts for the first two subscriptions were given out between six weeks and two months after the issue date.[52] Since it is likely that market expectations

[50] See, for example, 'A full confutation of the subscribers pretensions to receipts for the first payment made upon the third and fourth subscriptions . . .' London, 1721, p. 11.

[51] See, for example, Thomas Paterson, appellant, Richard Graham, respondent, the appellant's case, London, 1733, pp. 1–2.

[52] Receipts for the first subscription had to be given out by the time of the first call on 14 June (since the company was prepared to advance the money due on the security of the receipts), but it is known from the South Sea Company's Court minutes that the form of these receipts had not been finalized as of 2 June 1720: Minutes of the Court of Directors of the South Sea Company, 1720, British Library.

would be based on this experience, a two-month interval is assumed between the issue date of each subscription and the expected delivery of the corresponding receipts.

Having suitably discounted market prices for subscriptions during the period when receipts had not been delivered out by the Company, each subscription price for the period 14 May to 27 September 1720 is converted into a (fully paid) 'stock price equivalent', by adding the present value of all unpaid calls to the market price. For the second subscription, the schedule of calls was changed around 22 July 1720. Consequently, to produce 'stock price equivalents', the original schedule is used until 22 July, and thereafter the revised schedule is employed. As noted above, the fourth subscription did not qualify for the 10 per cent midsummer dividend; the discounted market price plus the discounted calls for subscription four are therefore increased by 10 per cent to produce a valuation that can be compared directly with the stock price.

The aim is to compare the stock price equivalent of the South Sea Company's subscription prices with the Company's stock prices. However, a complication occurs with quoted South Sea stock prices, since from 23 June to 22 August 1720 the transfer books were closed to allow processing of the midsummer dividend. During this period, shares could not be transferred and the quoted stock prices are for 'the opening of the books' (i.e. they are forward prices). Consequently, to calculate a present value equivalent, an appropriate discount rate is applied to the quoted prices during the period the books were closed. Castaing generally quotes South Sea stock prices 'ex-dividend', whereas Freke's prices are cum-dividend (these are therefore approximately 10 per cent higher than Castaing's prices). For purposes of comparison with prices prior to closure of the books, the cum-dividend price is the more appropriate, since the 10 per cent midsummer dividend amounted in effect to a capitalization or bonus share issue, which should not of itself have affected the stock price.[53]

From the above discussion, it is clear that an appropriate discount rate has to be selected in order to: (a) produce an equivalent stock price for South Sea stock during the period when the transfer books were closed; (b) produce an equivalent stock price for subscriptions during the period in which the subscription receipts had not been delivered out by the Company; and (c) discount the unpaid calls on subscriptions to arrive at a present value market price. A 5 per cent discount rate was applied throughout, since a number of factors suggest that a rate close to this figure is appropriate. First, the South Sea Company and the Bank of England lent money freely on the security of their stock from the spring of 1720 at 4–5 per cent, while the Bank also typically charged 5 per cent for discount-

[53] It is not clear exactly when those entitled to the dividend were credited with the 10 per cent stock and the prices became ex-dividend, but it is clear from a notice published in *Freke's Prices of Stocks etc.* on 20 September 1720 that the prices he quoted in September continued to be cum-dividend.

ing promissory notes and bills of exchange. Second, the contemporary benchmark short-term interest rate, the yield on the East India Company bonds, averaged 5 per cent during the latter half of 1720.[54] Third, subscribers to the first and second subscriptions who were prepared to prepay their remaining calls were given a 4 per cent per annum discount by the South Sea Company. Fourth, during the summer of 1720, some investors were able to borrow at rates as low as 5 per cent from goldsmith-bankers. Fifth, Hutcheson, in his own valuations of South Sea stock, assumes a discount rate of 4 per cent.[55] Lastly, Carlos, Moyen, and Hill provide evidence, based on historical studies, to justify a discount rate of 5 per cent throughout the period from Spring 1720 until January 1725, when the final calls on the subscriptions were due.[56]

Neal's view that a credit crunch may have occurred at the height of the Bubble[57] is disputed by some scholars,[58] and there is evidence that the Bank of England continued to lend at 5 per cent throughout the period covered by the analysis, even though it applied stricter criteria for lending in the later stages of the Bubble.[59] Hutcheson notes that some individuals were paying very high rates as early as April 1720,[60] but care must be exercised in distinguishing rates charged to individuals without an established credit standing who posed a high default risk, from properly secured lending rates charged to those of good standing. In addition, as noted above, regardless of their credit standing or the prevailing market conditions, individuals were able to borrow at between 4 and 5 per cent on the security of their stock in the Bank of England or the South Sea Company, or even on the security of subscriptions in the South Sea Company.

In summary, the evidence suggests that 5 per cent is an appropriate discount rate for the period under investigation, although it is acknowledged that some loans to certain individuals would have been made at a higher rate. Consequently, when applying the adjustments indicated above, a discount rate of 5 per cent is employed, but sensitivity analysis is also undertaken to explore the levels to which rates would need to have risen to contradict the conclusions of the analysis.

Applying the adjustments indicated above, and using a discount rate of 5 per cent, an 'equivalent stock price' is produced for South Sea stock at each time t (S_t, hereafter referred to as the South Sea stock price), and a 'stock price equivalent' is determined for subscription j's receipts at time t

[54] East India bonds were perceived as high quality instruments almost equivalent to cash in normal market situations. However, they did of course carry some degree of default risk, and during the credit scare of the first few days of October 1720, East India bonds fell to a discount: Weiller and Mirowski, 'Rates of interest', p. 5.

[55] Dale, *The first crash*, pp. 86,116.

[56] Carlos, Moyen, and Hill, 'Royal African Company share prices', p. 76.

[57] Neal, *Rise of financial capitalism*, p. 101.

[58] Dale, *The first crash*, pp. 133–5.

[59] Bank of England Minutes of the Court of Directors, 22 September 1720, Bank of England MS collection.

[60] Dale, *The first crash*, p. 134.

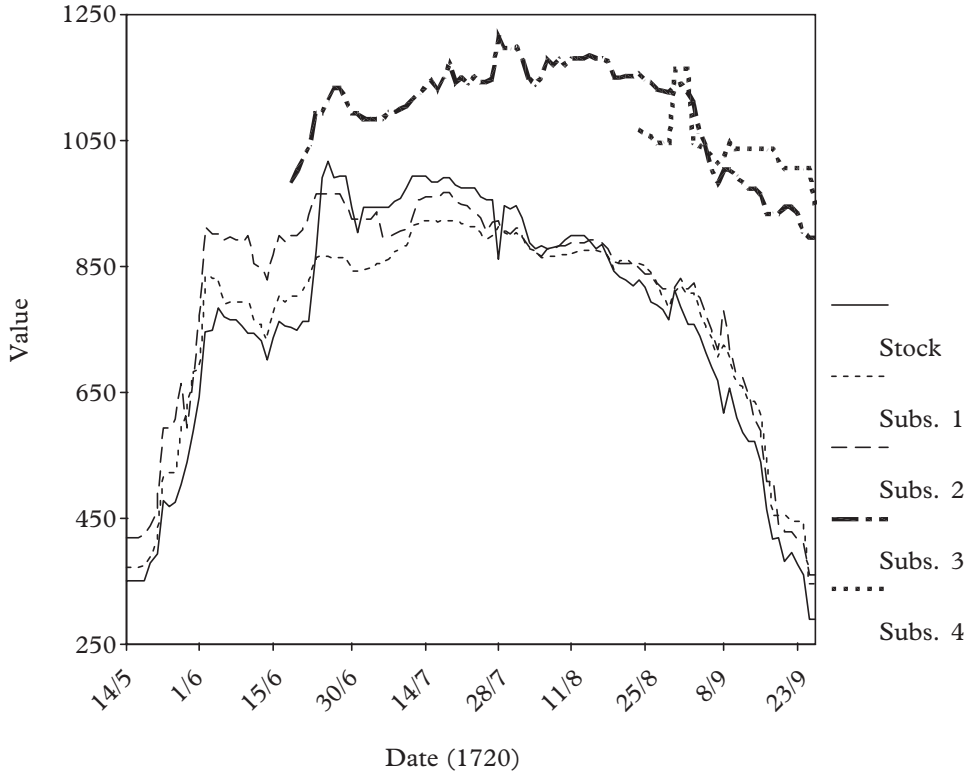

Figure 1. *South Sea Stock and Subscription Price Series (14/5–27/9, 1720)*

Notes: The most complete series of *Freke's Prices of Stocks etc.*, housed in the British Library, is used to construct the graph. Freke does not provide prices for subscription 3, during 18–21 June, and for this period, prices are taken from John Castaing's *Course of the Exchange*. *Freke's Prices of Stocks etc.*, issue number 96, covering data for 21–23 May 1720 is missing. Castaing's *The Course of the Exchange* does not supply subscription prices during this period either and, consequently, the data for this period is omitted from the graph.
To aid comparison between the series, non-trading days (Sundays) are not included on the date axis.

Table 2. *Statistical properties of the stock and subscription price series*

Series	*Mean*	*Std*	*Skew*	*Kurtosis*	*Normality, test statistic*[a]	*(sig.)*
stock	762.54	203.12	–0.82	–0.43	1.60	(0.01)
subscription one	765.50	163.56	–1.34	0.58	2.47	(0.00)
subscription two	802.34	172.26	–1.33	0.47	2.53	(0.00)
subscription three	1,095.24	84.17	–0.91	–0.33	1.68	(0.01)
subscription four	1,043.18	47.26	1.35	3.09	1.44	(0.03)

Notes: The sources of data and the method of compilation are discussed in appendix II.
[a] The Kolmogorov-Smirnov Z statistic.

(C_t^j, hereafter referred to as the price of subscription j, $j = 1, 2, 3, 4$).[61] The series of stock and subscription prices for the period 14 May to 27 September 1720 are displayed graphically in figure 1, and their statistical properties are summarized in table 2.

V

The aim is to explore the relationship between the South Sea stock price series (S_t) and each of the subscription price series (C_t^j), and this analysis is conducted in four stages. First, a static analysis is undertaken, simply comparing stock and subscription prices on and close to the issue date for each of the subscriptions. Second, residual analysis compares the differences between the price series for South Sea stock (S_t) and the price series for each subscription (C_t^j). Third, a comparison is made between the discount rates that would be required to align the South Sea stock and subscription prices. Lastly, the relationship between stock and subscription prices is investigated using co-integration analysis, which captures both the short-run dynamics of the price series and the long-run equilibrium relationships. Since the stock and subscription receipts (with prices adjusted in the manner indicated above) represent substitutable assets, a rational expectations framework would predict that at a given time t:

$$C_t^j = \alpha^j S_t^j + e_t \tag{1}$$

where $\alpha^j = 1$ and e_t represents a random error term.

A simple OLS regression could be used to test this relationship if the S_t and C_t series were stationary processes. However, most financial time series are not stationary, in that the underlying distribution changes through time, so that the series' unconditional variances do not exist. Applying OLS regression to a non-stationary time series can lead to 'spurious regression' in which a significant relationship may be detected among totally unrelated variables. The non-stationarity could be removed by simply taking the first difference of each series and using OLS to estimate the following:

$$C_t^j - C_{t-1}^j = \alpha^j (S_t - S_{t-1}) + f_t \tag{2}$$

where f_t represents a random error term. Rationality on the part of investors would imply that $\alpha^j = 1$.

However, such a formulation, whilst capturing the short-run dynamics of the time series, fails to incorporate information concerning the long-run equilibrium relationship. These failings are overcome by employing co-integration, introduced by Granger,[62] and details of the procedure are given in appendix IV.

[61] Throughout the paper, a continuous discounting procedure is employed such that the discounted value (£y) of a given amount (£x) is calculated as follows: $y = xe - \left(\frac{i}{365}\right)t$, where i = annual discount rate, t = discount period in days.

[62] Granger, 'Econometric model specificating', p. 127.

Since the South Sea stock and the subscription receipts represent substitutable assets, then rational behaviour on the part of investors should result in a close agreement between the adjusted subscription (C_t^j) and stock prices (S_t). Investor rationality should, therefore, lead to co-integration between the stock and each subscription price series. South Sea stock represents the asset to which subscription receipts relate and, therefore, stock prices are expected to Granger-cause subscription prices. Using the methodology indicated above, these propositions are tested.

VI

In the static analysis, stock prices are compared with the price of each subscription (a) on its issue date, and (b) one week after the issue date. The market premium on each new subscription issue relative to the issue price is also estimated (by comparing the market price of each subscription one week after its issue with the first down payment required on the issue date). The results are displayed in table 3 and demonstrate that, other than for the first subscription, the issue price (i.e. the 'stock price equivalent') of subscriptions two, three and four (C_o^j) exceed the prices (i.e. 'equivalent stock price', S_o) for South Sea stock (by between 9.7 and 27.6 per cent), the third and fourth subscriptions registering the largest premiums. Each subscription traded at a considerable market premium relative to its first down payment, the third and fourth subscriptions trading at 150 per cent and 53.5 per cent above the initial down payment within one week of being issued. In addition, one week after each subscription issue, the prices of subscriptions two, three, and four significantly exceeded the price of South Sea stock (by 11.2 per cent, 43.3 per cent, and 43.2 per cent respectively).

Consequently, the static analysis reveals that the first subscription was issued at 'fair value' relative to the stock price, but later subscriptions were issued at substantial premiums on the stock price. Within a week of its issue each subscription traded at an even larger premium compared to the down payment made at issue date; paradoxically, the subscription that was issued at the most substantial premium over the stock price (subscription three), displayed the largest premium over its first down payment. In addition, shortly after its issue date, each subscription traded at a premium over the price for the South Sea stock—a directly substitutable instrument.

Residual analysis is employed to investigate the tendency for subscription receipts to trade at a premium on the stock price over the longer term. To achieve this objective, the price series for South Sea stock (S_t) is compared with the price series for each subscription (C_t^j). Figure 1 suggests a reasonably close agreement between stock and subscription prices for the first two subscriptions, but with a large and increasing disparity between the daily prices of the third and fourth subscriptions and the equivalent stock prices. Daily prices for subscription one and subscription two exceed stock prices by 58.4 per cent and 62.8 per cent of the time, respectively, and the

Table 3. *Comparison of stock and subscription prices close to subscription issue date*

	Subscription			
	1	*2*	*3*	*4*
Issue Date (1720)	April 14	April 29	June 16	August 24
New issue price	300	400	1,000	1,000
First subscription payment	60	40	100	200
SPE of issue price	291	372	894	1,046.1
ESP at subscription issue date	294	339	737	820
Premium of subscription over stock price at issue date	−3 (−1.0%)	33 (9.7%)	157 (21.3%)	226 (27.6%)
Subscription prices one week after issue	66	44	250	307
Market premium of subscriptions over first payment	6 (10%)	4 (10%)	150 (150%)	107 (53.5%)
ESP one week after subscription issue date	344	338	763	812
SPE one week after their issue	297	376	1,093	1,163
Premium of subscription over stock price one week after issue	−47 (−13.7%)	38 (11.2%)	330 (43.3%)	351 (43.2%)

Note: The sources of data and the method of compilation are discussed in appendix III.

prices of subscriptions three and four always exceed stock prices. Mean daily subscription prices exceed stock prices by an increasing margin for successive subscriptions (subscription one: £2.09; subscription two: £38.36; subscription three: £284.04; and subscription four: £434.82). Whilst these results are indicative of differences in the daily stock and subscription prices, each series displays features of a non-normal distribution (see table 2). Consequently, non-parametric tests are employed to test for differences between these series. In particular, the Wilcoxian signed-rank test is used, since this incorporates information about the sign and margin of difference between two price series. These tests confirm the picture to emerge from comparing the differences in mean daily prices, namely that stock prices are not significantly different from subscription one prices ($z = -0.623$, sig. = 0.533) but subscription two, three, and four prices significantly exceed stock prices ($z = -5.12$, sig. = 0.000; $z = -8.05$, sig. = 0.000; $z = -4.78$, sig. = 0.000; respectively). Figure 1 suggests that the residuals for the third and fourth subscriptions increased over time with the prices of subscription three and subscription four exceeding the stock price by, respectively, £328.3 and £238.6 on 24 August, £313.3 and £344.5 on 8 September, £549.8 and £610.5 on 22 September, and £605.4 and £650.4 on 27 September 1720. These results indicate that the discount rates required to equate the present value of the stock and subscription prices rose significantly in August and September 1720.

The discount rates that would be required to bring the South Sea stock (S_t) and the subscription prices (C_t^j) into line are calculated. The results are displayed in figure 2, and two things are clear from this analysis. First, markedly different discount rates must be applied to bring the values of different subscriptions into line with the price of South Sea stock. This implies that to bring the market values of each of the subscriptions into line with each other would require the simultaneous application of significantly different discount rates. Second, the discount rate required, over the staged-payment lives of the four subscriptions—16, 36, 54, and 24 months respectively for subscriptions one, two, three, and four—to align the prices of South Sea stock with the prices for the first, third, and fourth subscriptions rose to well over 50 per cent late in September and, in the case of subscription four, to over 100 per cent. The large negative (in June and July) and large positive (in September) discount rates required to equalize prices of subscription one receipts and stock may appear surprising, given the relatively small differences between the price of subscription one receipts and the price of South Sea stock (shown in figure 1). However, calls for subscription one were required over a much shorter period than for any of the other subscriptions and, consequently, larger differences in discount rates are required to bring the equivalent stock and subscription prices into line for this subscription.

The large discount rates required to equalize stock prices with those of subscriptions one, three, and four in late August and September are completely out of line with the 5 per cent discount rate that has shown to be appropriate for this period. In addition, whilst there is evidence that high interest rates were charged on some personal borrowing during this period, these typically applied only to short term loans of around two months.[63] East India bonds were yielding only 5 per cent, and it is inconceivable that discount rates in excess of 50 per cent over the staged payment lives of the various subscriptions (16–54 months) were applicable during this period.

The evidence presented above points to considerable divergence between the South Sea stock and subscription prices, particularly for the third and fourth subscriptions. To explore this further, co-integration analysis was conducted, as outlined in appendix IV.

The stationarity of each of the stock and subscription price series was tested by applying the Augmented Dickey-Fuller (ADF) test. The results are reported in table 4. The null hypothesis of a unit root for all the price series cannot be rejected, confirming that all the price series are non-stationary processes in levels. The power of the ADF test is low when dealing with small samples[64] and, consequently, there is a low probability of rejecting the null hypothesis when it is false. This applies particularly to subscriptions three and four (see table 4 for details of the test power and size).

[63] Dickson, *Financial revolution in England*, pp. 191, 470.
[64] Campbell and Perron, 'Unit roots', p. 21.

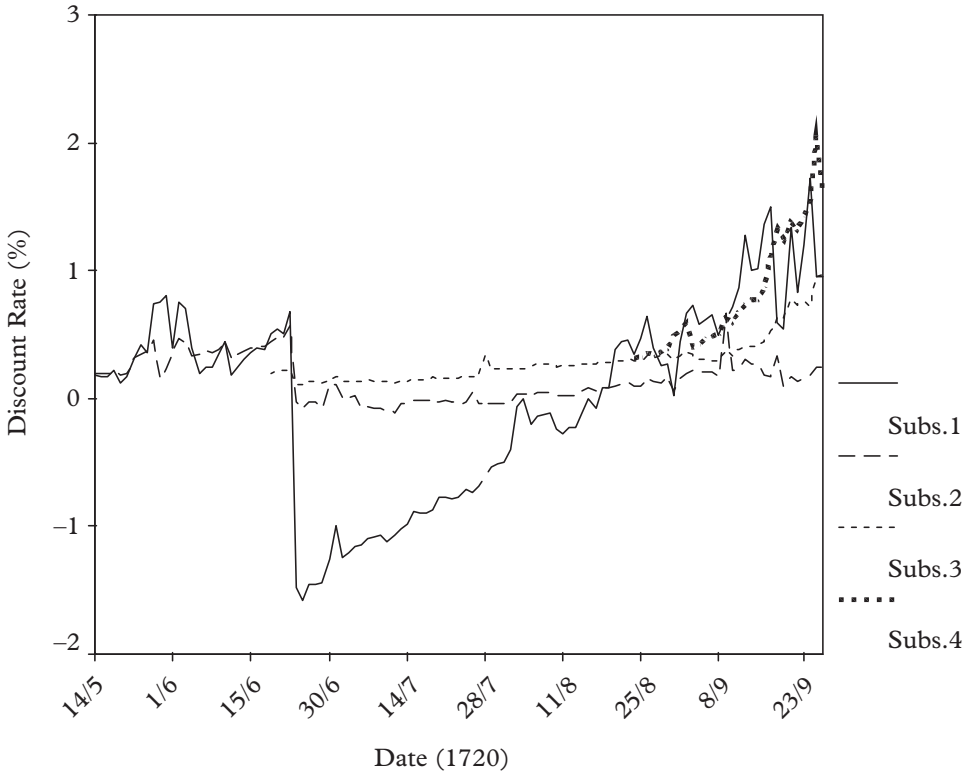

Figure 2. *Discount rate to equate South Sea stock and subscription prices*

Notes: To aid comparison between the series, non-trading days (Sundays) are not included on the date axis. There were two dates (28/7 and 9/9 for subscriptions 1 and 2) for which a discount rate which equated the equivalent stock price of the subscription with the equivalent spot price of stock could not be determined—the discount rate for these dates is left undefined.

The equalizing discount rate applicable to the first subscription, and to a lesser extent the other subscriptions, falls dramatically on 23 June 1720, which was when the books were closed. A partial explanation for this disparity is that the first subscription, having a relatively short repayment period, magnifies changes in the equalizing discount rate as compared to the later subscriptions, with longer repayment schedules.

However, the consequences of not rejecting the null hypothesis when it is false are less severe than rejecting it when it is true, since in the latter situation OLS would be employed, and may well discover a spurious relationship between the variables.[65] In the case where the series is stationary and it is assumed to be non-stationary, the co-integration procedure can still find the true relationship between the variables. Consequently, the unit root tests are taken at face value, the series are assumed to be non-stationary, and the Johansen and Juselius multivariate co-integration test is

[65] Engle and Granger, 'Co-integration and error correction', p. 271.

Table 4. *Unit-root test statistics for stock and subscription prices*

Augmented Dickey-Fuller test statistics	*Stock*	*Sub. 1*	*Sub. 2*	*Sub. 3*	*Sub. 4*
τ (without trend)[a]	–0.767	–1.021	–0.830	–0.177	–1.588
Critical value at 5%	–2.887	–2.887	–2.887	–2.896	–2.975
Number of observations[b]	114	114	114	86	29

Notes: a τ represents the test statistic using a lag of one day.
b The ADF unit root test has low power when dealing with small samples and, therefore, for subscriptions three and four in particular, the probability of rejecting the null hypothesis of a unit root when it is false is low. Simulations involving 50,000 replications indicate that for the third subscription the test size was 0.047 and the power was 0.07, 0.25, 0.64, and 0.99 for alternative hypotheses 0.99, 0.95, 0.90, and 0.80 respectively; similarly, for the fourth subscription the test size was 0.049 and the power was 0.06, 0.09, 0.16, 0.41, 0.68, and 0.89 for alternative hypotheses 0.99, 0.95, 0.90, 0.80, 0.70, and 0.60 respectively.

employed to explore whether a stationary linear combination of the stock and subscription price series exists.[66]

The co-integration test is sensitive to the order of lags included in vector auto-regression (VAR) models.[67] A general-to-specific approach is therefore employed to decide on the lag length, starting with a fourth-order VAR model, and then sequentially reducing the lag structure.[68] The Schwarz information criterion (SC) is used to choose the lag length. This criterion suggests one lag in the VAR for stock and subscriptions one, two, and four, and two lags in the VAR for stock and subscription three, as reported in part A of table 5.

The results of co-integration estimation are displayed in part B of table 5. Two hypotheses are tested, first, that no co-integration exists (i.e. rank = 0), and second that the number of cointegrating vectors is at most one (i.e. rank $\leq$ 1). The null hypothesis of no co-integration is not rejected for subscriptions one, three, and four at the 5 per cent level, on the basis of the maximum eigenvalue and trace tests.[69] The null hypothesis that stock (S_t) and subscription prices (C_t) are not co-integrated is rejected at the 5 per cent level for subscription two using the maximum eigenvalue test, but not using the trace test. The null hypothesis that the number of co-integrating vectors is at most one between the stock and the price series for subscription two cannot be rejected at the 5 per cent level.

To explore the relationship between the prices for South Sea stock and the prices for the second subscription further, an error-correction model

[66] Johansen and Juselius, 'Inference on cointegration', p. 170.
[67] Gonzalo, 'Estimating long-run equilibrium', p. 210.
[68] The issue of setting the appropriate lag length is important. While a large value for lag length may result in over-parameterization, which affects the estimation of co-integration rank, small values may distort the size of the tests: Cheung and Lai, 'Finite-sample sizes', p. 322.
[69] Reimers finds that with small samples it is generally easier to find co-integration relationships where none exist. Consequently, since no co-integration relationship is found for subscriptions one, three, and four (which involve small samples), this is highly suggestive of no co-integration existing between these series. In fact, since the Johansen procedure over-rejects when the null hypothesis of no co-integration is true in small samples, the maximum eigenvalue and trace tests that are applied to all four subscription series are adjusted for the small sample size: Reimers, 'Multivariate cointegration'.

Table 5. *Results of Johansen's multivariate co-integration tests for stock and subscription price series*

Part A: Lag order selection using the SC criterion[a]

Lag order	*Stock vs. Sub1*	*Stock vs. Sub2*	*Stock vs. Sub3*	*Stock vs. Sub4*
0	17.862	18.462	18.125	17.607
1	**13.247**	**13.649**	12.718	**14.204**
2	13.296	13.665	**12.601**	14.515
3	13.409	13.767	12.797	14.741
4	13.566	13.919	12.983	15.207

Part B: Johansen multivariate co-integration tests

Null hypothesis of rank r	*Test statistics*			
	λ_{max}[b]	λ_{max} *(95% value)*[c]	*Trace*	*Trace (95% value)*
	stock *vs.* sub1. (114 observations)			
$r = 0$	9.92	15.7	10.12	20.0
$r \leq 1$	0.20	9.2	0.20	9.2
	stock *vs.* sub2. (114 observations)			
$r = 0$	15.87*	15.7	16.26	20.0
$r \leq 1$	0.39	9.2	0.38	9.2
	stock *vs.* sub3. (86 observations)			
$r = 0$	6.17	15.7	8.57	20.0
$r \leq 1$	2.40	9.2	2.40	9.2
	stock *vs.* sub4. (29 observations)			
$r = 0$	6.69	15.7	7.06	20.0
$r \leq 1$	0.37	9.2	0.37	9.2

Notes: a The Schwarz criterion is defined as $SC = \log|\hat{\Omega}| + k\log(T)T^{-1}$, where $-2T^{-1}\log|\hat{\Omega}|$ is the estimated log likelihood, T is the sample size, and k is the number of parameters estimated. The selected lag-length is decided by the minimum criterion values.

b The test statistics are adjusted to account for the small sample size, according to the procedures recommended by Reimers 'Multivariate co-integration' (1992), as follows: l_{max} statistic $= -(T - nm)\ln(1 - l_r)$, the maximum eigenvalue test statistic (r vs. $r + 1$); trace statistic $= -(T - nm)\sum_{i=r+1}^{n}\ln(1 - l_i)$; where T is the number of observations, n is the number of variables, m is thelag length, r is the dimension of the co-integration space and l_i is the ith smallest squared canonical correlation in Johansen and Juselius 'Inference on co-integration' (1990).

c λ_{max} (95% value) and trace (95% value) are the critical values for the λ_{max} and trace tests, respectively.

* = rejection of the null hypothesis at the 5% level.

(ECM) is estimated, with an error-correction term and lagged values of the first differences of each series explicitly included.[70] The OLS estimation for the error-correction parameters and the lagged variable parameters are presented in table 6.

The results displayed in table 6 indicate that in the ECM for stock and subscription two prices the error-correction coefficient α_s (coefficient = –0.1065, $t = -2.273$) is significant at the 5 per cent level, but α_c (coefficient

[70] Granger first noted the relationship between co-integration and ECM, and Granger proves how co-integrated series may be represented by the ECM: Granger, 'Econometric model specificating', pp. 128–9; Granger, 'Cointegrated economic variables', p. 216.

Table 6. *OLS estimation of the error correction model for stock and subscription two*

Estimation of the co-integrating vector:

$$S_t = -218.6 + 1.2212C_t^2$$

$$\Delta S_t = \alpha_s \hat{z}_{t-1} + \theta^s_{s,t-1}\Delta S_{t-1} + \theta^{c2}_{s,t-1}\Delta C_{t-1} + \varepsilon_{st}$$

Variables	*Coefficients*	*t-values*
α_s	–0.1065	–2.273
$\theta^s_{s,t-1}$	0.0752	0.762
$\theta^{c2}_{s,t-1}$	0.3029	2.738*

$$\Delta C_t = \alpha_c \hat{z}_{t-1} + \theta^s_{c2,t-1}\Delta S_{t-1} + \theta^{c2}_{c2y,t-1}\Delta C_{t-1} + \varepsilon_{ct}$$

Variables	*Coefficients*	*t-values*
α_c	0.0181	0.380
$\theta^s_{c2,t-1}$	0.2132	2.123*
$\theta^{c2}_{c2,t-1}$	0.1072	0.951

$$\hat{z}_t = S_t + 218.6 - 1.2212C_t^2$$

Note: *significant at the 5% level.

= 0.0181, t = 0.380) is not. This confirms that there is a co-integration relationship between the prices of stock and subscription two, and suggests that stock prices respond to the previous period's deviations from the long-term equilibrium, while subscription two prices do not; that is, all long-run adjustments between stock and subscription two prices arise from stock price changes.

In terms of short-term price movements, there is evidence (see table 6) that stock prices Granger-cause subscription two prices ($\theta^s_{c_2,t-1}$ = 0.2132, t = 2.12) and that subscription two prices Granger-cause stock prices ($\theta^{c2}_{s,t-1}$ = 0.3029, t = 2.74). Similarly, short-run Granger causality analysis is conducted by estimating VAR in first differences for subscriptions one, three, and four. Table 7 reports the results of this analysis. The results indicate that the underlying stock prices and subscription one prices Granger-cause each other in the short-run ($\theta^s_{c_1,t-1}$ = 0.1974, t = 1.96; $\theta^{c1}_{s,t-1}$ = 0.2746, t = 1.99). Stock price changes have no influence on the change in subscription three prices in the short run ($\theta^s_{c_3,t-1}$ = 0.0970, t = 1.39; $\theta^s_{c_3,t-2}$ = 0.0516, t = 0.83). However, changes in subscription three prices Granger-cause stock price movements ($\theta^{c3}_{s,t-1}$ = 0.9564, t = 5.28). The results displayed in table 7 also suggest that there is no short-run relationship between stock prices and subscription four prices ($\theta^s_{c_4,t-1}$ = 0.2003, t = 0.76; $\theta^{c4}_{s,t-1}$ = 0.0343, t = 0.20).

Table 7. *OLS Estimation of the VAR models for stock and subscriptions one, three, and four*

$$\Delta S_t = \alpha_s + \theta^{s}_{s,t-1}\Delta S_{t-1} + \theta^{s}_{s,t-2}\Delta S_{t-2} + \theta^{cj}_{s,t-1}\Delta C_{t-1} + \theta^{cj}_{s,t-2}\Delta C_{t-2} + \varepsilon_{st}$$

	Stock with Sub.1		*Stock with Sub.3*		*Stock with Sub.4*	
Variables	*Coefficients*	*t-values*	*Coefficients*	*t-values*	*Coefficients*	*t-values*
α_s	–0.4418	–0.150	–4.467	–1.472	–23.08	–3.546*
$\theta^{s}_{s,t-1}$	0.0889	0.754	–0.0103	–0.091	–0.2243	–1.100
$\theta^{s}_{s,t-2}$	—	—	–0.0386	–0.382	—	—
$\theta^{cj}_{s,t-1}$	0.2746	1.990*	0.9564	5.283*	0.0343	0.2040
$\theta^{cj}_{s,t-2}$	—	—	0.1822	0.885	—	—

$$\Delta C_t = \alpha_c + \theta^{s}_{cj,t-1}\Delta S_{t-1} + \theta^{s}_{cj,t-2}\Delta S_{t-2} + \theta^{cj}_{cj,t-1}\Delta C_{t-1} + \theta^{cj}_{cj,t-2}\Delta C_{t-2} + \varepsilon_{ct}$$

	Stock with Sub.1		*Stock with Sub. 3*		*Stock with Sub. 4*	
Variables	*Coefficients*	*t-values*	*Coefficients*	*t-values*	*Coefficients*	*t-values*
α_c	–0.0945	–0.038	–0.5380	–0.287	–0.5179	–0.062
$\theta^{s}_{cj,t-1}$	0.1974	1.962*	0.0970	1.394	0.2003	0.759
$\theta^{s}_{cj,t-2}$	—	—	0.0516	0.828	—	—
$\theta^{cj}_{cj,t-1}$	0.0987	0.838	0.1378	1.232	–0.0184	–0.084
$\theta^{cj}_{cj,t-2}$	—	—	0.0338	0.267	—	—

Note: *Significant at 5% level

Overall, the co-integration analysis identifies no long-run relationship between the price series for stock and subscriptions one, three, and four. For subscription two, a co-integration relationship is found with stock prices, with all long-run adjustments between these price series arising from stock price changes. The picture that emerged from the earlier static, residuals, and discount rate analyses revealed an increasing separation between the prices of receipts for later subscriptions and the underlying stock. This pattern is confirmed by Granger-causality analysis, the short-run prices of both stock and subscription receipts Granger-causing each other for the first two subscriptions, subscription three prices Granger-causing stock prices, and no short-run relationship existing between stock and subscription four prices.

VII

In examining the results presented above, it is important to recall that 'stock price equivalents' of subscription prices (C^j_t) are being compared with 'equivalent stock prices' for South Sea stock (S_t). These are directly comparable prices, since the South Sea stock and the subscription receipts are directly substitutable instruments, representing equivalent claims on assets

and dividends. Furthermore, investors were free to exploit any arbitrage opportunities either by selling subscription receipts and buying stock (in the forward market when the books were closed) or by selling 'expensive' subscriptions and buying more favourably priced issues.

The results of the static and residual analyses present a consistent picture of a reasonably close correspondence between stock and subscription prices for the first subscription, but a significant and widening difference over time between stock and subscription prices for the third and fourth subscriptions. The discount rates required in order to equate both subscription three and subscription four prices with the stock price rise to inconceivable levels during September. Furthermore, there is no interest rate that could be applied simultaneously to all subscription series to equate the subscription price series with each other. During this period, subscription three and four receipts traded at prices that were significantly more expensive than subscription one and two receipts. This anomaly requires explanation.

The lack of co-integration between the prices of South Sea stock and subscriptions one, three, and four indicates a complete absence of a long-run equilibrium relationship between the prices of these substitutable instruments. In addition, although a co-integration relationship is found between the prices of stock and subscription two, it is not subscription two prices that adjust to deviations from this long-run relationship (as would be expected in a rational expectations framework), but rather adjustments are confined to stock prices. In the short run, stock prices appear to influence the prices of subscription one and two receipts (as might be expected in a rational market) but, in addition, subscription one and two prices influence stock prices. For subscription three there is not even a short-run influence of stock prices on subscription prices but, remarkably, subscription three prices appear to influence stock prices. Furthermore, there is a complete separation of the prices of stock and subscription four receipts with no long- or short-term relationship being discovered between these price series.

In summary, the results taken together pose a number of challenges to a rational explanation for investor behaviour during the South Sea Bubble. First, there appears to be a separation of the valuation of subscriptions from those of the underlying stock: subscription receipts, particularly subscriptions three and four, traded at prices far in excess of those for the directly substitutable South Sea stock, no long-run equilibrium relationship is detected between the prices of South Sea stock and the prices of three of the four subscriptions, and where a long-run equilibrium relationship is found (between the prices of stock and subscription two), it appears that stock prices rather than subscription prices are adjusting to deviations from this equilibrium. Second, the prices for subscriptions three and four diverged from stock prices increasingly during September 1720, as the South Sea Bubble burst. Third, the prices of the four subscriptions differed significantly from each other.

Before concluding that irrationality overtook investors in 1720, it is important to try to address each of the above challenges within a rational expectations framework. For example, the first of these challenges might be tackled by noting that subscription receipts required only a simple legal assignment compared with the obligation to register share transfers on the Company's books. Consequently, these minor differences in administrative effort required to trade the two assets might be expected to result in subscription receipts trading at a small premium over South Sea stock. However, it is highly unlikely that this could account for the large differences in their market valuations that are identified here. In addition, subscription receipts were subject to settlement risk because they were deferred contracts in which the counter-party might fail, whereas stock transactions (other than for the opening of the books) were based on delivery versus payment. This settlement risk is likely to have offset any liquidity premium on the subscription receipts. Equally, if there were a liquidity premium, this would apply uniformly to all four subscriptions, but significant valuation differences between the subscriptions are observed.

A second 'rational' explanation for the disparity in stock and subscription prices may involve investors' perceptions of the enforceability of the subscription contracts. If these were not legally enforceable, purchasers of subscriptions might simply walk away from their obligations, in effect treating their contracts as options. However, there can be no doubt about the legally binding status of subscriptions, since in early 1720 Parliament initiated legislation that was specifically designed to ensure that any subscription issue made by the South Sea Company would be legally valid, and transferable by simple legal assignment. Clause 27 of the so-called Bubble Act, which finally received the royal assent on 11 June 1720, provided that 'all such subscriptions [by the South Sea Company] shall be firm and valid, and all receipts made out and given, or to be made out and given, concerning the same, shall be assignable at law by endorsement made or to be made thereon'.[71] Furthermore, after the Bubble had burst, Parliament reasserted the binding nature of South Sea contracts by resolving in December 1720 that 'all the subscriptions of public debts and incumbrances, and other contracts made with the South Sea Company, by virtue of an Act made last session, remain in the present state, unless altered for the ease and relief of the proprietors by a General Court of the South Sea Company, or set aside by due course of law'.[72] The contemporary pamphlet literature also shows that investors were well aware of the legal enforcement issue.[73]

In addition, if subscriptions were treated as options by investors, they should certainly not sell at a discount relative to stock. Yet subscriptions

[71] 6 Geo I, ch. 18, c. 27.
[72] Cobbett, *Parliamentary history*, p. 680.
[73] See, for example, 'Further reasons offered and fresh occasions given for making void and annulling fraudulent and usurious contracts', London, 1721, pp. 3–6.

one and two traded at a discount on the share price for 41.6 per cent and 37.2 per cent of the period covered by the analysis, respectively, and there is no evidence of a widening gap between stock valuations and those of subscription two as the share price fell to levels below the amount of calls outstanding late in September. These are not trading patterns one would associate with financial instruments where investor's viewed their outstanding obligations as unenforceable. The 'non-enforceability' argument also fails to account for the different Granger-causality relationships between the prices of stock and the receipts for successive subscriptions. In addition, this explanation does not account for the increasing divergence between the prices of stock and those of subscriptions three and four during September, nor does it explain why the prices of the four subscription receipts differed from each other. In summary, the evidence points to an expectation on the part of subscribers that they could not walk away from their obligations.

More generally, if subscription receipts were merely options, it is difficult to explain how the South Sea Scheme got off the ground, since few rational individuals would invest in a company that was known to be issuing call options on a dramatic and ever-increasing scale. In addition, given that the company itself would face highly uncertain cash flow from such operations, it is highly unlikely that it would issue unenforceable subscriptions. Lastly, it is difficult to understand why the government and Parliament would specifically endorse the issue of subscriptions if they thought they were unenforceable.

The evidence, therefore, indicates that subscription contracts created legally binding obligations that could not be construed as options, and that investors were fully aware of this. Nevertheless, there is scope for further research in order to determine the extent to which subscription prices deviated from modern option-pricing formulae.

A third potential 'rational' explanation for the difference between the price of South Sea stock and subscription receipts may lie in the gearing effect built into the subscriptions. Clearly, if investors believed that the stock—and their related subscription receipts—was likely to rise in price, a larger potential return for a given outlay could be obtained by investing in subscriptions compared with stock. This may have caused the demand (and hence the price) of subscriptions to rise beyond that of stock. However, the gearing effect of subscriptions could be replicated to some extent by investors in stock who could borrow either from the company or from goldsmith-bankers against the security of South Sea shares up to around two-thirds of their market value. In fact, large numbers of investors took this option, and £9 m was borrowed in this way from the company.[74] Stockholders who took this option entered a legally binding agreement, and the expectation would have been that they could not walk away from their outstanding obligations

[74] Cobbett, *Parliamentary history*, p. 736.

any more than investors in subscriptions could default on future calls. A gearing effect explanation of the results also fails to explain why subscription one and two receipts traded, for substantial periods, at a deficit on stock prices, and it does not explain why the equivalent stock prices of each subscription differed significantly from each other.

The second challenge to rational investor behaviour stems from the increasing difference between the prices of subscriptions three and four and the underlying South Sea stock as the Bubble began to burst. This might be explained by the fact that many investors borrowed heavily on the security of stock, and as stock prices fell, lenders accelerated the process by distressed selling of pledged stock.[75] While borrowing did take place on the security of subscription receipts, this was largely restricted to loans from the South Sea Company. Borrowing was thus concentrated on stock, as subscription receipts did not represent safe security because they had no value if the calls were unpaid. The concentration on distressed selling of stock (cf. subscription receipts) might partially account for the increasing divergence between stock and subscription prices in September 1720. However, this explanation does not account for the different valuations placed on the various subscriptions either during September, or earlier in 1720. It is in fact difficult to develop a rational explanation for such differences in directly substitutable instruments.

The co-integration analysis suggests that there is no long-run relationship between the prices of stock and those of subscriptions one, three, and four. While a long-run relationship is shown to exist between stock and subscription two prices, it appears that investors focused more on the movements of subscription two prices than on those of stock prices. Granger-causality analysis confirms a separation of stock and subscription prices for later subscriptions, with subscription three prices influencing stock prices in the short run, and no short-run relationship existing between the prices of stock and subscription four receipts. This suggests that the South Sea Bubble was not a 'rational bubble', to the extent that it did not have its origin in self-fulfilling expectations. It appears that investors viewed each new subscription as a distinct asset, with a valuation increasingly divorced from the underlying stock. The view is reinforced by the South Sea directors' claims that they were under constant pressure from the public to issue new subscriptions.[76] The issue prices of successive subscriptions were set at a progressively higher premium over the equivalent stock prices. However, this appears to have simply spurred investors to 'irrationally' expect that the projectors of the scheme (Blunt and his cabal of South Sea directors) would ensure that the new subscription would be an unparalleled success in its own right, irrespective of the price of the underlying stock or previous subscription receipts. This view was presum-

[75] Scott, *Constitution and finance*, p. 326.
[76] Dickson, *Financial revolution in England*, p. 127.

ably based on their understanding that the South Sea scheme could only be perpetuated if successive subscriptions raised increasing receipts, which could be redistributed as dividends. The increasing premiums of successive subscriptions over the stock price at issue date were sustained in the secondary market. This may have resulted from investors being subject to the anchoring heuristic whereby individuals bias their subsequent judgements (e.g. of an asset's value) on an initial estimate irrespective of how spurious that initial valuation might be, subsequent adjustments being crude, imprecise and inadequate.[77] Consequently, progressively larger premiums of subscription prices over the stock price at issue date may have generated, via the anchoring heuristic, expectations of a still larger premium in the secondary market.

Many of the accounts that argue that the South Sea Bubble resulted from irrational behaviour point to the spirit of gambling that pervaded early eighteenth-century England.[78] In this regard it is interesting to note that Blunt himself helped fuel the nation's thirst for gambling, since he persuaded the Chancellor of the Exchequer, Robert Harley, to introduce a National Lottery in 1711. Blunt organized this lottery, which was a great success, and he went on to market a second, much larger-scale lottery known as 'the Adventure of Two Millions'; this involved an enormous top prize of £20,000.[79] Similarities exist between the manner in which Blunt structured this lottery and the way he organized the issue of South Sea subscription receipts. The draw was divided into five classes, each with a different, and a successively higher, set of prizes; the lowest class prizes ranged from £110 to £1,000, and the fifth, and final class featured prizes from £130 to £20,000. The staged prize draws were deliberately designed to build excitement, investors being unsure 'whether to be pleased or disappointed until the last ticket of the fifth and final draw was produced from the box to win the biggest prize of all'.[80] Blunt's lotteries succeeded in capturing the attention of much of England, and they were successful in raising £3.5 m.

The successive issues of subscription receipts mirrored the successive draws of the lottery, which the population had associated with increased excitement and higher prizes. To a nation whose thirst for excitement and gambling had been stimulated by Blunt's successful lotteries, the successive South Sea subscription issues may have been viewed in a similar manner to successive lottery draws. The rising premia of the issue prices of successive subscriptions over the equivalent stock price might also have been suggestive of the ever-larger prizes featured in successive lottery draws, with their attendant excitement. The central role of Blunt in both enterprises is likely to have furthered this view. It has been demonstrated that individuals often

[77] Kahneman, Slovic, and Tversky, *Heuristics and biases*, pp. 14–18.
[78] Dickson, *Financial revolution in England*, p. 156.
[79] Balen, *A very English deceit*, p. 35.
[80] Ibid., p. 35.

place too much emphasis on similarities between new stimuli (i.e. the subscription issues) and events with which they are familiar (i.e. the lottery), irrationally overlooking differences. This 'representativeness heuristic',[81] might well have caused investors to expect the later subscription issues to produce greater returns than the earlier issues.

It might be argued that even if investors were tempted to perceive the subscription issues as akin to successive lottery draws, this would not cause them to misprice the assets since they had available to them comprehensive and authoritative valuations of the South Sea stock, most notably produced and publicized by the highly respected Archibald Hutcheson MP. However, Hutcheson's calculations were relatively complex for the average investor (particularly as many were new entrants to capital markets), and research has demonstrated that individuals increasingly rely on heuristics, non-rational strategies, and biases when faced by a complex information environment; this is especially true for those who are relatively naïve in a particular decision domain.[82] Increased complexity has also been demonstrated to lead to increases in risk propensity[83] and to a deterioration in the quality of investors' decisions.[84] In addition, as complexity increases, participants in speculative markets increasingly allow the market to drive their behaviour[85] and Shiller argues that consideration of past price changes when making current decisions is the 'essence of a speculative bubble . . . feedback from price increases to increased investor enthusiasm, to increased demand, and hence further price increases'.[86]

The degree to which echoes of the lottery featured in South Sea subscription investors' minds is obviously open to question, but it is clear that sales of financial instruments at this time exploited a growing addiction to gambling. Excitement attended the earlier lottery draws and featured in many contemporary accounts of trading during the South Sea Bubble. Dickson suggests that the period was characterized by 'an appetite for gain . . . [that] could and did become uncontrolled'.[87] This, he argues, even influenced the judgement of experienced investors. Chancellor points to the speculative excess that fuelled the markets in 1720,[88] and the central role of excitement in changing behaviour within speculative markets is well established.[89] It has also been demonstrated that exposure to excitement in such markets can impose substantial financial costs.[90] Previous research has shown that excitement in wagering markets is more likely to be raised to levels that

[81] Kahneman, Slovic, and Tversky, *Heuristics and biases*, pp. 23–98.
[82] Eiser and van der Pligt, *Attitudes and decisions*, p. 99; Keren and Wagenaar, 'Psychology of playing blackjack', p. 157.
[83] Johnson and Bruce, 'Risk strategy', pp. 11–14.
[84] Bruce and Johnson, 'Decision-making under risk', pp. 72–4.
[85] Johnson and Bruce, 'Effect of complexity', pp. 769–70.
[86] Shiller, 'Bubbles', p. 3.
[87] Dickson, *Financial revolution in England*, p. 156.
[88] Chancellor, *A history of financial speculation*, pp. 76–8.
[89] Brown, 'Normal and addictive gambling', p. 165.
[90] Bruce and Johnson, 'Costing excitement', pp. 57–61.

damage rational judgement where market participants build on each other's excitement in a face-to-face arena.[91] This is precisely the frenetic, charged atmosphere that was evident in Exchange Alley, where South Sea stock and subscription receipts changed hands; attested to by the London attorney of a Dutch investor, who, on visiting the alley, proclaimed, 'it is like nothing so much as if all the lunatics had escaped out of the madhouse at once'.[92] Certainly, the relative market valuations of stock and subscriptions became so distorted that it is difficult to find a rational justification for the discrepancy. If market activity had been particularly low then this might have inhibited prices adjusting to reflect the same information across markets. However, whilst total trading volume data is not available, there are contemporary accounts which indicate that market activity was on a considerable scale. For example, Hoare and Company's trading accounts indicate that Hoare's own trading in South Sea stock exceeded £140,000 in 1720.[93] In addition, a single investor, Mr Waller, generated a turnover of £795,000 in his South Sea trading account from March to November 1720,[94] and the Chancellor of the Exchequer, John Aislabie, stated that such activity was typical of many investors. In addition, contemporary reports suggest that one-sixth of the third subscription was resold for cash within a few days of its issue.[95] Consequently, the indications of heavy trading volumes for stock and subscription receipts during 1720 suggest that the prices of these substitutable financial instruments should have equalized if investors had behaved rationally.

The results reported here are clearly dependent on the validity of the assumptions employed, but if these hold then it appears that investors simply lost the ability to adequately price these assets, or simply developed overconfidence in their own intuition[96] that later subscription issues would outperform previous issues. In conclusion, while the precise roles played by excitement and heuristics are difficult to discern, the results suggest that South Sea investors may have been the victims of their own irrational behaviour, or may have, in Shiller's words, suffered from 'irrational exuberance'.[97]

VIII

The article sets out to resolve some of the controversy that has arisen concerning the nature of investor behaviour during the South Sea Bubble. Some studies have attributed the Bubble to irrational behaviour, but these

[91] Johnson and Bruce, 'Successful betting strategies', pp. 643–8.
[92] Wilson, *Anglo Dutch commerce*, p. 122.
[93] Temin and Voth, 'Riding the South Sea Bubble', p. 11.
[94] Cobbett, *Parliamentary history*, p. 730.
[95] The pattern of trading by the original subscribers cannot be meaningfully analysed because of the widespread practice of using nominee accounts.
[96] Shiller, 'Bubbles', pp. 4–5.
[97] Shiller, *Irrational exuberance*, p. 18.

accounts have largely relied on contemporary anecdotes and quotations. More recent contributions to the debate have attempted to explain the rise in the South Sea share price within a rational expectations framework, different accounts attributing the South Sea episode to a rational extrinsic or intrinsic bubble. Garber, for example, concludes that the South Sea Bubble was 'understandable as a case of speculators working on the basis of the best economic analysis available and pushing prices along by their changing view of market fundamentals'.[98]

In an attempt to shed light on the behaviour of South Sea investors, data is employed on subscription receipts issued by the South Sea Company in 1720 that has not hitherto been used. The results demonstrate the lack of a long-run relationship between the prices of South Sea stock and those of three of the four subscriptions, a widening gap between the valuation of the stock and subscription price series for successive subscription issues, and a weakening of the short-run relationship between stock and subscription prices for later issues; with a complete breakdown in this relationship for the fourth subscription. Despite being directly substitutable assets, the equivalent share prices for each of the four subscriptions also appear to diverge significantly from each other. However, these results depend crucially on certain assumptions, notably that Freke's stock and subscription prices were not subject to systemic distortion, and that the discount rate employed is appropriate. Steps are taken in the article to defend these assumptions, and the sensitivity analysis that is conducted suggests that the results are robust to large deviations from the adopted discount rate.

Some explanations for the results are offered which preserve the notion of rational investor behaviour, but none of these proves wholly adequate. Neal defines an irrational bubble as one where the 'relationship of an asset to its market fundamentals simply breaks down because of overzealous trading or an unrealistic appraisal of the value of the stock'.[99] The results suggest that this description more accurately portrays the South Sea episode than any alternative based on a rational expectations framework. It is also suggested that the frenetic activity in Exchange Alley and the naïvety of many of the investors (who were new to capital markets) may have caused excitement levels to rise to destructive levels (in terms of rationality) and led to biased judgements, caused by widespread use of a range of heuristics. Alternative explanations that are offered include the thirst for gambling in England at this time, and the manner in which the subscription issues were designed to mimic previous lotteries, each successive issue building levels of excitement and greed. Certainly, investor behaviour at this time appears to mirror that observed in recent studies of gambling markets. Interestingly, the lottery paradigm has been applied to more recent stock market events.

[98] Garber, 'Famous first bubbles', p. 52.
[99] Neal, *Rise of financial capitalism*, p. 76.

Alan Greenspan, Chairman of the US Federal Reserve Board, has drawn this comparison between lotteries and the Internet stock boom:

> There is something else going on here, though, which is a fascinating thing to watch. It is, for want of a better, term, the 'lottery principle'. What lottery managers have known for centuries is that you could get somebody to pay for a one-in-a-million shot more than the value of that chance. In other words, people pay more for a claim on a very big pay-off, and that's where the profits from lotteries have always come from. So there is a lottery premium built into the prices of Internet stocks.[100]

What then is the significance of the South Sea Bubble for today's financial markets? The central lesson that both investors and policy-makers have to take account of is the fact that today, as in 1720, investor behaviour can become manic and irrational. The South Sea episode was short-lived, the boom–bust cycle occurring within a single year, and there was therefore no great dislocation of the real economy. However, more extended bubbles, such as those experienced by Japan in the 1980s and by the USA, in particular, in the late 1990s, can have more enduring consequences, resulting in a serious misallocation of resources and severe economic fluctuations. Policymakers need to be aware, therefore, of the potential damage caused by irrational investor behaviour and may need to intervene to prevent financial market excesses. It is hoped that a better appreciation of the factors contributing to the South Sea Bubble will inform the current debate on this important issue.

APPENDIX I: The sources of data used in, and the method of compilation of, table 1

Table 1 displays the schedule of payments and the issue price (shown as 'total' in the table) for each of the four subscriptions, issued on 14 April, 29 April, 16 June, and 24 August 1720, respectively. These are based on the schedules of payments published in *Freke's Prices of Stocks etc* and Castaing's *The Course of the Exchange*.[101]

However, there are two complications in using this data. First, according to both Freke and Castaing, the schedule for the second subscription was changed around 22 July 1720. The instalment payments remained at £40, but the payment dates were changed. The revised payment dates are shown in table 1,[102] with the original payment dates shown in brackets.[103] The revised schedule had the effect of bringing forward the final instalment date from 24 April 1723 to 14 December 1722. In subsequent calculations that employ the data displayed in this table, the original

[100] *Washington post*, 21 Jan. 1999, A1.

[101] See, for example, *Freke's Prices of Stocks etc*., no. 93, 26 August 1720 and Castaing's *The Course of the exchange*, 26 August 1720.

[102] Reported in *Freke's Prices of Stocks etc*, no. 84, 26 July, 1720 and Castaing's *The Course of the exchange*, 26 July 1720.

[103] Reported in *Freke's Prices of Stocks etc*, no. 82, 19 July 1720 and Castaing's *The Course of the Exchange*, 19 July 1720.

schedule of payments is used for prices up to 22 July 1720, and the revised schedule is used thereafter, since investors would have been aware of the schedule revision.

The second difficulty relates to the fourth subscription. Anderson indicates that when this was issued on 24 August 1720 it was stated to be payable as to 20 per cent down, with four further equal payments at six-monthly intervals over two years.[104] This two-year repayment period was also reported in the contemporary press.[105] However, it seems that the precise dates of the calls were not initially specified, so that Freke gives only the payment months (February and August) in his schedule of payments.[106] Castaing publishes no schedule for the fourth subscription until October, when the schedule had in any case been changed to reflect a retrospective adjustment of terms proposed by the South Sea Company. Consequently, Freke's schedule has been employed, but it has been assumed that payment dates fall on the 24th of each relevant month (i.e. corresponding to the issue date of 24 August).

APPENDIX II: The sources of data used in, and the method of compilation of, table 2

The stock price and subscription price series used to determine the statistics displayed in table 2 are compiled using *Freke's Prices of Stocks etc*, which provides a continuous series of stock and subscription prices from 14 May 1720. The reasons for employing this data source are fully discussed in section IV.

The stock price series is taken directly from Freke without adjustment, other than for the period 23 June to 22 August 1720, when the transfer books of the company were closed.[107] As explained more fully in section IV, the prices quoted by Freke during this period were 'for the opening of the books' and were, therefore, forward prices. The prices during this period are, therefore, converted to a present value equivalent by discounting using a 5 per cent discount rate (a justification for employing a 5 per cent discount rate is given in section IV).

In addition, a number of assumptions and adjustments are made in relation to the subscription prices quoted by Freke in order to convert them into (fully paid) stock price equivalents. The assumptions and adjustments are fully discussed in section IV, and in brief, include the following:

(a) The subscription receipts were not delivered out by the South Sea Company immediately on the issue date. For the reasons outlined in section IV it is assumed that all four subscriptions were to be delivered out two months after the issue date.[108]
(b) Where Freke quotes both regular and 'for money' subscription prices,[109] the former are employed, as discussed in section IV.
(c) Where Freke does not distinguish between 'for money' and regular transactions, it is assumed that he is referring to regular transactions.

[104] Anderson, *Origin of commerce*, p. 113.
[105] For example, *The Weekly Journal*, published by John Applebee, 27 August 1720.
[106] *Freke's Prices of stocks etc*, no. 93, 26 August 1720.
[107] Dale, *The first crash*, p. 172.
[108] Ibid., p. 174.
[109] See, for example, *Freke's Prices of stocks etc*, no. 88, 9 August 1720.

(d) During the two-month period when receipts had not been delivered out by the Company, the prices quoted by Freke are forward prices. These prices are therefore discounted from the expected delivery date at 5 per cent (see section IV).
(e) The prices of all four subscriptions are converted into values that can be compared directly to the stock price by adding the present value of the unpaid calls back to the market price (adjusted in the manner indicated above).
(f) For the second subscription, the schedule of payments was changed on 22 July 1720 (as indicated in table 1 and discussed in appendix I). Consequently, the original schedule is used in calculations of a stock price equivalent to subscription two prices until 22 July, and the revised schedule is used after that date.
(g) The first three subscriptions were entitled to the 10 per cent midsummer dividend of 1720[110] and, consequently, the prices of these subscription receipts (adjusted in the manner indicated above) are equivalent to stock prices. However, the fourth subscription was not subject to the 10 per cent stock dividend and, therefore, the prices for subscription four receipts (adjusted in the manner indicated above) are raised by 10 per cent to put them on a comparable basis with the first three subscriptions and the stock price.

Following the assumptions and adjustments indicated above the resulting subscription price series are directly comparable with the stock price series, and it is these adjusted price series which are used to calculate the statistics displayed in table 2.

APPENDIX III: The sources of data used in, and the method of compilation of, table 3

Table 3 compares the stock and subscription prices close to the subscription issue dates. The source of the data and/or the method of calculation for each row of the table are as follows:

(a) The issue date, new issue price and first subscription payment are taken from *Freke's prices of stocks etc*.[111]
(b) The stock price equivalent of the issue price of each subscription (SPE of issue price) is calculated by adding back to the first payment required for each subscription the unpaid calls on the subscription concerned[112] discounted at 5 per cent, to arrive at a present value equivalent (at issue date) to these unpaid calls (the justification for using 5 per cent as a discount rate is given in section IV).
(c) The equivalent stock price of South Sea stock (ESP) at the subscription issue date is taken from *Freke's prices of stocks etc*, and represents the latest stock price quoted on the day before the subscription date. During the period when the transfer books were closed (23 June to 22 August 1720) the prices quoted by Freke are forward prices, and are therefore discounted at 5 per cent to arrive at a present value equivalent.

[110] Dale, *The first crash*, p. 162.
[111] See, for example, *Freke's prices of stocks etc*., no. 93, 26 August 1720.
[112] Ibid.

(d) The premium of the subscription price over the stock price at the issue date represents a comparison of the SPE of the subscription issue price and the ESP at the subscription issue date. It measures the extent to which the subscription issue price exceeds or falls short of the prevailing stock price.

(e) The market prices for subscriptions three and four, one week after their issue, are taken from *Freke's prices of stocks etc*. However, because Freke did not publish subscription prices until 14 May (and Castaing later still) Defoe is used to determine the equivalent prices for subscriptions one and two; he states that the first two subscriptions rose initially to a premium of 10–12 per cent over the issue price.[113]

(f) The market premium of subscriptions over the first payment compares the market price for subscriptions one week after their issue date with the initial down payment required when the subscriptions were issued. For this purpose, the market prices are taken from *Freke's prices of stocks etc* (without adding back the unpaid calls) and the down payments are taken from *Freke's Prices of Stocks etc* no 93, 26 August 1720. The comparison shows the market premia over issue price or profit attaching to successive subscriptions shortly after their issue.

(g) The equivalent stock price of South Sea stock (ESP) one week after the subscription issue date is taken from *Freke's Prices of stocks etc*. The method of calculation is indicated in (c) above.

(h) The stock price equivalent of subscription receipts (SPE) one week after their issue is calculated by adding back to the subscription market prices, as reported by Freke at the relevant date, the discounted value of unpaid calls on the subscription concerned, using a 5 per cent discount rate.

(i) The premium of the subscription price over the stock price one week after issue of the relevant subscription compares the values calculated in (h) with the values calculated in (g) above. The comparison shows the market premium attaching to successive subscriptions over the stock price shortly after the subscription issue date.

(j) The subscription prices used in (e) and (h) above involve some adjustment to the prices quoted by Freke, since subscription receipts were not delivered out by the company immediately on the issue date. For the reasons outlined in section IV it is assumed that receipts for all four subscriptions are delivered out, or are expected by the market to be delivered out, two months after the issue date. During this two-month period, Freke quotes prices for regular and 'for money' transactions for the third and fourth subscriptions.[114] The former are employed in table 3 to avoid distortions caused by settlement risk associated with the latter type of contract (see section IV for a full discussion of this issue). Where Freke does not distinguish between 'for money' and regular transactions, it is assumed that he is referring to regular transactions. The prices quoted by Freke during the two-month period when receipts had not been delivered out by the company are, in effect, forward prices. These prices are therefore discounted from the expected delivery date at 5 per cent (the reasons for employing 5 per cent are fully discussed in section IV).

[113] Defoe, *True state of the contracts*, p. 10.

[114] See, for example, *Freke's Prices of stocks etc*, no. 88, 9 August 1720.

APPENDIX IV: The methodology employed in the co-integration analysis

The aim is to examine the relationship between stock and subscription prices. If these time series were stationary then it would be possible to explore this relationship using a simple OLS regression. However, in many cases, time series of this sort are not stationary and Granger demonstrates that the relationship can then be examined using co-integration.[115] Engle and Granger showed that the co-integrated variables can be written in the form of an error-correction model (ECM).[116] These provide a means of determining, simultaneously, the nature of any long-run relationship and the short-run dynamics that exist between the stock and subscription prices series, even though the absolute values of the series may be non-stationary. The starting point for the analysis therefore involves an exploration of whether there exists a co-integration relationship between the stock price S_t and subscription price C_t^j series. To test for this it must first be decided whether the stock and subscription prices contain a unit root (i.e. are non-stationary); achieved by applying the Augmented Dickey-Fuller unit root test. If the series S_t and C_t^j are identified as non-stationary variables, tests for a co-integration relationship are conducted to decide whether a stationary linear combination of the two series exists of the following form:

$$\hat{z}_t = S_t - \beta^j C_t^j - \mu^j \tag{3}$$

where μ^j and β^j are estimated constant and parameter values (discussed more fully below).

Johansen and Juselius' multivariate co-integration approach is employed to test for such co-integration.[117] However, since the co-integration test is sensitive to the order of lags included in the vector auto-regression (VAR) a general to specific approach is employed to decide on lag length before the co-integration test is conducted. If the two price series are co-integrated and $\mathbf{\Pi}$ is of reduced rank, the following error-correction model representation (ECM) can be applied to examine the long- and short-run dynamic system.

$$\Delta \mathbf{Z}_t = \mathbf{\Theta}_1 \Delta \mathbf{Z}_{t-1} + \ldots + \mathbf{\Theta}_{k-1} \Delta \mathbf{Z}_{t-k+1} + \mathbf{\Pi} \mathbf{Z}_{t-1} + \boldsymbol{\varepsilon}_t \tag{4}$$

where Δ is the difference operator; thus $\Delta \mathbf{Z}_t$ is a vector of stationary variables of stock and subscription prices. The term $\mathbf{\Theta}_i \Delta \mathbf{Z}_{t-i}$ captures the short-run dynamics. The matrix $\mathbf{\Pi}$ provides information about the long-run relationship between S_t and C_t^j. The existence of co-integration implies that matrix $\mathbf{\Pi}$ can be represented as $\mathbf{\alpha\beta'}$, where $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are $(p_z \times r)$ matrices (r is the number of co-integration relationships and p_z is the number of variables). In this form, the vector $\boldsymbol{\beta}' \mathbf{Z}_{t-1}$ captures the deviation of the system from its long-run relationship and $\boldsymbol{\varepsilon}_t$ is the vector of martingale difference sequences.

The long-run relationship between the stock price (S_t) and subscription price (C_t^j) series can be examined using matrix $\mathbf{\Pi}$. If $\mathbf{\Pi}$ has zero rank, co-integration does not exist between the stock and subscription prices. If $\mathbf{\Pi}$ has full rank, then both price series are stationary and OLS can be applied to explore the relationship

[115] Granger, 'Econometric model specificating', p. 127.
[116] Engle and Granger, 'Co-integration and error correction', pp. 255–9.
[117] Johansen and Juselius, 'Inference on cointegration', p. 170.

between S_t and C_t^j. If $\mathbf{\Pi}$ has reduced rank, then the price series are co-integrated and $\mathbf{\Pi}$ can be expressed as $\mathbf{\Pi = a\beta'}$. Consequently, if $\mathbf{\Pi}$ has reduced rank, the form of the ECM to be estimated will be given by:

$$\Delta S_t = \alpha_S \hat{z}_{t-1} + \sum_{i=1}^{k-1} \theta_{i,s}^{s} \Delta S_{t-i} + \sum_{i=1}^{k-1} \theta_{i,s}^{c_j} \Delta C_{t-i}^{j} + \varepsilon_{st} \tag{5}$$

$$\Delta C_t^j = \alpha_{c_j} \hat{z}_{t-1} + \sum_{i=1}^{k-1} \theta_{i,c_j}^{s} \Delta S_{t-i} + \sum_{i=1}^{k-1} \theta_{i,c_j}^{c_j} \Delta C_{t-i}^{j} + \varepsilon_{ct} \tag{6}$$

where $\theta_{i,s}^{s}$ and θ_{i,c_j}^{s} measure the influence of previous changes in the stock price on current stock and subscription (j) price changes, respectively; $\theta_{i,s}^{c_j}$ and $\theta_{i,c_j}^{c_j}$ measure the influence of previous changes in the subscription (j) price on current stock and subscription price changes, respectively; $\hat{z}_t$ is the error correction term that identifies the long-run relationship between stock and subscription prices (i.e. $\hat{z}_t = S_t - \beta^j C_t^j - \mu^j$).

The coefficients, α_s and α_{c_j} of the long run equilibrium error $\hat{z}_t$, measure, respectively, the adjustment speed of ΔS_t and ΔC_t^j toward the long-run equilibrium. These speed adjustment coefficients can also help determine the direction of the long-term causal relationship between the series, since, for example, if $\alpha_s = 0$ and $\alpha_{c_j} \neq 0$, then a deviation from the long-run equilibrium will be corrected by a change in the subscription prices (not in stock prices); this implies that stock prices are weakly exogenous for the subscription prices, indicating that more information is contained within the stock price series. In such a case it would be likely that the stock prices Granger-cause the subscription prices; although it would be possible for the subscription prices to also Granger-cause the stock prices.

Short-run information flows between the price series are specifically captured by the coefficients $\theta_s^{c_j}$ and $\theta_{c_j}^{s}$, which, respectively, determine the Granger causality effects from stock to subscription (j) prices and from subscription (j) to stock prices. Provided there exists a long-run equilibrium relationship between the price series then there must exist Granger causality effects from stock to subscription prices (or vice versa) or in both directions. If the price series are co-integrated and one of the price series Granger-causes the other series then prediction of the latter series can be improved by using lagged values of the former series and lagged values of itself.[118] If both series Granger-cause each other, both can provide useful information about the other.

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[118] Granger, 'Investigating causal relations', p. 431.

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