Recreating the South Sea Bubble: Insights from an Experiment in Financial History[*]

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Abstract

Major bubble episodes are rare events. In this paper, we examine what factors might cause some asset price bubbles to become very large. We study, in a laboratory setting, some of the specific institutional features investors in the South Sea Company faced in 1720. Several factors have been proposed as potentially contributing to one of the greatest periods of asset overvaluation in history: an intricate debt-for-equity swap, deferred payment for these shares, and the possibility of default on the deferred payments. We consider which aspect might have had the most impact in creating the South Sea bubble. The results of the experiment suggest that the company's attempt to exchange its shares for government debt was the single biggest contributor to the stock price explosion, because of the manner in which the swap affected fundamental value. Issuing new shares with only partial payments required, in conjunction with the debt-equity swap, also had a significant effect on the size of the bubble. Limited contract enforcement, on the other hand, does not appear to have contributed significantly.

Keywords: Financial bubbles, experiments, South Sea bubble, risk-shifting, government debt, equity issuance

JEL codes: G01, G12, G14, N23, C92.

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I. Introduction

From the Dutch Tulipmania of the 17th century to the NASDAQ bubble, the rise and fall of speculative bubbles has produced massive gains and losses for investors. As the financial crisis of 2007-08 has demonstrated, bubbles can also be a major source of economic instability. Large swings in asset prices over short periods of time have often been considered as a sign of inefficiency and a telling testament to the "irrational exuberance" of investors. One important strand in the literature denies the existence of bubbles altogether (Garber 2001; Fama 1965). Other scholars have sought to explain their emergence as a result of risk shifting, investor inexperience, and limitations of market micro-structure such as an inability to short over-valued stocks (Allen and Gale 2000; Greenwood and Nagel 2009; Hong et al. 2006; Lintner 1971). Empirical work has demonstrated that sophisticated investors – instead of attacking mispricing – often "ride" bubbles, aggravating price swings (Brunnermeier and Nagel 2004; Temin and Voth 2004). The experimental evidence shows that the size and duration of bubbles are sensitive to the market parameters, institutions, and incentives in place (Palan 2013).

While the theoretical and empirical literature offers explanations for the continuation of mispricing, the origins of bubbles are not well-understood. In particular, there is no convincing explanation for why bubbles appear at certain times in particular markets, but not at other times or in other markets. Experimental work suggests that bubbles emerge readily in laboratory settings (Smith, Suchanek, and Williams 1988). This makes it all the more puzzling that major bubbles have only erupted on a handful of occasions over the last 400 years, such as during the Tulipmania, the South Sea bubble, and the NASDAQ episodes. Milton Friedman (2001) concluded that "…the start and end of a bubble just cannot be explained rationally."

In this paper, we report the results of a laboratory experiment designed to study which specific institutional features played a role in igniting the South Sea mania. We recreate many of the incentives faced by investors in 1720 in our laboratory experiments, and then isolate their effects by "switching them off" one-by-one. Of course, many historical features cannot be recreated. Nevertheless, if an institution exerts a systematic effect on mispricing in our experiments, some 400 years after the event, we argue that it is likely to have played an important role in the original episode. Because our interest is in understanding a specific historical episode, we do not adhere closely to any previously studied paradigm, but rather develop a new experimental design that is tailored to the purpose of our study.

Together with the Tulipmania and the Mississippi Bubble, the South Sea bubble is one of the three famous, early bubbles that occurred during the 17th and 18th centuries (Carswell 1960; Dale 2004) . It is among both the best-documented and the least well-understood episodes in the history of financial markets.[1] Originally created to trade with Spanish America, the South Sea Company's main source of revenue was interest payments from its holding of UK government bonds. In late 1719, it proposed to swap all outstanding government debt for its own equity. After the contract was awarded by Parliament, it began to issue new stock through subscriptions. Eventually, it exchanged government debt for equity. The South Sea Company's stock rose in value from a little more than £120 at the start of the year 1720 to nearly £1,000 in June, before crashing by some 80 percent before year-end (figure 1). While other stocks also saw their prices surge, the sheer scale and speed of the South Sea Company's price explosion and decline are without parallel.[2] The South Sea bubble did not only matter for investors at the time. As a result of lobbying by the company, when the stock price was near its peak, England effectively prohibited the issuance of shares in new companies. This closed the stock market to firms for over a century, resulting in markedly greater difficulties in raising funds for new ventures (Harris 1994; Temin and Voth 2013).

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[1] One example demonstrating the extent of disagreement is the debate between Shea (2007) and Dale et al. (2005).

[2] Temin and Voth (2004) compare the magnitude of the price run-up and decline in the South Sea and the NASDAQ bubble, and find the former to be markedly larger.

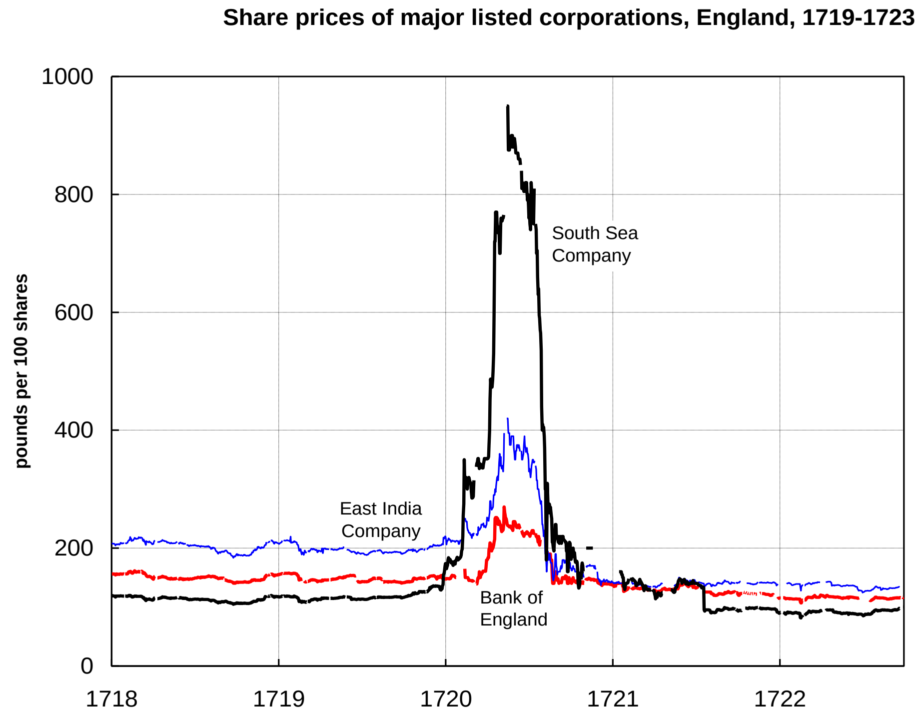

Figure 1: *Share prices of major listed corporations, England, 1719-1723*

The institutional features of the South Sea scheme inform our choice of experimental treatments. The explosion in the South Sea Company's stock price took place when it (1) was seeking to swap government debt for equity, (2) allowed investor to purchase shares while deferring payment of most of the purchase price, and (3) had limited ability to enforce collection of the deferred payments. We examine all these specific features in isolation. The baseline treatment of our design includes all of these features and generates a large bubble. In the other treatments, we remove the institutional features (1) – (3), one at a time. The magnitude of the bubble in these treatments is compared to that in the baseline treatment. In this manner, we are able to identify which aspects likely contributed to one of the greatest and most famous bubbles in history.[3]

Our paper makes two main contributions. The first is substantive: Our key contribution is to shed light on factors that contributed to the eruption of one of history's greatest bubbles. Our findings suggest that the attempt to swap government debt for company equity was the single most important contributing element that helped to create the South Sea bubble. The plan to take over all of England's government debt was highly unusual; its large role in igniting the

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[3] We discuss the possible influence of confusion in more detail below (cf. Kirchler et al. 2012).

bubble offers one explanation why similar episodes have been rare. In addition, the ability to defer payment for shares helped to increase the likelihood of a bubble forming, and increased its size. Limited contract enforcement played only a smaller role. The second contribution is methodological: We use the laboratory to try to understand a specific episode in economic history, recreating incentives agents faced nearly 400 years ago. We exploit the possibility, offered by laboratory experimentation, to observe the fundamental value and thus measure the magnitude of a bubble, to introduce and remove institutional features keeping all else constant, and to generate new data designed to reproduce conditions that ceased to exist hundreds of years ago. We view this last feature as particularly beneficial to the study of economic history – a logical extension of counterfactual method.

The paper proceeds as follows. Section II summarizes the historical context and background of the South Sea bubble. Section III presents our experimental design and describes how we capture the essential historical details of trading "in the South Seas" (as contemporaries would have said). In Section IV, we report our results, and Section V concludes.

Section II: Historical Context and Background

The South Sea Company was founded to trade with South America. The Peace Treaty of Utrecht in 1713, which brought the War of the Spanish Succession to an end, granted Britain the right to send trading ships periodically to Spain's possessions in the Americas. The company took over some of the government's debt in exchange for the trading privileges. Its mercantile operations never amounted to much. By the late 1710s, the South Sea Company amounted to little more than a shell company distributing interest payments on government debt to its shareholders.

In 1719, the Company took over another part of the national debt, referred to as the "lottery loan". While paying a high rate of interest, the loan was highly illiquid. Bonds could not readily be transferred; price discounts were substantial. The operation that swapped these government bonds for equity in the South Sea Company was widely considered a success – the investors gained a more liquid asset, the government lowered the interest charges on its debt, and the company made a profit.

The 1720 scheme was vastly more ambitious – and it contained one crucial difference with the 1719 operation. The South Sea Company proposed to take over the entire remaining national debt (except for the parts held by the Bank of England and the East India Company). Instead of swapping debt for equity at a pre-established price, the company remained vague as to the exchange ratio. This implied that as the stock price appreciated, more debt could be bought for each share.

Bidding against the Bank of England for the right to do the debt conversion, the South Sea Company finally won the contract in a parliamentary vote in 1720. Massive bribery preceded the award of the contract. By this stage, the stock price had more than doubled. After the award of the contract, the South Sea Company began to issue new shares in repeated rounds of offerings. As shown in table 1, it did so at steadily rising prices – for £300 in early April, £400 in late April, £1,000 in June, and £1,000 in August. These were known as "subscriptions", and were bought on installment plans. Actual down payments amounted to only £40-200 (10-20% of the total cost). Subscribers did not become owners of shares until all payments had been made. Subscription receipts could themselves be traded. Their prices moved in parallel with the price of the underlying stock, but in relative terms, price changes were magnified – as they are with options.[4]

[4] For the exact details of the analogy with options pricing, cf. Shea (2007)

Subscription round	1	2	3	4
Date	14 April,	29 April,	16 June,	24 August,
Issue Price	300	400	1000	1000
Final Payment Due*	14 August, 1721	24 April, 1723	2 January, 1725	24 August, 1722
Premium**	-1 %	9.7 %	21.3 %	27.6 %
Gain of Subscription Value within One Week***	10 %	10 %	150 %	53.5 %

* according to the original issuance schedule
** NPV of subscription payments relative to the market price at time of issuance
*** calculated as the difference between the subscription price and the price of South Sea stock one week after the subscription closed

***Table 1**: South Sea Company Issues of New Shares, 1720*

Throughout the spring and summer of 1720, the stock price moved up, reaching nearly £1,000 by June. Many other stock schemes sprang up during the same time, luring investors. Also, many inexperienced investors entered the market, often in the expectation of a quick profit. The company initially did not use the proceeds from share issues to actually buy back government bonds, as the original scheme had envisaged. Instead, it lent generously against its own shares. Many of these loans were later not repaid.

The actual exchange of government debt for equity took place in May and in August. Eventually, in the spring, the company began to offer bond holders a chance to exchange bonds for South Sea stock. Terms were not overly generous, but a significant share of bondholders nonetheless accepted the deal. As the stock price increased, existing bonds could be bought in exchange for fewer share certificates. This increased the intrinsic value of the stock. In other words, the rise in the stock price, the issuance of new shares, and the possibility of buying out debt holders created winners and losers (Carswell 1993 : 120). Contemporaries were keenly aware of this fact. As a matter of fact, a Member of Parliament – Archibald Hutcheson – published several pamphlets in the course of 1720, pointing out the losses and gains to different subscribers and the original bondholders, as a function of when they had bought.

One of the tables published by Hutcheson is reproduced as Table 2. We see that in the fall of 1720 – after the second subscription of shares at £1,000 per 100 shares had closed – there were clear winners and losers. Column 1 gives the proportion of the stock held by different groups – the old proprietors, who bought South Sea stock at £100, and the subscribers, who had bought at increasing prices. The company had issued shares for a nominal value of £42 million. In the aggregate, it had sold them to the public for £234 million, or £557 per 100 shares. At the time, South Sea stock was worth close to £600. Thus, all the subscribers who paid less than this had made money; and those who had bought for £1,000 had lost. Column 2 gives, for each group, the market value of stock held; column 3 summarizes what investors paid for it. The magnitude of gains and losses is summarized in column 4. Some £90 million of losses accrued to the new subscribers at £1,000. Most of these ended up in the pockets of the old proprietors (£ 57 million) and, in much smaller quantities, in those of the early subscribers.

	Proport^{s}. in this Stock.	Value thereof.		Paid for the same.	Loss thereon.		
	l.	*l.*	*Decim.*	*l.*	*l.*	*Decim.*	*l.* *Decim.*
The First Subscribers at 1000 *l.*	6,600,000	36,771,428	571428	60,000,000	23,228,571	428572	
The Second Subscribers at 1000 *l.*	15,400,000	85,800,000	- - - -	154,000,000	68,200,000	- - - -	91,428,571 428572
					Gained thereon.		
The Old Proprietors at 100 *l.*	12,320,000	68,640,000	- - - -	11,200,000	57,440,000	- - - -	
Subscribers at 300 *l. per Cent.*	2,475,000	13,789,285	714286	6,750,000	7,039,285	714286	
Ditto at 375 *l.*	3,665,000	20,419,285	714286	12,494,318	7,924,967	714286	
Ditto at 400 *l.*	1,540,000	8,580,000	- - - -	5,600,000	2,980,000	- - - -	75,384,253 428572
	42,000,000	234,000,000	- - - -	250,044,318	- - - - - - - -		16,044,318

***Table 2**: Winners and Losers from the South Sea Conversion Scheme*
Source: Hutcheson (1720)

The basic principle that ensured that investors put their money into the South Sea scheme was simple enough. The expected losses and gains for various groups, as set out in detail by Hutcheson, could not have remained a secret. One key question is then why the new owners bought shares which gave them cash flow rights that were lower than their market price? Put simply, an investor in 1720 could acquire the rights to future interest payments by buying a government bond, or by buying South Sea stock. Why pay more for the latter? One logical possibility is that some commercial venture might produce vast profits. This was highly unlikely.

Our answer is that new subscribers could possibly benefit from rising inherent values of their shares as a result of additional stock issuance in the future – again, if bondholders could be bought out more cheaply, the intrinsic value of shares would increase. Note that for this mechanism to work no actual purchase of bonds is necessary – it is enough that it is planned. New investors are willing to buy because they hope that they will gain if prices continue on an upward trend (which then translates into a self-fulfilling prophecy). The prospect of future issuance can turn the loss in the present into a purchase that, at least in expectation, can turn out to be profitable at some point in the future.

The structure we just described is, of course, that of a classic Ponzi scheme. The secret to success is to join early (and to get out before things fall apart). As long as there is a good chance that another wave of investors will enter, it is a good idea to participate. The details of the South Sea operations were complex, and there is some evidence that investors and the general public did not find it easy to see through it all. The *Flying Post*, a newspaper at the time, argued on April 9, 1720 that the intrinsic value of the South Sea Company stock would be £448 if the share price went to £300. At £600, it would be £880. We do not know how these numbers were calculated; it is clear that they cannot be correct. The basic structure is right, with higher share prices justifying a higher fundamental. At the same time, the relative prices are wrong – the intrinsic value in this operation can never catch up with the price at which the last issue was undertaken.

Based on the historical background described above, it is possible to distill a number of hypotheses about the factors that might have contributed to one of the biggest bubbles in history:

Hypothesis 1: Redistributing revenue from new issues to existing shareholders increases prices and bubble magnitude.

As indicated earlier, the redistribution of new revenues to existing shareholders, in the form of interest payments on the bonds purchased with these revenues, increased the inherent value of South Sea stock; this created gains for existing shareholders at the expense of new investors. This increase in fundamental values could launch a bubble, if, for example, heterogeneous beliefs about the likelihood of future issues may lead those with particularly optimistic beliefs to bid up the price. Furthermore, the increases in price could attract the attention of momentum traders who also buy because they expect past price trends to continue, thereby creating further upward pressure on prices. Finally, speculators may attempt to take advantage of the presence of momentum traders, magnifying the bubble further.

Hypothesis 2: When new shares issues can be paid for in installments, bubbles are greater than when they must be fully paid for up front.

The possibility of payment by installment would, in principle, relax cash constraints on those individuals who are speculating on future new share issues.

This would allow them to take larger long positions, possibly inflating a bubble. Furthermore, deferment of payment for new shares allows greater leverage for investors who are speculating on a rising market. Consider an individual who is interested in a purchase for later resale, and who expects the price to appreciate by 20% between period t and t + 1. If deferment of payment is not feasible and he purchases and resells, his return is simply 20%. However, if he can pay only 20% in period t, sell for 120% of the original contract price and pay back the remaining 80% at that time, his return is 100%. This magnifying effect of leverage could magnify a bubble once prices have begun to rise.

Hypothesis 3: If outstanding installment payments do not have to be paid back at the end of the life of the asset, bubbles are greater than if they do have to be paid.

The ability to purchase in installments increases the capacity to speculate on future price increases. If the resulting debt does not have to be paid back, it lowers the downside risk of holding the asset. If prices fall to a level below the amount the individual owes, she might find it more profitable to default on her remaining installment payments and give up the share. Thus, if prices are volatile, the default option gives the asset the properties of a call option, limiting downside risk in a similar manner. In our experiment, we implement the possibility of default by nullifying any outstanding debts owed at the end of the life of the asset. If traders take this effect into account, it could increase demand for the asset when future prices are unpredictable, and thus exacerbate any bubbles that occur.[5]

Section III: Experimental Design

III.A Procedures Common to All Treatments

i. <u>General Structure</u>

The experiment consisted of four treatments, called Baseline, NoInstall, NoDefault, and NoSwap. We conducted eight sessions of the Baseline treatment and four sessions of each of the other three treatments, for a total of 20 sessions.

[5] Here, the risk-shifting intuition is similar to that in Allen and Gale (2000). Note also the similarity with recent work exploring the analogy between options pricing and stock prices under high uncertainty (Pastor and Veronesi 2006).

The sessions were conducted at University Pompeu Fabra and Tilburg University.[6] Each session consisted of two consecutive horizons, with each horizon made up of a sequence of between ten and twenty 150-second periods. At the beginning of the second horizon, endowments were reinitialized to the same levels as the beginning of the first.[7] This means that the two horizons can be viewed as two distinct economies, linked only by the experience participants accumulate during the first horizon.

When subjects arrived at the laboratory, they received approximately 45 minutes of instructions. They were taught both the use of the computer software and the specific conditions of the treatment in each session. All subjects could both purchase and sell the asset. After instruction, they familiarized themselves with the game by trading during a practice phase in which there was one auction of new shares and three periods of trading of shares. Thereafter, the first trading horizon began.[8]

In each period, up to two markets could operate simultaneously. In Market A, the shares originally issued at the beginning of the trading horizon could be exchanged. That is, market A served for trading those shares in circulation at the outset of the first period of a horizon. Market B enabled trading of newly-issued shares, those shares issued after the horizon began. New shares could be issued in any period, beginning in period four. Shares trading in market A and market B were identical in terms of the dividends paid and their expected lifetime, and therefore also identical in terms of their fundamental values.[9]

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[6] The sessions were conducted at University Pompeu Fabra (17 sessions) and at Tilburg University (3 sessions) between July 2012 and December 2012. Each session took approximately 2 hours and 40 minutes. The average payment was 9 Euros per hour at UPF and 13 Euros per hour at Tilburg.

[7] We use the term session in this paper in the manner in which it is typically employed in experimental economics, which differs from common usage in finance. In experimental economics, a session refers to a continuous time interval in which a particular cohort is present in the laboratory. The sessions of our experiment are divided up into two trading horizons. The horizons are independent of each other. At the beginning of the second horizon all parameters are reinitialized, and the only link between the two horizons is the possible effect of subjects' prior experience. Each horizon is divided into periods. A trader's cash and asset position at the end of one period carry over to the next period within the same horizon. Thus, according to one common notion in finance, a period in our experiment corresponds to a trading session or a trading day.

[8] Participants were graduate and undergraduate students in various majors, but most were majoring in business and economics. No subjects had previously participated in any asset market experiment. The number of subjects participating in each session ranged from 6 to 10.

[9] The reason for keeping asset markets separate is that during the South Sea bubble, shares and "scrib" (subscription certificates) were trading in parallel (Dale 2004).

The markets were organized using continuous double auction rules (Smith 1962), and implemented with the z-tree computer software (Fischbacher 2007). Trade took place in terms of an experimental currency, called "ducats", which was converted into Euros at the end of the experiment at a conversion rate that was common knowledge.

ii. The Asset

At the end of each period, each unit of the asset paid a dividend that took on one of four values, 0, 8, 28, or 60 Ducats, each with equal probability. Therefore the expected dividend per period was equal to 24 Ducats. Dividend realizations were unknown until the time they were determined.

The asset had a life of several periods. The maximum possible lifetime was 20 periods and the minimum was 10 periods. For each period from 10 to 19, whether the trading session would continue to the next period or not was determined randomly at the end of the period. The probability that the current period was the last one was equal to 1/6 in each of the periods from 10 to 19.

The fundamental value of both assets can be calculated at any time from the dividend and the probability of termination. This fundamental value is the sum of the expected dividends to be received from the current period t until the end of the life of the asset. This is given by the expression:

$$FV_t = \sum_{s=t}^{T} d_s * (1 + \pi)^{(T-s)}$$

where d_s denotes the expected dividend in each period and π is the probability that the horizon ends after the current period. For example, consider a fixed d_t of 24 for each period until end of the horizon. The fundamental value in period 16 would be:

$24 * (5/6)^4 + 24 * (5/6)^3 + 24 * (5/6)^2 + 24 * (5/6)^1 + 24 = 85.54$ Ducats.

Subjects were provided with a table that indicated the fundamental value in each period and how it was calculated. The same table was also displayed on each subject's computer screen before the start of each trading period.

iii. Initial Endowments and New Issues

Before period 1, each subject was endowed with 5 shares and 30,000 ducats. These shares could then be traded in market A at any time and the cash endowment could be used for new asset purchases. New issues of the asset could occur in any period beginning in period 4. Issues occurred at the beginning of the period, just after the dividend from the previous period was paid and before the market opened for trade in the current period. The criterion for whether or not a new issue would take place in period t was the following: If the average transaction price in market B was greater than the fundamental value of the preceding period, a new issue would occur.[10]

New shares were issued with sealed bid auctions that took place at the beginning of some periods. In each period in which there was an issue, a subject could bid for up to two shares of the K new shares offered for sale. The bids were ordered from highest to lowest and the K highest bidders were awarded units. Winning bidders paid a per-unit price equal to the lowest of the accepted bids, that is, the K^{th} highest bid. Thus the auction format was a uniform-price sealed bid auction with lowest accepted bid pricing.[11] In the first period in which there was a subscription, eight shares were auctioned. In subsequent subscriptions, five shares were auctioned. The criterion for issuing shares was unknown to participants.

III.B Treatments

The treatments are designed to assess the impact of (a) swapping debt for equity, (b) deferring payment for newly-issued shares, and (c) the possibility of default on these payments, for bubble formation. The baseline treatment is characterized by the presence of all institutional features (a) – (c). Each of the other three treatments eliminates one of the features (see Table 3). Consequently, we can isolate the marginal contribution of each factor when all of the others are present.[12] Table 3 displays the features characterizing each of the treatments, and distinguishing it from the other treatments.

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[10] Before starting trading in period 4, there is a subscription auction if the price in period 3 for asset A is greater than the fundamental value.

[11] While not demand-revealing, this auction format tends to generate highly efficient allocations when individuals demand is for a single unit or for two units (Alsemgeest et al. 1998).

[12] Notice that the absence of payment in installments automatically implies that default was impossible. However this does not cause problems of inference, because we are still able to disentangle the effect of each single factor.

	Baseline	NoInstall	NoDefault	NoSwap
Swapping	Yes	Yes	Yes	No
Installments	Yes	No	Yes	Yes
Default	Yes	No	No	Yes

Table 3*: Treatment features*

1) The NoInstall treatment: No payment through installments.

In the *NoInstall* treatment, newly issued shares must be paid in full at the time of purchase. In the remaining three treatments, an individual who purchases newly-issued shares is not required to pay the full price of the share he has bought at the time of purchase. Only 20% of the price is subtracted immediately from his current cash balance. The remaining 80% is registered as debt that the individual owes. This debt is repaid as follows: In each of four periods immediately following the period of the share issue, 20% of the price originally paid is subtracted from his cash balance.

2) The NoDefault treatment: Limited contract enforcement

In 1720, many investors used the default option in the fall, when prices of South Sea stock tumbled. In our experiment, we do not allow investors to voluntarily default at any time, as this would have added another layer of complexity. Instead, we implement the default at the end of the horizon, when all individuals would clearly prefer to default. This setup leaves the incentive to buy and then default intact, because demand should rationally be higher near the end of the horizon when the default probability is relatively high.

In particular, we implemented the default option as follows: The number of periods that the trading horizon continues is not known to traders. The horizon terminates with a 1/6 probability at the end of each period from 10 to 19, and with probability 1 at the end of period 20. The horizon may end before the debt of a trader from a purchase of new shares in the auction has been fully repaid. Subjects were informed that they would not have to repay any debts outstanding at the time a horizon ends. In other words, the debt owed is not subtracted from their cash holdings at the end of the trading horizon[13]. The exception to this is the NoDefault treatment, in which the amount due is subtracted in full from the subject's cash account when a horizon ends.

3) The NoSwap treatment: Distribution of revenue from new share issues to existing shareholders.

There is no direct swapping of shares for equity in our experiment. Instead, we recreated the 1720 incentive structure by supplementing the dividend payment to existing shareholders with funds raised through the issuance of new shares. Our setup makes the Ponzi-scheme nature of the South Sea scheme clearer, but it leaves the key payoff features intact. While the mechanics "in the background" are different, the direct recycling of payments creates an analogous effect to using the revenue from new shares to purchase additional government bonds, thereby raising the intrinsic value of old shares which now entitle the owner to higher interest payments.

In three of the treatments, each time that new shares are issued, 15% of the new revenue from the issue is distributed to shareholders (both new and old) in proportion to their total share holdings. For example, if there are 20 shares outstanding and 5 more are issued for 1000 each, then 750 is handed out in total to existing shareholders during the current period, 37.5 to the holder of each outstanding share. In each period, this additional payment continues until the end of the horizon, and is added to the original dividend. In this way, the fundamental value of shares increases after each new subscription.[14] In contrast, in the NoSwap treatment, the revenue from the issue of new shares is not paid out to shareholders. This means that new

[13] One of the consequences of the implementation of the default condition is that the expected future dividend stream is not necessarily an equilibrium price. This is because, if investors have the option of defaulting on future payments, they should be willing to pay a premium over the sum of future expected dividends (Allen and Gale 2000). Nonetheless, we use the future expected dividend stream as a benchmark in our analysis because of its relative simplicity.

[14] At the beginning of each market period, the table displayed on subjects' computer screens that indicates the future expected dividend stream, is updated accordingly.

issues do not contribute to the future expected dividend stream and thus do not affect fundamental values.

We do not include short selling in our experimental setup. The design focuses on features that distinguish the South Sea episode from other asset markets. During the 1720 bubble, short-sellers existed, though short selling was a highly risky activity due to counterparty risk.[15] In experimental markets, short-selling tends to reduce prices. Prices are lower the larger the short selling capacity of traders is, and a sufficiently large short sale capacity pushes prices to levels below fundamental values (Haruvy and Noussair, 2006). There is no reason to suppose that the effect of introducing short-selling would be any different across our four treatments. It would have the effect of pushing prices lower, and would exert a larger effect in this direction, the larger the short sale capacity.

Investors in the market for South Sea shares differed substantially in terms of experience. Arguably, there was scope for relatively sophisticated investors to exploit less sophisticated ones, such as new entrants (Temin and Voth 2004). This was also the case for other asset markets throughout history, including those that did not see bubbles or crashes. Thus, we do not include a flow of new entrants in our design. Nevertheless, our laboratory markets, like most asset markets, are characterized by differences in trader sophistication. Traders are sampled from the student population of diverse public universities. In experimental asset markets with such populations, individuals with relatively high cognitive ability substantially outperform those with lower ability (see for example Corgnet et al., 2012, or Breaban and Noussair, 2014). In this regard, our study captures some of the investor heterogeneity during the South Sea bubble. While modern-day students are different from investors in the South Sea company, most of the available evidence suggests that the behavior of students and professionals in experimental paradigms does not differ systematically (Frechette, 2009). In our experiment, in which there are two consecutive trading horizons, we are able to gather data at two different experience levels for each cohort. As can be seen from figures 1 and 2 in the next section, the results do not differ appreciably between horizons, particularly with regard to which treatment condition generates a greater bubble.

The stakes in our experiment are much smaller than those of many investors in South Sea shares. However, most of experimental literature suggests that changing

[15] There were also difficulties enforcing the corresponding contracts in law (Neal, 2000).

the magnitude of stakes does not alter qualitative patterns in the data (Camerer and Hogarth, 1999; Carpenter, 2005; Fehr et al. 2014, Kocher et al. 2008), even if the magnitude of an effect may be sensitive to stake sizes. For this reason, if we find a treatment effect with smaller stakes, it is likely that we would find the same or larger effect with bigger stakes.

Section IV: Results

IV.A Market outcomes

Figure 2 shows transaction prices over time (top panel) as well as the difference between transaction price and fundamentals (bottom panel). The left part of the figure corresponds to the first horizon, and the right part to the second horizon. Each series represents the average over all four sessions of a given treatment. The data from markets A and B are pooled.[16]

[16] Trading prices could differ between the two markets, even though the assets exchanged in the two markets share the same fundamental value. We test for differences in median prices between the two markets. A total of 464 prices were compared (232 prices for each asset type). The differences in prices between the two markets are very small (797 vs 792, t-test = 0.099, p-value 0.92). Earlier experimental research has already shown that identical assets trading in parallel tend to have the same price (Fisher and Kelly, 2000).

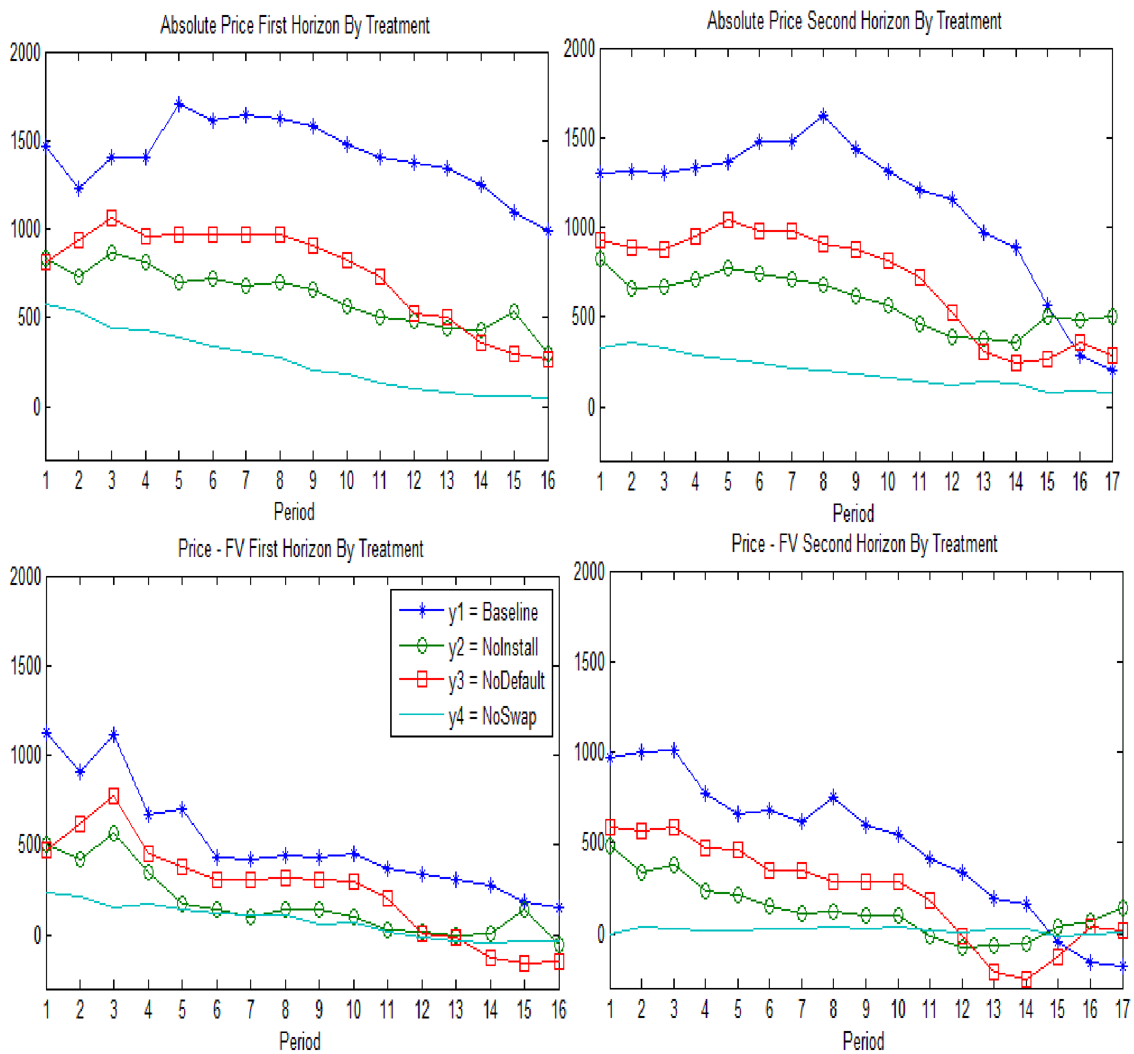


Figure 2. *Top Panel: Absolute transaction price by treatment. Bottom panel: Transaction price minus fundamental value by treatment. Left panel: First horizon. Right panel: Second horizon.*

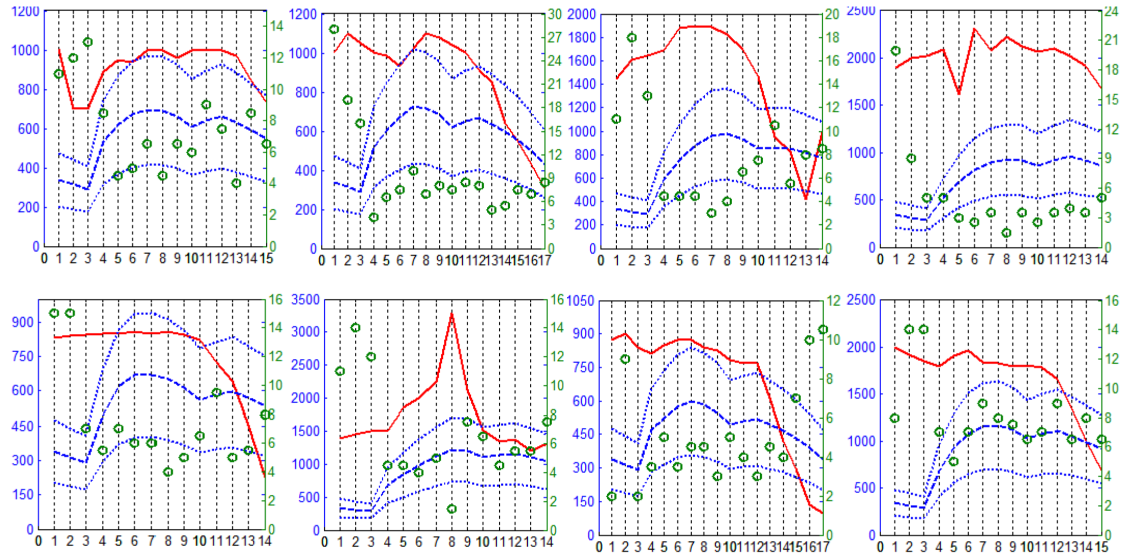
Some consistent patterns are evident in the figures.[17] In the Baseline treatment, prices deviate from fundamental values to a great extent; here, we find the highest prices among any of the treatments. This suggests that in combination, all three factors helped to create a large bubble. The second pattern is that prices are lowest and closest to fundamental values in the NoSwap treatment. Indeed, in the second horizon, prices in the NoSwap treatment closely track fundamentals. This indicates that the paying out of funds raised through new issues is the single most important factor in creating the bubbles in our experiment. This suggests that the

[17] In the absence of a swap, the fundamental value declines over time because fewer dividend payments will be made before the game terminates.

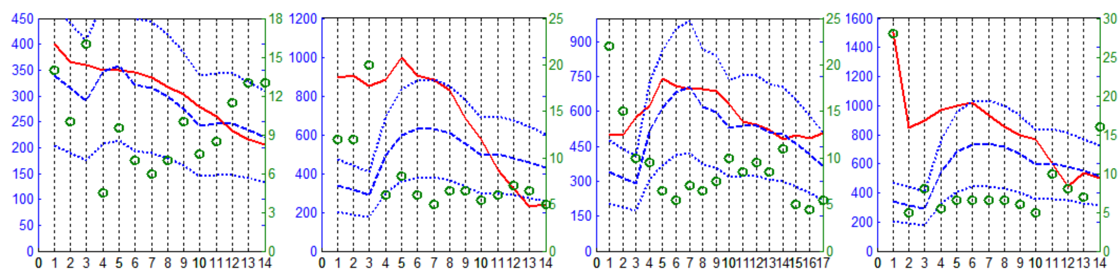
swapping of equity for government bonds – the most unique feature of the South Sea episode – was also the biggest individual driver of overvaluation.

The differences between treatments are similar in the two horizons. The Baseline treatment generates the largest bubble, followed by the NoDefault, the NoInstall, and lastly the NoSwap treatments. The differences tend to be more pronounced and of generally greater magnitude in the first trading horizon. The price dynamics, relative to fundamentals, follow a similar pattern in three of the treatments, with a price boom in early periods and steep price declines late in the session the typical dynamic. The exception is the NoSwap treatment, in which prices tend to track fundamental values closely.

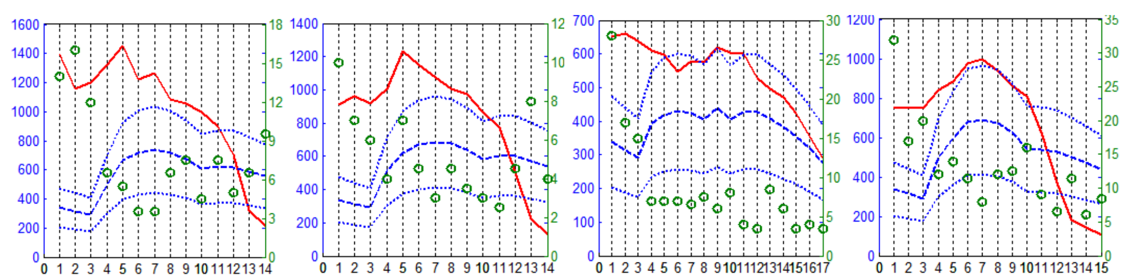
Baseline



NoInstall



NoDefault



NoSwap

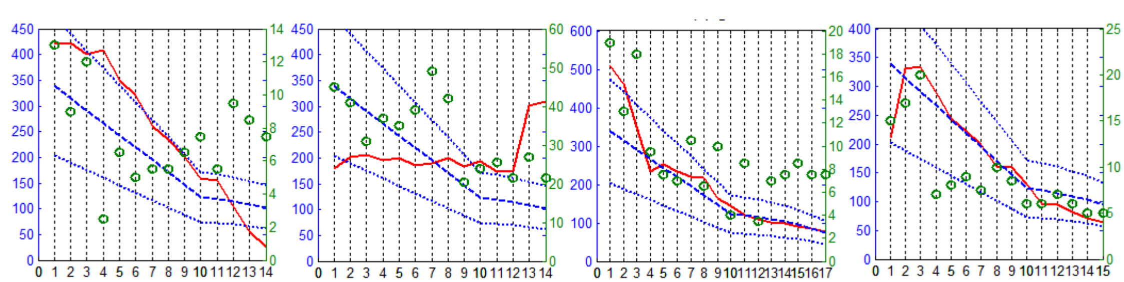


Figure 3. *Transactions prices and fundamental value for each trading session. 1) First two rows: Baseline. 2) Third row: NoInstall. 3) Fourth row: NoDefault. 4) Fifth row: NoSwap. Graph legend: Left vertical axis: Price. Right vertical axis and green circles: number of trades. Horizontal axis: trading period. Red line: Average median trading price. Bold-dotted blue line: Fundamental value. The upper blue dotted lines indicate* $1.3\ x\ FV_t$, *and the lower blue dotted line represents* $.7\ x\ FV_t$. *They serve as reference levels to visualize the extent of mispricing.*

Figure 3 shows the time series of transaction prices for the second horizon of each session, as well as the time path of fundamental values. The fundamental value increases at the time of the first issue in all treatments except for NoSwap, since swapping debt for equity redistributes some of the new funds to existing shareholders as dividends. There is considerable heterogeneity between sessions within each treatment but, broadly speaking, they follow the basic overall patterns illustrated in figure 2.

In most sessions, after several new share issues, the price begins to decline. This decline typically begins in approximately periods 6 – 8. In the four treatments other than NoSwap, prices exceed fundamentals by a considerable margin for an extended time before crashing. In some sessions, prices even fall below fundamental value at the end of the horizon. This eventual drop in prices might be triggered by the impending end of the market by period 20 as well as the ever greater supply of shares on the market. The increasing supply lowers the quantity of cash available for purchases relative to the quantity of asset available to purchase. Reductions in this ratio tend to lead to lower prices (Caginalp et al., 2001; Haruvy and Noussair, 2006).

To measure bubble magnitudes and compare them across treatments, we use the RD and RAD measures, as proposed in Stöckl et al. (2010). These are particularly well-suited for situations in which different markets in the dataset are characterized by differing numbers of periods and/or by different fundamental values, as they are in our study. This is because they normalize for average fundamental value and number of periods.

The relative absolute deviation, RAD = $\left(\sum_{t=1}^{T}\frac{|P_t - FV_t|}{\overline{FV}}\right)/T$, measures the average level of mispricing compared to the average fundamental value of the asset, where the fundamental value is taken as the expected future dividend stream. The relative deviation, RD = $\left(\sum_{t=1}^{T}\frac{P_t - FV_t}{\overline{FV}}\right)/T$ measures the extent of over or under-valuation relative to this benchmark. The values of RD and RAD observed in the second horizon of each session are indicated in table 4, along with the treatment averages.

Treatment	**Baseline**	**NoInstall**	**NoDefault**	**NoSwap**
	0.610	0.093	0.952	0.379
	0.608	0.602	0.758	0.422
	1.069	0.170	0.425	0.181
RAD	1.744	0.527	0.580	0.135
	0.511			
	0.917			
	0.627			
	0.939			
Average	0.878	0.348	0.679	0.279
Treatment	**Baseline**	**NoInstall**	**NoDefault**	**NoSwap**
	0.610	0.066	0.797	0.277
	0.568	0.410	0.533	0.049
	0.984	0.162	0.425	0.149
RD	1.744	0.483	0.291	-0.057
	0.399			
	0.917			
	0.459			
	0.904			
Average	0.823	0.280	0.512	0.105

Table 4. *RD and RAD for each session of each treatment (second horizon).*

To investigate whether these differences are statistically significant, we run four (2-tailed) Mann-Whitney U-tests to test for differences in RD and RAD between the baseline and each of the other treatments. Table 5 reports the z-scores and the resulting significance levels, for each treatment pair. The significant difference between the baseline and NoSwap treatments provides the basis for our first result.

	RAD	RD
Baseline	0.878	0.823
NoInstall	0.348	0.28
Z-Score	2.378	2.208
Significance	2%	3%
N	12	12
Baseline	0.878	0.823
NoDefault	0.679	0.512
Z-Score	0.85	1.53
Significance	40%	13%
N	12	12
Baseline	0.878	0.823
NoSwap	0.279	0.105
ZScore	2.717	2.717
Significance	< 1%	< 1%
N	12	12

Table 5. *Mann-Whitney-U-test of differences in RD and RAD between Baseline and each other treatment*

Result 1: Redistributing revenues from new issues to existing shareholders increases bubble magnitude.

Support for result 1: There is a strong and significant difference between the Baseline and NoSwap treatments in table 5; in all eight sessions of the Baseline treatment, both RD and RAD are greater than in any session of the NoSwap treatment. The hypothesis that RD is equal in the two treatments, as well as the analogous hypothesis for RAD, is rejected at $p < .01$ ($z = 2.717$).

Figures 2 and 3 also indicate that prices are considerably lower in NoInstall than in the Baseline treatment. Result 2 is that the difference is significant, and indicates that paying in installments does increase prices and bubble magnitude.

Result 2: Payment for new shares in installments increases prices and bubble magnitude.

Support for result 2: In seven of the eight sessions of the Baseline treatment, both RAD is greater than in any session of the NoInstall treatment. The same is true for six of the eight Baseline sessions for RD. Mann-Whitney tests indicate that the Baseline treatment has higher RAD ($z = 2.378$, $p < 2\%$) and RD ($z = 2.208$, $p < 3\%$) than the NoInstall treatment.

Finally, the possibility of defaulting on debt if the life of the asset ends does not have a significant effect on both bubble measures.

Result 3: The ability to default on debts owed does not increase bubble magnitude.

Support for result 3: When the Baseline treatment is compared with NoDefault, there is no significant difference in RD ($z = 1.53$, $p = 13\%$) or in RAD ($z = 0.85$, $p = 40\%$).

In addition to comparing average prices, we can study the likelihood that a bubble forms. In the literature, there is no consensus of what constitutes a bubble. For the purposes of our experiment, we define a bubble as five consecutive periods during which the asset price remains more than a certain percentage above its fundamental value. In table 6 we report the number of sessions with a bubble for threshold values of 30%, 40%, and 50% of fundamentals.

%	Baseline	NoInstall	NoDefault	NoSwap
30%	8	2	4	2
40%	7	2	4	1
50%	7	1	2	0
N	8	4	4	4

Table 6. *Number of sessions with a bubble in each treatment, for different cut-off values*

Table 6 shows that the Baseline and NoDefault treatments produce bubbles in all sessions if the 30% criterion is used, and in at least half of all sessions under the 50% criterion. NoInstall and NoSwap always generate fewer bubbles, independently of the cut-off used. Under the 50% criterion, the difference is particularly marked, with 7 sessions in the baseline showing bubbles – but only 1/2 in the NoInstall/NoDefault treatments. NoSwap generates no bubbles at all under the 50% criterion.[18]

[18] Bubbles arise readily in the laboratory under some conditions but not others. The likelihood that a bubble forms is influenced by the fundamental time path (see Noussair et al., 2001; Noussair and Powell, 2010; Kirchler et al. 2012, Giusti et al. 2014), the particular experience subjects have in similar settings (Smith et al., 1988; Hussam et al. 2008; Dufwenberg et al. 2005), and initial

IV.B Individual Behavior

In this section we explore how the institutional factors highlighted earlier interact with individual trading strategies. We employ the profile of trader types first proposed by Delong et al. (1990), and applied to experimental data by Haruvy and Noussair (2006) and Haruvy et al. (2014).

In this structure, there are three types of trader. (1) *Fundamental Value Traders* use the fundamental value as a limit price. They increase (decrease) share holdings when the current price is below (above) fundamental value. (2) *Momentum Traders* increase (decrease) share holdings in response to an upward (downward) price trend in the recent past. (3) *Rational Speculators* correctly anticipate the next period's price movement. If the price move is upward (downward), they increase (decrease) current holdings of shares.

First, we classify an individual's behavior as follows. Let p_t be the average price in period t, f_t be the fundamental value in period t, and s_{it} denote the number of units of asset that individual i holds in period t. Then we define a Fundamental Value Trader type in period t as someone who in period t meets one of two conditions: (1) if $p_t > f_t$, then $s_{it} < s_{i,t-1}$, or (2) if $p_t < f_t$, then $s_{it} > s_{i,t-1}$. That is, the fundamental value trader purchases more shares than she sells in period t if the price is below fundamentals, or sells more than she buys if the price is above fundamentals. A market populated predominantly with such types will tend to have prices that broadly track fundamental values.

We classify behavior as consistent with the Momentum Trader type if it is consistent with either condition (3) or (4). Condition (3) is that if $p_{t-1} < p_{t-2}$, then $s_{it} < s_{i,,t-1,}$ and (4) holds that if $p_{t-1} > p_{t-2}$, then $s_{it} > s_{i,t-1}$. The momentum trader accumulates units in period t if the price increased between t – 2 and t - 1, or she sells units if there has been a price decline. This type of trader generally does not contribute to pricing close to fundamentals. Instead, it enhances the continuation of earlier trends, which can aid in inflating a bubble once it has begun.

A trader's behaviour is consistent with the Rational Speculator type if her behaviour in period t satisfies one of the following conditions: (5) if $p_{t+1} < p_t$, then $s_{it} < s_{i,t-1}$, or (6) if $p_{t+1} > p_t$, then $s_{it} > s_{i,t-1}$. This type of agent anticipates the price in the next period in an unbiased manner. She makes positive net purchases if the price

cash/asset ratios (Caginalp et al 1998). In our environment, bubbles do not occur unless swapping is included.

is about to increase between the current and the next period. She makes net sales if the price is about to decrease. These traders anticipate future trends and can initiate and sustain bubbles. When they expect prices to increase, they demand more shares, and thus their prediction becomes self-fulfilling.

We first assess each person's trading record in each period t, using the prices from periods t – 2 and t + 1 and the change in her holdings of asset, s_{it} - $s_{i,t-1}$. We then classify her by the trading style that applies for greatest number of periods. If there is a tie between two types, we classify the trader as belonging to each type with proportion 0.5, and if there is a tie between all three types, she is assigned to each type with proportion 0.33.

As a measure of how much influence an individual exerts, we use two variables. The first is a measure called Market Influence. The *Market Influence* of subject *i* in period *t* is defined as:

$$MI_{i,t} = P_t * s_{it} + c_{it}$$

Where s_{it} and c_{it} indicate shares and cash owned by subject i in period t, respectively while P_t indicates the median transaction price for period t. The second measure of an individual's impact on the market that we use is simply the share of the total outstanding shares that the individual holds, s_{it}/s_t.[19]

Table 7 shows the distribution of types in the different treatments. Overall, there are no large differences between treatments. This suggests that there is some consistency in the percentage of individuals that fit best into each of the three types.

	Baseline	NoInstall	NoDefault	NoSwap
Momentum	0.4	0.4	0.4	0.4
Fundamental value	0.3	0.4	0.3	0.5
Rational speculator	0.2	0.2	0.2	0.1

Table 7: *Percentage of traders by type and treatment*

[19] Haruvy and Noussair (2006) and Haruvy et al. (2013) use another measure of an individual's weight in the market, which they call *Market Power*. This is a weighted average of the percentage of the total cash, and the total stock of asset, in the market that an individual holds. The results reported in this section concerning Market Influence are very similar if Market Power is used instead as a measure of an individual's weight in the market. The Market Influence measure is an index of the current market value of a trader's position.

The market influence of traders of each type in each treatment is shown in figure 4. It reveals that the NoSwap treatment is the only one characterized by Fundamental Value traders with more market influence on average than the other two types at all times during the trading horizon.[20] In each of the other treatments, Momentum traders have more market influence than the other two types for most of the trading session. In the Baseline treatment, momentum traders are dominant. NoDefault is similar in that momentum traders have the most influence throughout the trading session. In NoInstall, momentum traders have the most influence for most of the session, but fundamental value traders surpass them at the end. Speculators have similar market influence in all of the treatments, except for NoSwap, where they have less.

[20] Periods 15, 16, and 17 contain data from only one session per each treatment, because only one of the randomly-generated termination sequences lasted that long. This accounts for the abrupt changes in period 15 in some of the panels of figure 3.

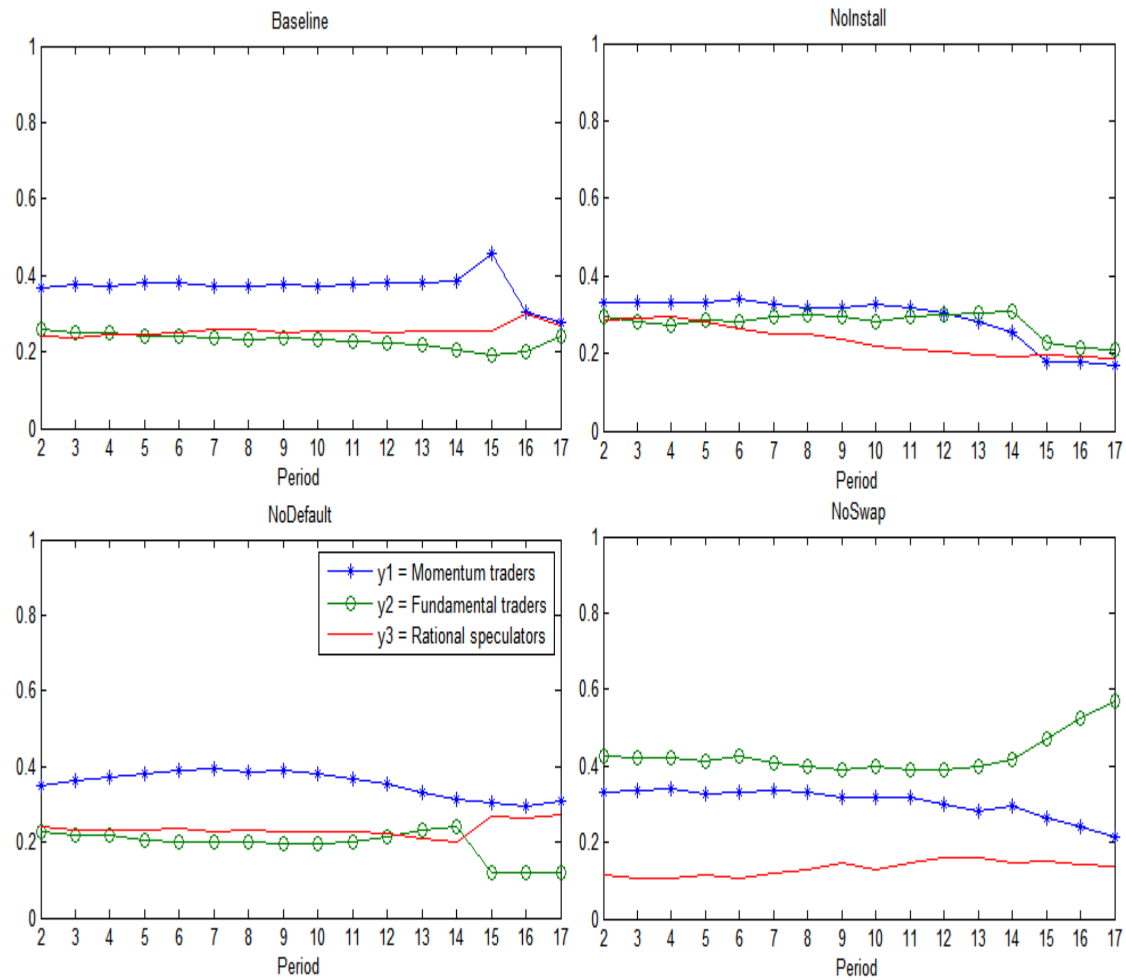


Figure 4. *The market influence for an individual of each trader type, averaged over all sessions of a treatment.*

Table 8 illustrates how the total number of units, as well as the market influence of each type, depends on the asset's return in the preceding period. The asset's return is defined as:

$$\text{Return (t)} = \frac{P_t - P_{t-1} + d_{t-1}}{P_{t-1}}$$

The second independent variable is the order of the new issue. This order variable is equal to the number of issues that have occurred up to and including the current period. In the first two columns, the market influence and total number of shares held by rational speculators are the dependent variables. In the last four columns, the analogous variables for fundamental value and momentum traders are the dependent variables.

	Rational Speculators		Fundamental Value Traders		Momentum Traders	
	1. Market Influence	2. Number of Shares Owned	3. Market Influence	4. Number of Shares Owned	5. Market Influence	6. Number of Shares Owned
Return	0.142**	11.369**	-0.245**	-11.710**	0.108**	3.746
	(0.056)	(5.776)	(0.074)	(5.088)	(0.056)	(5.675)
Order	0.005	0.901**	-0.007	-0.770*	0.001	1.222**
	(0.003)	(0.270)	(0.007)	(0.242)	(0.003)	(0.270)
Constant	0.186**	11.690**	0.348**	11.770**	0.330**	19.990**
	(0.016)	(1.690)	(0.348)	(1.490)	(0.016)	(1.670)
Observations	182					

OLS estimates, Standard errors in parentheses; ** p<0.05, * p<0.1

Table 8*. Estimation of Market Influence and Quantity of Shares Held of Speculators, Momentum and Fundamental Value Types as a Function of Return and Number of Share Issues.*

The estimates reveal several interesting patterns. High returns in the previous period attract purchases from rational speculators and momentum traders; they induce sales by fundamental value traders. These purchases increase the market influence of momentum traders and speculators and decrease those of fundamental value types. Low returns have the opposite effect, and induce the rational speculators to sell to fundamental value traders. The results for market influence imply that rational speculators on the whole are right in their prediction that past returns during our bubble experiment predict future returns. Fundamental traders, on the other hand, lose out – their influence decreases as they "lean against the bubble" when prices exceed fundamentals. Furthermore, as more new issues come to the market at prices greater than fundamentals, fundamental value traders hold fewer units and exercise less market influence. This is because they are less likely than the other types to purchase the newly-issued shares.

Does looking at individual-level trading behavior in the early periods of the markets shed light on the origins of the South Sea bubble? The data in table 7 and 8 are consistent with the following account of how new issues lead to a bubble. The debt-for-equity swap/new issuance of shares raises the fundamental value of shares (at the expense of new purchasers). This increases the price Fundamental Value Traders are willing to pay. Momentum traders, who are the modal type of agent in the markets, increase their asset demand when observing the resulting increase in price – whether justified or not. This combination tends to create and enhance bubbles. Speculators correctly anticipate this behavior of Momentum traders (and in the case of new issuance, Fundamental Value traders). They attempt to buy in advance of these investors, during the early stages of the price boom. Hence, the Baseline treatment offers a 'perfect storm' for creating bubbles because each group of trader is bidding up the price. After prices have risen above fundamentals, the Fundamental Value traders sell their holdings to the other two types. The resulting market, dominated by irrational momentum traders and speculators, then exhibits high prices. The debt swap is critical, according to our experimental evidence. It starts off this whole process by providing the initial boost to the fundamental value, and creating the expectation of future increases.

The new issues serve to lower the market influence of fundamental value traders. The new shares are sold at prices above fundamentals, so that they are purchased by momentum traders and speculators. They also raise returns, further drawing in momentum traders and rational speculators; exacerbating the breakdown in the link between prices and intrinsic value. When the supply of units becomes excessively large, and the end of the life of the asset comes into view, prices drop, with the speculators selling to momentum traders before the downturn. Under NoSwap, in which new issues have no effect on fundamental value, the risk of a bubble is markedly smaller and fundamental value traders come to dominate the market.

V. Discussion and Conclusion

The South Sea bubble and crash was one of the most famous episodes in financial history. Historians have proposed many explanations for the extreme run-up in prices in London in the year 1720. While some authors have emphasized corruption in the awarding of the debt swap contract, others point to misleading information issued by the company about its prospects in the New World, and contagion from a concurrent bubble in Paris (Dale 2004; Carswell 1960). In this paper, we seek to isolate the influence of particular institutional features of the South Sea bubble. We analyse if these promote bubble formation in laboratory experiments. This allows us to examine the impact of each aspect individually and in combination, offering insight into the constellation of market features that led to the extreme asset price movement during the South Sea episode.

Our results suggest that several historical features can contribute to the formation of large bubbles. At its core, the South Sea bubble was a debt-for-equity swap: the company undertook to exchange government debt for its own shares (with the support of the UK government). At its peak, the South Sea company held 23% of Britain's entire stock of public debt. The key manner in which this changed incentives for shareholders is that with each issue of fresh shares, more interest payments would accrue to shareholders. In our NoSwap treatment, in which these payments did not occur, we observe no bubble. When no swapping of debt was possible, the other features that could enhance the formation of bubbles, such as the risk shifting resulting from delayed payments for new shares, or the chance to default on these payments, did not generate a bubble. Of course, our results do not imply that swapping shares for government debt will necessarily lead to or contribute to the bubble; but they do suggest that they create the potential for major bubbles.

In our experiments, we classify investors according to their predominant behavior into momentum traders, rational speculators, and fundamental-driven investors. Crucially, the swapping of equity for debt raised the fundamental value of shares. This meant that new subscriptions of shares raised the expected value of future dividends, and thus justified an increase in prices. An increasing price in turn attracted momentum investors and speculators. Because these buy in parallel with the fundamental investors, prices increase and can exceed fundamentals for some time. The increase in fundamentals induced by particular contractual features of the 1720 debt swap is therefore crucial for generating the rapid rise in prices. In particular, the fact that the South Sea Company did not fix the "exchange rate" between stock and debt ex ante allowed it to buy out bond holders ever more cheaply (in terms of stock) as long as the stock price kept increasing. Interestingly, a fixed exchange rate was present in 1719, when the South Sea Company swapped its shares for so-called "lottery tickets", another kind of government debt (Carswell 1960). At that time, there was also no explosion in share prices.

When there was swapping and new issuance took place, the ability to delay payment on newly-issued shares further increased the likelihood and magnitude of bubbles. The possibility of leverage raised the return to speculation in treatments with swapping because the swapping induced an increasing trend in prices. Without the establishment of an initial increasing price trend, higher leverage would not enhance the returns to speculation.

One possible objection to our findings is that subjects in our experiment may simply be confused, contributing to the formation of bubbles. Some experimental papers using a declining fundamental value show that subjects can have difficulty understanding the dividend process – especially if only limited instructions are provided (Lei et al. 2001; Kirchler et al. 2012). However, this finding is not robust to changes in experimental procedures and can be eliminated with appropriate instructions or framing; it also does not appear when the fundamental value is stable (Kirchler et al, 2012). In our study, we carefully explained the fundamental value process and administered a quiz to participants that was designed to reduce misunderstanding. Of course, we cannot rule out some residual subject confusion. Indeed, we believe that possible misperceptions of the nature of the future dividend stream may well have been present during the South Sea episode, especially amongst inexperienced investors. We believe it is entirely possible that some of the debt swap's potent influence on bubble formation arises from increasing confusion amongst participants – today and in 1720.

A large literature has argued that bubbles are caused by initially fundamental-driven, rational increases in share prices that become exaggerated through feedback loops in the market (Shiller, 2000) – such as in the case of electrification, the automobile, and aviation in the 1920s, or the internet in the 1990s. Our evidence about the importance of the debt-equity swap, which boosted the intrinsic value of South Sea stock, appears to be in line with this interpretation. Note also that the laboratory findings coincide precisely with Charles Kindleberger's (1987) classic definition of the origins of a bubble:

> "A bubble may be defined loosely as a sharp rise in price of an asset …, with the initial rise generating expectations of further rises and attracting new buyers—generally speculators interested in profits from trading rather than in its use or earning capacity."

Our experimental evidence lends support to classes of bubble models emphasizing investor heterogeneity. For example, in Hong et al. (2006), investors receive different signals about the fundamentals of an asset. Bubbles can form because the resale (option) value to the other group induces even those who are pessimistic about fundamentals to buy. This is similar to the interaction between fundamental-driven investors, rational speculators, and momentum traders in our experiment, which requires an increase in fundamental value, resulting from the debt-equity swap, to ignite a major speculative frenzy.

Overall, our results demonstrate the potential of combining experimental economics with financial history. Instead of using experiments to implement broad 'metaphors' of asset markets in general, we focus on isolating institutional features during key periods of financial market development. By replicating crucial aspects of past trading conditions in the laboratory, we can shed new light on key episodes in financial history. While many intuitive interpretations of boom-and-bust episodes in the past have been proposed (Reinhart and Rogoff 2000), archival data and detailed examinations of the specifics of each case may not be enough to pin down the main drivers of mispricing. Our methodology – while necessarily restrictive – offers the potential to shed new light on the key factors behind turning points in asset markets.

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Online Appendix

Baseline treatment instruction.

You are taking part in an experiment on decision making. The instructions are simple and if you follow them carefully and make good decisions, you can earn some money, which will be paid to you at the end of the experiment.

The experiment consists of a sequence of trading periods, each one lasting 150 seconds. During each period, you will have the opportunity to buy and sell units of two assets of an imaginary Company named "Blue River" in a market. The first asset is called **"Share A"** while the second is called **"Share B"**. During the instructions we will explain differences between them. The currency used in this experiment is called *ducats*, which will be converted into Euros at the end of the experiment at an exchange rate of xx DUCATS for 1 Euro. You will have to participate in two separate markets. At the end of the experiment one market is randomly selected and your payment will correspond to this selection.

1. How to buy and sell shares

We will first explain how the market works, and then you will have time to practice trading. If anything is unclear at any time, you can raise your hand and ask the experimenter any question you may have.

This is the trading screen you will use during the experiment.
You start the experiment with a quantity of money called "*DUCATS*" and a number of shares "A". You will not start with any share "B".

We will explain how trade occurs in the market for "Share A", which occurs exactly in the same way as for "Share B".

The top left corner shows the current trading period, and the top right corner shows how much time (in seconds) is left in the current period. Your ducat balance is shown in the middle of the screen. Using this screen, you can buy or sell shares in **four** ways.

First, you can initiate a sale of shares by submitting an offer to sell.

If you have shares, you may choose to sell them. You can initiate a sale in the text area below "Enter offer to sell" in the first column. Here you can enter the price at which you are offering to sell a share. To send the offer, you have to click the "Submit offer to sell" button. After that, your offer to sell will appear in the second column labelled "Offers to sell". Each offer introduced corresponds to **one single** share. If you want to sell more shares, repeat this process.

Note that by submitting an offer to sell, you initiate a sale, but the sale will not be executed until someone accepts it.

Try offering to sell a share now. Enter a number in the text area labelled "Enter offer to sell" in the market for "Shares A" and then click on the button "Submit offer to sell". You can see that a set of numbers will appear in the column labelled "Offers to sell". Each number corresponds to an offer from one of the participants. Your own offers are shown in blue; others' offers are shown in black. The offers to sell are ranked from high to low, so that the **cheapest (best)** price is displayed at the **bottom** of the list.

Second, you can buy shares by accepting an offer to sell.

If you have enough *ducats*, you can buy a share at one of the prices in the "Offers to sell" column (which also contains your previously submitted offer to sell). You buy a share by selecting one of the others' offers (shown in black) and then clicking on the red button "Buy". Note that you are not allowed to accept your own offers, which are shown in blue. Remember that the **cheapest (best)** price is displayed at the **bottom** of the list.

It may happen that when you select the best price and press the "Buy" button, someone else is doing the same thing but acting faster than you. In that case, a message "someone has been faster than you" or "you have to select a price" will appear.

Try buying a share now. Choose a price in the "Offer to sell" column and then click on the "Buy" button, or click directly on the "Buy" button and buy at the cheapest price listed in the "Offers to sell" column.

Whenever an offer is accepted, a trade occurs. When you **accept** an offer to sell, you realize a purchase and the number of *ducats* in your ducat balance goes down by the transaction price; at the same time, your trading partner makes a sale and his/her ducat balance increases by the trading price. In contrast, when your offer to sell **is accepted**, you make a sale, your trading partner makes a purchase, and an amount of money is transferred from your trading partner to you that is equal to the amount of the trading price.

Because you have each submitted one offer to sell and accepted one offer to sell, you have all realized one purchase and one sale so that you have the same number of shares as you started out with.

Third, you can initiate a purchase of a share by submitting an offer to buy.

If you have *ducats* and would like to buy a share, you can initiate the purchase by submitting an offer to buy. Enter a number in the text box under “Enter offer to buy” situated on the right side of the screen and then click on the “Submit offer to buy” button.

Try submitting an offer to buy a share now. Enter a number in the text area “Enter offer to buy” in the market for “Shares A” Then press the red button labelled “Submit offer to buy”. Immediately, in the column labelled “Offers to buy”, you will see a list of numbers ranked from low to high, so that the **highest (best)** price is displayed at the **bottom** of the list. If you want to sell more shares, repeat this process. Again, your own offers are shown in blue; others’ offers are shown in black.

Fourth, you can sell a share by accepting an offer to buy.

You can sell a share at one of the prices offered in the “Offers to buy” column (which also contains your previously submitted offer to buy). Select one of the offers and then click on the red button “Sell”. Again, note you are not allowed to accept your own offers (shown in blue). Remember that the **highest (best)** price is displayed at the **bottom** of the list.

Try selling a share now. Choose a price in the column “Offer to buy” and then click on the “Sell” button.

A transaction occurs whenever an offer to buy is accepted. If you accept an offer to buy posted by another person, you make a sale and as a result, the amount of *ducats* you have increases by the trading price. In contrast, when your offer to buy is accepted by someone else, you realize a purchase and the number of *ducats* you have decreases by the trading price. The opposite happens to your trading partner.

You can see that these four trading methods are complementary: you can **initiate** a trade by **offering** a price to sell or buy and wait for the offer to be accepted by others; you can **execute** a trade by **accepting** an offer to buy or sell submitted by another participant.

In the column situated in the middle of the screen and labelled "**Trading price**", you can see the prices at which shares have been traded during the trading period by all participants playing in the market.

2. Information display at the end of each period

At the end of each trading period a screen appears that summarizes your situation.

"End-of- period screen"

In this screen you have the following information:

A) Period: This is the trading period just finished.

B) SHARE A: The number of shares of type "A" you own at the end of this period.

C) SHARE B: The number of shares of type "B" you own at the end of this period.

D) DUCATS before dividends (dividends will be explained later): This is the money you have before you receive the current period's dividend payment.

E) Random dividend per share: As explained later, each share you own may pay a dividend at the end of each trading period. The random dividend per share is the amount in *ducats* you get in this trading period for each share you own.

F) Dividend generated from last issue: Share issues, in which the experimenter makes new B shares available, will be described later in the instructions. Each time that new shares are issued on the market, the dividend you receive on both shares A and B increases. This *dividend generated from last issue* is the increase in dividend that results, **from the last issue of shares only**. If no shares are issued it is equal to 0.

G) Accumulated dividend from all new issues: As will be explained later, during the experiment new shares may be issued. Each time that new shares arrive on the market, if you decide to buy them, the amount of dividend you receive on the shares that you own increases. The Accumulated dividend from all new issues is the total of all dividends derived from all new issues of shares.

H) Total dividend per share: This is the sum of E + G.

I) Total dividend x total share: This is the total dividend per share [H] **times** the number of shares (shares A + shares B) you own since each share "A" and "B" receives the same dividend per period.

L) Ducats after all dividends: This is the sum of total dividend x total shares plus your Ducats before dividend. (D + I).

M) Debt: This will be explained later.

3. Random Dividend

For each share you own of both type of shares "A" and "B" you receive a dividend at the end of each trading period. A random device determines the dividend you get for the period for each share you own.

The amount and the chance of each possible dividend are the following:

25% chance you get 0 *ducats* per share you own
25% chance you get 8 *ducats* per share you own
25% chance you get 28 *ducats* per share you own
25% chance you get 60 *ducats* per share you own

Each participant gets the same dividend per share at the end of the period. The average dividend in a period is equal to 24 *ducats*. This is calculated as following: (0 + 8 + 28 + 60)/4=24. The dividends that were drawn in earlier periods do not influence the chance of getting a given dividend this period; in other words, if dividends were high in earlier periods, it doesn't mean that they are more or less likely to be high or low this period than if previous dividends had been low.

4. How long the market lasts

The market lasts for a minimum of 10 and a maximum of 20 trading periods, each period lasting 150 seconds. In each of the periods between 10 and 20 the experiment could end. Whether it ends or not is determined with a random device. Beginning in period 10, at the end of every period there is:

an 83% chance that the market continues to the next period, and
a 17% chance that the market ends immediately.

This means that dividends from period 10 onward are not guaranteed because the market might end.

5. Your average holding value table

Your "Average holding value" table indicates the total of the dividends you would get on average if you held a share from any period until the market ends, <u>if there are no new shares issued (</u>i.e. subscribed) you can use this table to help you make decisions.

Average holding value table

1 Current period	2 Average random dividend per share **this period**	3 Average **Remaining** Dividends per share	4 Chance next period occurs
1	24	339	100%
2	24	315	100%
3	24	291	100%
4	24	267	100%
5	24	243	100%
6	24	219	100%
7	24	195	100%
8	24	171	100%
9	24	147	100%
10	24	123	83%
11	24	119	83%
12	24	115	83%
13	24	109	83%
14	24	103	83%
15	24	95	83%
16	24	86	83%
17	24	74	83%
18	24	60	83%
19	**24**	**44**	**83%**
20	24	24	0

The columns in the table refer to the following:

Current period: The period corresponding to the number in the row. For instance for period 2 you would receive on average total future dividends of 315 for each share you held until the end of the market in **case there are NO issues of new shares**.

Average random dividend per share this period: The average amount of dividend per period for each share you own. This is equal to 24 in each period as explained above.

Average remaining dividends per share: The average amount of total dividend you will receive for each share that you own from now until the end of the experiment. It is the average amount of dividend (24 *ducats*) multiplied by the average remaining number of periods. From period 11 on, there is an 83% chance that the market will continue for another period. The calculation of the average remaining dividends takes this into account. For instance if you are currently in period 5, the average expected dividend you would get from owning one share until the end of the experiment is 243.

Chance next period occurs: The probability that the following period exists.

6. Issues of type "B" Shares

Beginning in period 3 you might have the opportunity to buy additional shares of type "B" from the experimenter. Type B shares pay the same dividends as type A shares and can be bought and sold in the same way as A shares. B shares are issued in some rounds for a price determined in an auction, which is described below. However, you will not be informed in advance about the total number of times or in which periods B shares will be issued.

If an issuing round takes place (i.e. a screen like this appears), you have to participate to an auction.

Screen 3. Auction

You can make bids on up to 2 B shares.

You must bid on two shares. If you do not want to buy a share, you can type in a bid of 0 in both spaces. If you are sure that you don't want to buy any more than 1 unit, you can type 0 in the box labeled "Bid 2" and enter the bid for the one unit you are interested in bidding for in the box labeled "Bid 1"

Once you and the other participants have submitted their bids, by clicking on the "submit bids" button, a new screen appears. It looks like the one shown below

On this screen you can see the accepted bids from all participants in the market, ranked in order of how large they are. The people who sent in these accepted bids receive a unit for each bid they have accepted. If you have one bid on the list, you get 1 unit, and if you have 2 bids on the list you get two units.
The last price on this list, which is the lowest accepted bid, is the amount of Ducats that you will have to pay for each of your bids on the list.

On the right corner of the screen you can see whether you purchased one or two newly issued shares B, and the price you pay for each share.

If you purchase newly issued shares "B", the experimenter **lends you some of the money to buy them.** This means that you do not have to have enough ducats on hand at the moment to buy the shares, because you pay most of what you owe for the shares later on.

In the period where you buy the newly-issued B shares from the experimenter, you pay 20% of the auction price. The remaining 80% are debt that you owe to the experimenter. In each of the following 4 periods, 20% of the price will be subtracted from your ducat balance. Your debt is therefore paid off over 5 periods. The amount of debt that you have at any time will be reported on your "After period screen" after each period in the field labeled DEBT.

If the market ends before you pay back your debt, you do not have to pay back your remaining debt.

For example. Suppose that there are two issues of shares "B", one in period 4 and one in period 12. Suppose that the game ends after period 13, and that the issued price of each share was of 300. You purchased one B share in period 4 and one in period 12.
In period 8, you will have fully repaid your debt on the first share (20% in period 4 and 20% in each of the following four periods).
In period 13, when the market ends, you will have paid back 120 ducats on the share you purchased in period 12. The 120 is equals to 20% of the 300 plus the 20% of the 300 of period 12 and 13 respectively. **If the market ends and you still owe debt (as it is the case in this hypothetical example), you do not have to repay it.**

Notice that after the unit has been purchased in the auction, <u>A and B</u> <u>shares are the same from the point of view of any new buyer</u>. The two types of share pay the same dividends in each period, and the two types of shares will continue to exist until the game ends. Because the two types of share are the same, an individual can make a profit if she can sell one at a higher price and buy the other at a lower price. This is because the asset she bought and the asset she sold will always pay the same dividends and she has more cash than he did before. For example, suppose that you sell an A share at 300 Ducats and you purchase a B share at 200 Ducats five seconds later. You then have the same number of shares as before, but have 100 Ducats more than before, so you have made a profit of 100 Ducats.

8. Increasing in the amount of dividend received.

The number of issues is unknown. Each time that you subscribe to new shares B, "Blue River Company" is using the collected money to buy investment certificates in a secondary market. The higher the price at which Blue River shares are issued, and the more buyers there are for these new shares, the more of these investment certificates can be bought. The dividends from these certificates will be added to the ones paid out by Blue River on share A and B.

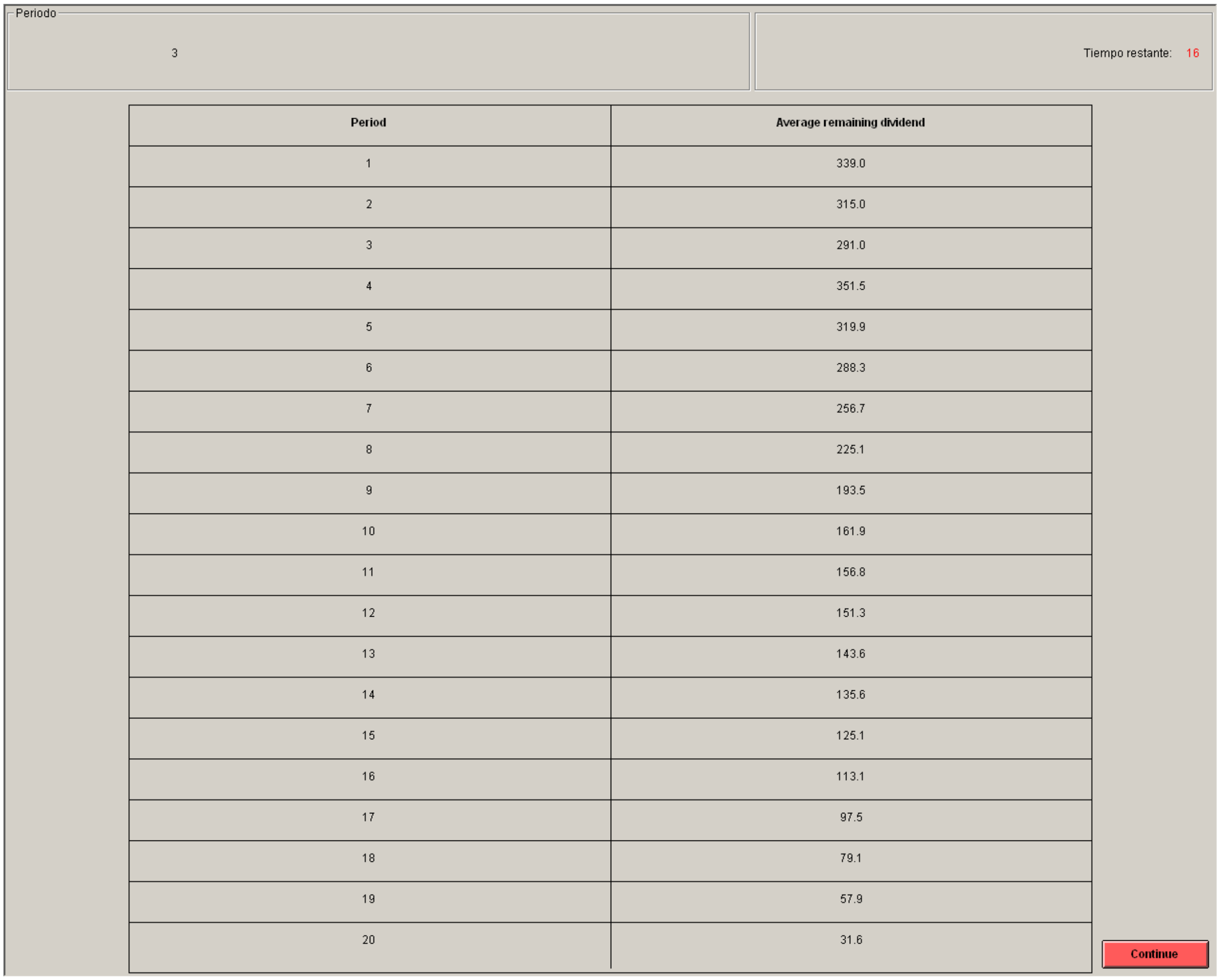
For example: suppose that in period 10 the Company offers the possibility of buying new shares B. Therefore you participate in an auction. Imagine that the result of the auction is that the price for one share B is 320 ducats each. If all of you in total have bought 8 shares, Blue River will gather 2560 ducats (320 *8).
With this money the Company buys 25.6 certificates (2560 ducats/100). Each certificate pays a dividend of 15 ducats. Therefore a total of 384 ducats will be divided for the total number of shares outstanding in the market and paid to each of you as dividends after each market.
This means that if in the market there is a total of 30 shares (22 initials and 8 new issued), you receive additionally to the random dividend (explained in the instructions) a new increment of 12.8 ducats for each share you own (384/30).
This means that the value of owning both A and B shares increases as the total number of B shares in the market increases.

If B shares are issued, the numbers "Average remaining dividend per share" column will change. For example, after a single issuing round of shares "B", in period 4, for a price of 320 ducats (the same example as above), the "Average remaining dividend per share" column of the row 4 will change from 267 ducats to 351 ducats. The entire column will change automatically, and the average remaining dividends will be increased again each time new shares are bought.

A table called "Average remaining dividends per share" will be displayed at the end of each period. This table is the current updated version of the "Average holding value table" described earlier and should be read exactly in the same way. You might want to use the information in the table to see how "Average remaining dividends" are updated after each issuing round.
In the screenshot shown here you can see how "average remaining dividends per share" has been affected after a single share issue and compare it with the "Average holding value table" above. In the example reported below, at the end of period 3 there was an issue of shares and all values in the "Average remaining

dividends" column for future periods increased substantially compared to the original "Average holding table"

Updated "Average holding value table"



Periodo

3

Tiempo restante: 16

Period	Average remaining dividend
1	339.0
2	315.0
3	291.0
4	351.5
5	319.9
6	288.3
7	256.7
8	225.1
9	193.5
10	161.9
11	156.8
12	151.3
13	143.6
14	135.6
15	125.1
16	113.1
17	97.5
18	79.1
19	57.9
20	31.6

Continue