# The boats that did not sail

# Evidence on the sources of asset price volatility from an 18th century natural experiment[1]

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**WORK IN PROGRESS**

## Abstract

How much of the short run volatility of asset prices is due to the arrival of news? And how much can be accounted for by factors unrelated to the arrival of new information such as trading frictions, changing preferences for risk, behavioral factors and asymmetric information? Because news arrival is difficult to measure, this question is difficult to answer with modern day data. I use a natural experiment provided by financial history to address the question. During the 18th century a number of British stocks were traded on the Amsterdam exchange and all relevant price information from England reached Amsterdam through the use of mail packet boats. I can precisely identify the arrival of boats, and thus the flow of information. I use this to measure the influence of news on the volatility of the British stocks traded in Amsterdam. Results show that the variance of stock prices after the arrival of news was significantly higher than in the absence of news. Nonetheless, price movements in the absence of news were considerable. They amounted to between a third and half of the volatility observed during periods with news. This suggests an important role for factors not related to news in the day to day movement of asset prices.

## 1 Introduction

How much of the short run volatility of asset prices is due to news on the fundamental value of an asset and how much can be accounted for by the trading process itself? According to Fama's (1970) formulation of the efficient market hypothesis, price movements should reflect the arrival of news only. Shiller (1981) was one of the first to argue that asset prices are too volatile relative to the volatility of the underlying value of the asset. Trading frictions, changing preferences for risk, behavioral factors and asymmetric information are all unrelated to the arrival of news but could still explain an important part of volatility.

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A number of papers try to determine the relative importance of news and trading for asset price movements, but so far no general consensus has emerged. Some papers construct proxies that measure the intensity of news directly (eg Mitchell and Mulherin 1994). These proxies only explain a small fraction of volatility. It has been suggested that this is not due to the irrelevance of news but to measurement problems (Boudoukh et al. 2007). Other papers, most notably French and Roll (1986), compare asset price volatility for periods with and without trade. These papers show that volatility in the presence of trading is significantly higher than when trade is restricted. Is has been argued however that trading and information flow usually occur at similar moments in time, making it difficult to identify their independent contributions. In addition, the flow of information itself is not exogenous and may respond to the trading process, further complicating identification (Fleming, Kirby and Ostdiek 2006).

The Amsterdam equity market of the 18th century offers a unique natural experiment to circumvent these problems. In Amsterdam an active trade existed in the shares of a number of English companies (the East India Company, the Bank of England, and the South Sea Company). It can be expected that normally all relevant information on the fundamental value of these shares originated from London. Not only did the most relevant developments take place there, the main market for the stocks was also in London, generating highly relevant price data Dutch investors could use (Neal 1990). The news from London reached Amsterdam investors through a mail packet boat service, operated by sailing boats equipped for this purpose. The boats were scheduled to leave every Wednesday and Saturday, but because of the weather conditions on the North Sea these sailing boats were often delayed or not able to sail at all. As a consequence the Amsterdam market could be starved from information for a number of days in a row which could last to up to two weeks. Trading in the English shares continued however and prices kept fluctuating, even in the absence of news. This provides the perfect environment to test the influence of news and the trading process itself on short run volatility of stock prices.

This approach, which is only feasible in a historical setting with serious constraints on the communication technology, goes a long way to solve the problems in the existing literature. First of all, the information flow between London and Amsterdam during the 18th century was exogenous. It would be hard to argue that the weather conditions on the North Sea were influenced by the sentiment on the Amsterdam exchange. Secondly, instead of approximating the intensity of information flow, this experiment allows to discriminate between trading days with and without news. I will demonstrate in more detail below that, for all practical purposes, alternative ways by which English news could reach Amsterdam can be safely ignored. If relevant news did manage to reach Amsterdam through alternative channels, its impact is shown to have been very limited.

During the 1770's, the period studied in this paper, the Amsterdam equity market was at its pinnacle. Since the early 17th century there had been an active trade in shares of the Dutch East India Company (VOC) (Smith 1939 and Gelderblom and Jonker 2004). The unprecedented capital accumulation that taken place during the Dutch Golden Age and the openness of the Dutch Republic for merchants of all religious backgrounds had accelerated financial innovation and development. In a very short period Amsterdam grew from a local exchange to an international capital centre, only to loose its dominant position to London after the French invasion of 1794 (Smith 1919, p. 107, De Vries 1976 and Jonker 1996).

The financial ties between Amsterdam and London had always been tight, but were strengthened further in 1689, when the Dutch Stadtholder William III was crowned King of England. This spurred the integration of the Dutch and English economies. Large amounts of Dutch money flowed into the English economy and Dutch investors obtained significant positions in English companies like the Bank of England and the East India Company (Wilson 1939 and Carter 1975). Around 1700 Dutch investors started to trade shares of the English companies at home, on the Amsterdam exchange (Smith 1919, p. 107 and Neal 1987, p. 97). The English companies were traded alongside the Dutch stocks. Neal (1990) shows that during most of the 18th century the London and Amsterdam equity markets were highly integrated. Trade in 'the English funds' was an integral part of the Amsterdam exchange.

Documenting the flow of information between these two integrated markets and linking it to asset price movements, I find that news had a significant impact on volatility. However, an important component of return volatility of the English shares in Amsterdam can be attributed to factors unrelated to the arrival of news. I estimate that between half and two thirds of total volatility is directly related to the arrival of news. Between one third and a half of total volatility seem to have been generated by other factors. I show that these results are not simply driven by the fact that news could flow through alternative channels. Neither did news seems to have originated from Amsterdam or other places on the European continent. These findings indicate that, at least during the 18th century, the trading process itself is key to understand asset price volatility.

Work related to this paper can be split in two groups. The first group of papers attempt to link the intensity of public information flow to return volatility (Barclay, Litzenberger and Warner 1990, Ederington and Lee 1993, Berry and Howe 1994, Mitchell and Mulherin 1994, Andersen, Bollerslev and Cai 1998, 2000, Bollerslev, Cai and Song 2000, Melvin and Yin 2000, Fair 2002, Kalev, Liu, Pham and Jarnecic 2004 and Evans and Lyons 2008). In general, the evidence for the relevance of public information flow intensity has been mixed. Certain key events, like macro announcements, have a big impact on volatility, but in the aggregate the relation between news and prices seems to be weak. Most papers indicate that this is most likely due to the fact that it is extremely difficult to construct broad encompassing proxies for news. Not all news is relevant and not all relevant news has the same impact on prices (Kalev et al. 2004 and Boudoukh et al. 2007). In other words, news is usually measured with a large error.

A second group of papers focus on the comparison between trading and non-trading periods to gauge the impact of trading and information flow. The main insight of these papers is that, although trading and the arrival of information usually go together, there are instances where trading and information flow can, to some extent, be separated. French and Roll (1986), for example, make use of the fact that NYSE restricted trading during some business days in 1968. Assuming that on average the total flow of information is the same on any given business day, this allows them to isolate the importance of trading. Ito and Lin (1992), Chan, Fong, Kho and Stulz (1996) and Ito, Lyons and Melvin (1998) make use of certain institutional features of the Tokyo exchange and have a similar approach. In general, these studies find that trading itself generates substantial volatility. Most of these studies argue that this is driven by the revelation of private information that accompanies informed trading. A critique on this literature is Fleming, Kirby and Ostdiek (2006) who focus on the relation between weather and the price of weather-intensive goods like oil or agricultural products. They document an important role for public information.

The rest of the paper is organized as follows. Section 2 discusses the historical background and context of this paper in more detail. I will provide further details about how the English news reached 18th century Amsterdam and how, from a number of various sources, I can reconstruct when this information arrived in Amsterdam. Section 3 presents some descriptive statistics and provides a number of insights about the transmission of news from London to Amsterdam. Section 4 presents formal estimates of asset price volatility in periods with and without news. Section 5 provides a number of robustness checks. Section 6 concludes.

## 2 Historical context and background

During the 18th century a number of English assets were traded on the Amsterdam exchange: the East India Company (EIC), the Bank of England (BOE) and the South Sea Company (SSC). In addition to these three stocks, two English annuities (the three and four percents) were traded in Amsterdam as well. This paper focuses on the share prices of the three companies between 1771 and 1777.

This paper is not the first to analyze the share prices of these English companies on the Amsterdam exchange. In *The rise of financial capitalism* (1990) Larry Neal studies the behavior of these share prices on the Amsterdam exchange and compares it to the share prices in London. Neal makes a strong argument for the efficiency of the Amsterdam and London capital markets in the 18th century. He argues that the two markets for the English companies did not exhibit any return predictability. In addition, Neal shows that the Amsterdam and London exchanges were well integrated. News arriving with the packet boats from Harwich ensured that Amsterdam investors were well informed about developments in London. Differences in share prices between London and Amsterdam were small and generally short lived. In general, it was only a matter of days before the asset prices in Amsterdam would reflect recent developments in England.

The English stocks were not the only foreign assets traded in Amsterdam. During the 18th century Dutch capitalists invested in a wide range of assets and in Amsterdam a thriving secondary market was created in a wide variety of assets, from shares in Swedish Iron works to bonds issued by the Russian Czar (Carter 1975, De Vries 1976, p. 12-13, Neal 1990, De Vries and van der Woude 1995, p. 194). Only the share prices of the main English and Dutch companies, as well as English annuity bond prices were regularly (three times a week) published in the main newspaper, the *Amsterdamsche Courant*, indicating that these shares were most actively traded in the Amsterdam market. The scarce records brokers have left us give the strong impression that an active trade indeed existed in these assets (Van Dillen 1931 and Van Nierop 1931). Although volume data are unavailable for the period, some inferences can be made about the size of the Amsterdam market for the British stocks. A number of papers have attempted to estimate the size of holdings of British shares by Dutch investors (Bowen 1989 and Wright 1999). These studies show that during the 1770's more or less one third of the shares in the British companies were in the hands of Dutch investors[2]. This is only a rough indicator of the Amsterdam market's importance since British investors could also choose to trade in the Netherlands and Dutch investors could likewise place their orders in London (Van Nierop 1931 and Wilson 1939). Nevertheless it seems reasonable to assume that, although the London market for British shares was most important, secondary markets in Amsterdam were not negligible.

Trading on the Amsterdam market was well organized during the 18th century. In the 17th century a large part of European goods trade was conducted through Amsterdam. The financial techniques Amsterdam merchants had to apply here were easily transferred to the trade in shares. De la Vega (1688, 1939) describes the wide variety of financial instruments already available to the Dutch investor in 1688. Most famous are the put and call options in use, but in general a wide menu of spot and future transactions was available. Smith (1919) shows that by the beginning of the 18th century the use of financial instruments was fully institutionalized. The existence of specialized groups of brokers ensured that all different types of transactions were handled efficiently. In addition free entry of brokers ensured that no specific group would dominate a certain part of the market. (Jonker 1996, p. 147).

London and Amsterdam do not only provide for an interesting case to study the impact of news and factors on volatility, it is also possible to reconstruct the actual data necessary to make such a study feasible. Data on the share prices are available from the *Amsterdamsche Courant*, which reports prices for three dates a week (with intervals of two or three days)[3]. The dates of arrival of news in Amsterdam are reconstructed using a number of sources, most importantly the *Rotterdamsche Courant* which reports the arrival of boats. Based on this I determine which prices contained news from England and which prices did not.

What kind of prices were reported in the *Amsterdamsche Courant*? First of all, share prices were reported in Pounds Sterling. This is very convenient as it implies that exchange rate fluctuations did not play a role in the volatility of the share prices. Secondly, the prices reported to the newspaper were based on the 'dominant price' that was observed during trading hours. It is most likely that this price reflected the midpoint of transactions that took place at the bid and ask points. In appendix B I provide further detail about the price reporting. Finally, the prices referred to contracts on time. As I describe in appendix B the *Amsterdamsche Courant* reported prices for a future contract in which delivery and payment of a stock was deferred to certain fixed settlement date. As is well known, future prices include a so-called cost-to-carry element. In order to study the return volatility of future prices, this has to be taken into account. I will discuss this in more detail in section 3.

How did the English news reach Amsterdam? A mail packet boat service was organized between Harwich and Hellevoetsluys, a small harbour town close to Rotterdam, bringing in the English letters. From Hellevoetsluys the information was transported to

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[2] Bowen (1989) estimates that in 1774 20% of outstanding EIC stock was held by Dutch investors. Wright (1999) estimates indicate that in 1768 29% of stock in the BOE was held by Dutch investors, in 1790 46% of SSC stock was in Dutch hands and in 1767 30% of EIC stock was held by the Dutch.

[3] The *Oprechte Haarlemsche Courant* published share prices regularly as well.

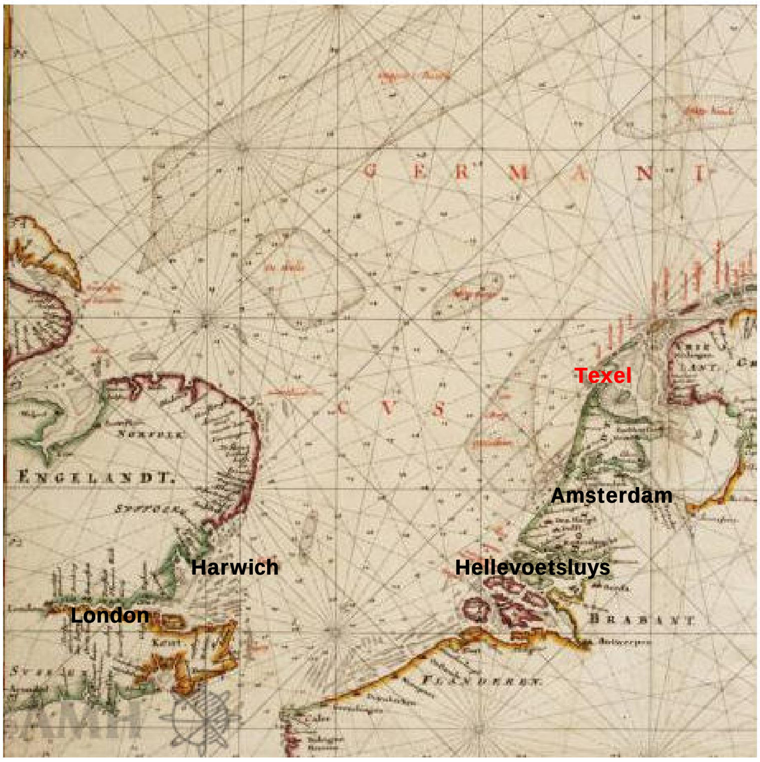
Amsterdam by coach. The English letters contained information on the share price movement of the British stocks in London, other public news and private correspondence between business partners, private individuals, and government officials. (Van Nierop 1931). This was the main and by far the fastest way information from London could reach Amsterdam (Hemmeon 1912, Ten Brink 1969, Hogesteeger 1989, and OSA 2599).

A regular postal service had existed since 1660. In 1668 the system had evolved to its definitive form that would be maintained through the 17th and 18th centuries. Two boats per week were scheduled to leave Harwich (and Hellevoetsluys for the opposite direction) on Wednesdays and Saturdays. During the sample period, the packet boat captains never deviated from this schedule. The service was run by the British post (Hemmeon 1912) and in Holland the City of Amsterdam had obtained a monopoly on the distribution of the letters (Ten Brink 1969, Hogesteeger 1989 and OSA 2599). Steamships were not available yet and the packet boats therefore had to rely on wind power. The boats were specifically designed for the trajectory. King William III, the Dutch Stadtholder who became King of England in 1689, replaced the existing boats with faster ones. The boats formed the lifeline between England and Holland (apart from letters the boats also transported passengers among whom were dignitaries and government messengers), and it was of essential importance that they were fast. Not only was it useful if they reached their destinations as quickly as possible, it was also of key importance they would 'out sail' any potential enemy at sea (Hemmeon 1912, p. 115-116). To make sure that there was always a boat available to ship the news, four boats were in service. Each boat would sail from Harwich to Hellevoetsluys one week, and in the opposite direction the other week. Given that the median sailing time was three days, this implied that there was overcapacity. This situation was maintained to ensure that when a boat was behind schedule because of adverse wind conditions, the English letters (almost) never had to wait for its return. There was always another packet boat in port who could take the next shipment.

Figure 2.1 shows how the ships sailed. The English letters were first taken to Harwich by coach. In Harwich they were brought aboard a packet boat that would sail too Hellevoetsluys. In Hellevoetsluys the letters were offloaded and brought to Amsterdam, again by coach. This final stage would take one additional day. It is possible to precisely reconstruct when news arrived in Amsterdam. This reconstruction is based on three sources: (1) the arrival dates of the packet boats, (2) the average time it took for letters to be transported between Hellevoetsluys and Amsterdam, and (3) the appearance of the English news in the Dutch newspapers. In appendix A I explain the exact methodology in more detail.

Because of data limitations the period of the analysis is confined to the years from 1771 to 1777. Only in September 1771 did the *Rotterdamsche Courant* start to structurally report the arrival of the packet boats (before this date the newspaper only reported it incidentally). The end date of the sample is determined by a war between England and France that started in February 1778. This war generated information on the continent possibly relevant for the English stocks. The danger exists that this information reached Amsterdam before it reached London, making the experiment unsuitable. I therefore decided to omit all information from the sample from 1778 onwards. The remaining sample years between 1771 and 1777 are very suitable for the natural experiment pursued in this paper because all main developments took place in London. This ensures that there was no or very little information generated in Amsterdam that would be price relevant in London. In the next section I will elaborate on these points.

Figure 2.1 Route of the packet boats




There was considerable variation in the time it took for the packet boats to reach Hellevoetsluys. On average it took packet boats around three days to reach Hellevoetsluys, but in reality it could take anything between one and twenty days (see table 3.1 for the exact distribution of sailing times). As a consequence English news reached Holland with varying intervals. This variation allows me to compare the volatility of returns in periods with and without news.

## 3 Information flow between London and Amsterdam

To actually perform this analysis, it has to be the case that Amsterdam received most (if not all) of their information through the packet boats. In this section of the paper I will review the process by which information was transmitted between London and Amsterdam. I will argue that, although there will always remain a possibility that Amsterdam investors received news through other channels, these alternatives played a minor role at most. The first issue that will be addressed is the possibility that Dutch investors got relevant price information before their English counterparts. I will argue that as long as one focuses on specific periods, news was flowing from London to Amsterdam and not the other way around. The second point is whether the flow of information from London to Amsterdam was truly exogenous. It is of crucial importance to know whether the frequency and timing of packet boats crossing the North Sea were to any extent related to developments on the exchanges or to fundamental shocks relevant for the share prices. Thirdly, it is important to analyze whether the packet boat service was the only channel through which the English news could reach Amsterdam. I will show that, at least as a first approximation, alternative channels can be ignored.

### 3.1 The direction of news

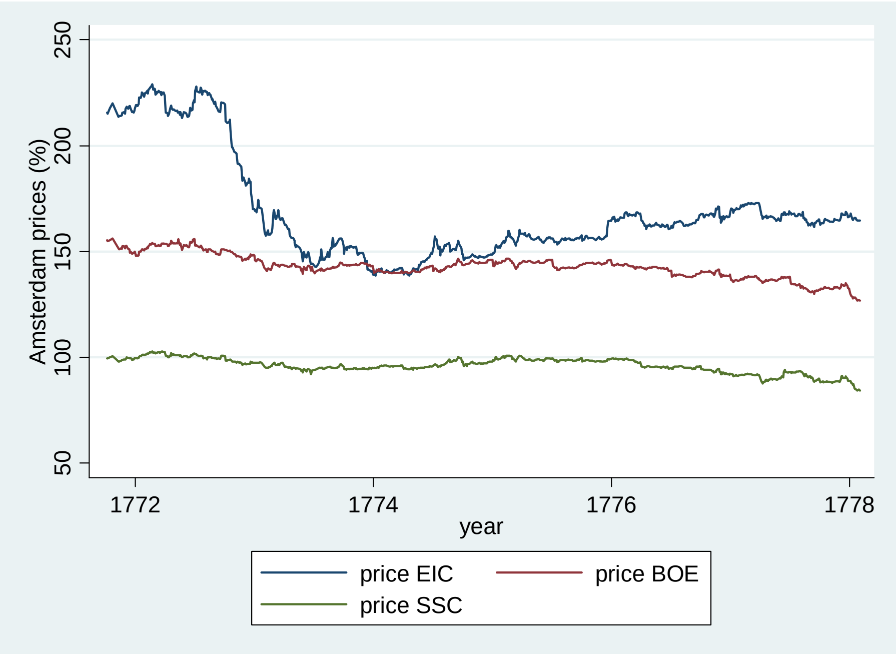
Implicit to the methodology of this paper is that all relevant price information originated from London. Taking a closer look at history this seems to be a reasonable assumption, at least for the period 1771-1777. Reviewing the historical record it becomes clear that news of all main developments would have reached London before Amsterdam. I will show this more formally comparing the development of share prices in London and Amsterdam and the differences in timing.

For the three English companies traded in Amsterdam most important news would have reached London first, before being disseminated to the rest of Europe. The East India Company held large, continuously expanding possessions in South-Asia and made considerable profits from the trade in Colonial wares. During the early 1770s a debate in Parliament raged on about the influence the English government should have on the company and how much of its profits it was entitled to (Sutherland 1952). Price relevant information on the EIC was therefore related to three things: domestic developments in English politics, the products brought from India and military developments in India. All three types of news can be expected to have originated in London or have reached London first. There is a slight probability that some news might have reached Amsterdam first. The Dutch East India Company (VOC) and the EIC were competing for influence and products in Asia. It is possible that news of specific English victories or losses reached Amsterdam first. Below I will address this concern.

The Bank of England (BOE) and the South Sea Company (SSC) were both set up to help finance British government debt. The BOE was set up in 1694 to function as the government's banker. Its function was to supply the government with loans that were financed with equity, deposits and later note issues. In addition, the bank endeavored in the discounting of bills, but on a relatively small scale (Roosegaarde Bisschop 1896 and Clapham 1944). The SSC was set up in 1711 and originally had the purpose to transport slaves from Africa to the Spanish American colonies. However, its role in these ventures was rather limited as from 1713 on the company was involved in several schemes to transfer illiquid British debt into liquid shares (debt for equity swaps). These schemes resulted in the famous South Sea bubble of 1720 (see among others Neal 1990 and Temin and Voth 2003). After the bubble burst the SSC continued to exist until 1850 and mainly functioned as an investment vehicle in British Government debt. To summarize, both the BOE and the SSC were mainly involved in British government debt. News relevant for the price of these two stocks can therefore be expected to have originated from London. Only in case of war or major political developments on the European continent could price relevant information have reached Amsterdam before London.

This last point has important implications for the period of this study. Not all time periods are suitable for the analysis presented here. The 18$^{th}$ century was filled with European continental wars or the threat of a war breaking out and England was involved in nearly all of them (Neal 1990). Given that Amsterdam was (effectively) closer to places on the continent it is possible that price relevant news would have reached Amsterdam before London. Taking this and certain data limitations into consideration, the period of the analysis starts in September 1771 (the month the Rotterdamsche Courant starts listing the arrival of the Harwich packet boat) and ends in December 1777 (in February 1778 England became involved in a war with France).

Figure 3.1 Share prices of the English companies in Amsterdam, 1771-1777




Source: *Amsterdamsche Courant*, September 1771 – December 1777

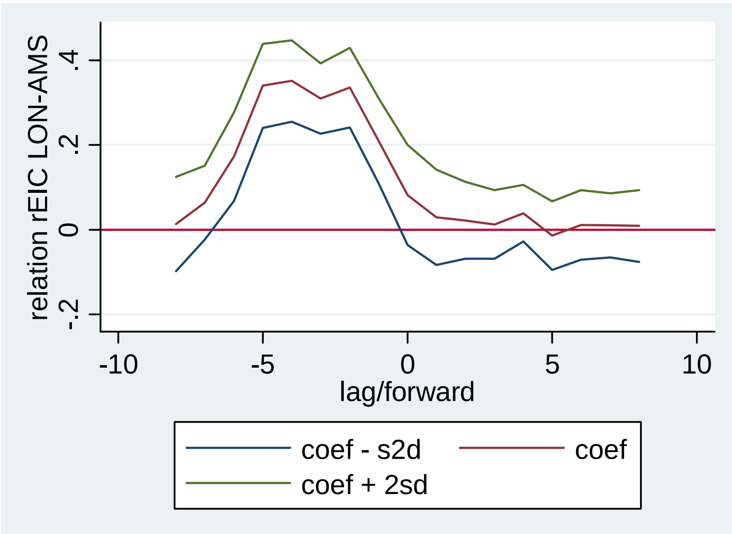
During this period I am confident that all relevant information originated in London. Between 1771 and 1777 two distinct developments had a big influence on asset price volatility. In both cases all relevant information originated from London. Figure 3.1 presents the development of share prices in this period. First of all a huge fall in the price of EIC stock occurred in 1772. The EIC had made significant territorial gains in the second half of the 1760s and this raised hopes that profitability of the company would rise. The directors of the EIC played into these hopes by overestimating revenues and paying out too much dividends. As a consequence share prices climbed quickly (Sautijn Kluit 1865 and Clapham 1944). In reality the company was not doing so well. Matters deteriorated further when a huge famine struck Bengal in 1769-70. The directors of the EIC tried to hide the effects of the famine on the company and continued to pay out high dividends. They were able to continue doing so until 1772 when the bomb burst. In the spring of that year the EIC had to repay a short term loan from the BOE and it failed to do so, having to postpone payments. The bad state of the company was revealed and share prices dropped dramatically (from 227 to around 150 percent) (Sutherland 1952).

Another event heavily influencing share prices in this period was the American War of Independence that started in 1775. It is well known that this war had a big impact on the English government. As a consequence the price of English debt (and related stock like the BOE and the SSC) fell in value from 1775 onwards. The important point here is whether news from America would reach Amsterdam directly or through London. It is likely that all American news came through London. Officially there was no news service between Holland and America. Traditionally, all news relating to the Americas came from London (Ten Brink 1969, p.22). In addition, close inspection of the Dutch newspapers of the period indicates that all America-related information came from London. Usually news on America was reported in the London column. In case there was a separate column reporting news from America, this was always accompanied by a column reporting the English news, suggesting that both news reports came in at the same time, most likely originating from one and the same place: London.

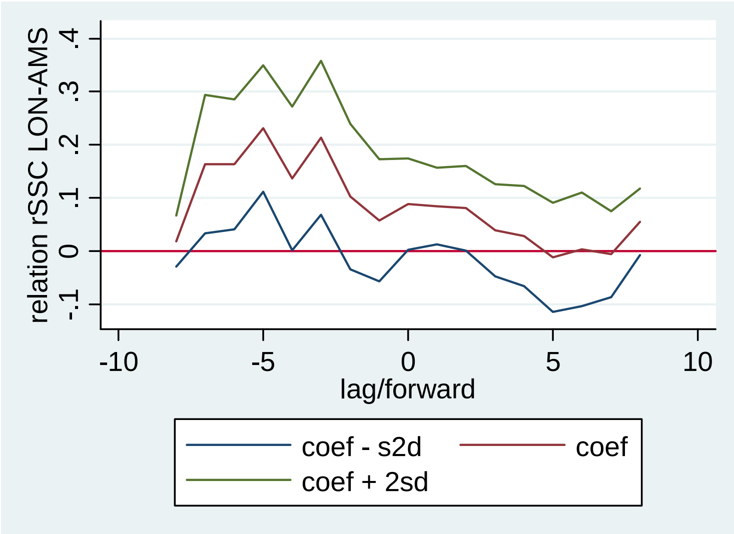
These claims can be tested by taking a closer look at the data. If all news originated from London, Amsterdam prices should lag London prices with a delay consistent with the time it took for the English letters to reach Amsterdam: on average a period of four days (a median sailing time of three days plus one additional day to transport the news from Hellevoetsluys to Amsterdam). Neal (1990) presents some evidence on this, showing that Amsterdam prices in general lagged London prices by three days. In this section I redo his analysis focusing on the period September 1771 – December 1777 and looking at returns instead of prices.

For the Amsterdam market three prices were reported each week: for Monday, Wednesday and Friday. Based on these prices, returns are calculated for two (Fri-Wed and Wed-Mon) or three day periods (Mon-Fri). For the same intervals, the returns in London can be computed. These London returns are then lagged or forwarded and related to the Amsterdam returns. Figures 3-2a to 3-2c show the results from simple uni-variate regressions of Amsterdam on London returns, lagged or forwarded a number of periods.

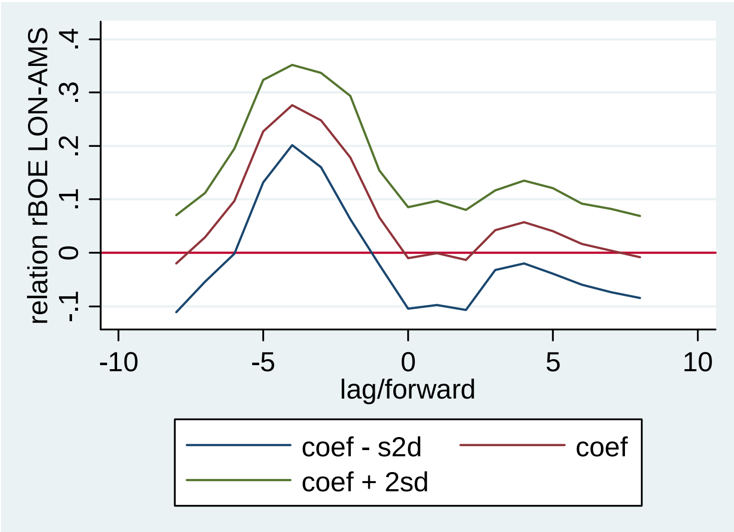
Figure 3.2 The relation between Amsterdam and London returns: different lags and leads.
3.2a EIC



3.2b SSC




3.2c BOE




Number of observations: 801.

Coefficients presented are from uni-variate regressions of Amsterdam returns on London returns (for the same time window, see text) lagged (L) or forwarded (F) a number of days. Lags or forwards are on the horizontal axis, coefficients and confidence intervals are on the vertical axis. Confidence intervals calculated from bootstrapped standard errors (1000 replications).

Source: *Amsterdamsche Courant*, September 1771 – December 1777 and Neal (1990)

Figures 3.2a – 3.2c clearly show that for each stock London returns explain Amsterdam returns with a lag, not a lead. This is evidence for the interpretation that price relevant information had its origin in London. In general all lags (from 1 to 8 days) have some impact, but the biggest effect is found by lagging the London return four or five days. The economic effect is considerable. For the EIC, for example, a one percent return in London is associated with a 0.35 percent return in Amsterdam four days later. A lag of four days is consistent with the average time it took for the English letters to arrive in Amsterdam.

There are a number of points that deserve further attention. First of all, when the London returns are lagged by only a small number of periods (one or two days), they still significantly explain returns in Amsterdam. Does this imply that some information could reach Amsterdam faster than the official English letters did? The answer is no. Note that the London returns are calculated over the same period as the Amsterdam returns: i.e. two to three days. This implies that the lags presented here include information that goes further back than the lag length. For example the London return lagged for two periods includes price information up to five days in the past. A second point that merits fuller explanation is the fact that the London returns on SSC shares forwarded one or two periods have a statistically significant effect on Amsterdam returns. Although the economic effect of the leads is small compared to the lags, this implies that at least some relevant price information for the SSC was generated in Amsterdam and subsequently flowed to London. This can be explained by the fact that in the 1770s the fraction of SSC owned by Dutch investors was very large, possibly approaching 50 % of alls shares outstanding (see footnote 2). This would imply that circumstances specific to the Amsterdam market like investors' liquidity, risk aversion or discount factors could be relevant for the price formation in London. However, figure 3.2b shows that the size of this effect was small. The size of the coefficients on the forwarded London returns is about a third of the size of the lagged coefficients. Just as with the other stocks, the information flow from London to Amsterdam was most important.

These results are still not completely satisfactory with regard to the possibility of news from Asia. Suppose for example, that only a few times in the sample period highly important news from Asia reached Amsterdam before it reached London. Given the low frequency of these events, its effect would not be picked up in the regression analysis, but it would have an important impact on the volatility measures used in this paper. To address this issue directly, I select the 10 most important price movements in the EIC stock that took place in Amsterdam. I check by hand to which price movements in London these can be related. Results are presented in table 3.1 and indicate that 9 out of 10 price movements can be related to developments in London and that in all of these cases London returns lead Amsterdam returns and not the other way around. The average lag with which Amsterdam prices respond is consistent with the average sailing time. This is also consistent with the findings of figures 3.2a to 3.2c.

Table 3.1: The ten most significant movements of the EIC

| Date | return | news | corresponding date London | lag |
|---|---|---|---|---|
| 01-06-72 | 2.46% | yes | 29-05-72 | 3 |
| 21-09-72 | -3.18% | yes | 18-09-72 | 3 |
| 23-10-72 | -3.48% | yes | 16-10-72 | 7 |
| 20-11-72 | -3.05% | yes | 18-11-72 | 2 |
| 27-01-73 | 4.55% | yes | 22-01-73 | 5 |
| 26-04-73 | -2.88% | yes | 21-04-73 | 5 |
| 23-06-73 | 3.54% | no | blip | |
| 26-07-73 | 3.25% | yes | 21-07-73 | 5 |
| 06-06-74 | 3.23% | yes | 2-06-74 | 4 |
| 28-10-76 | -2.97% | yes | 23-10-76 | 5 |
| | | | av. | 4 |

Sources: see figure 3.2

## 3.2 Exogeneity of the arrival of information

What determined the frequency and timing of this information flow? Why would a packet boat filled with London newspapers and letters from Harwich arrive in Hellevoetsluys today and not yesterday or tomorrow? The departure of boats was scheduled on fixed dates (every Wednesday and Sunday). However, boats did not always succeed in leaving on that exact day. In addition, the time packet boats actually spent at sea could differ by quite a bit. Sometimes a boat would only need one day to get across the North Sea, sometimes it would take multiple days. What explains this variation and can it be considered exogenous?

The *Rotterdamsche Courant* gives no information about delayed departures from Harwich. Fortunately, the newspaper does give information about the departure of the boats sailing in the opposite direction; from Hellevoetsluys to Harwich. Reading the newspapers it becomes clear that delays, which occurred regularly, were caused by the weather. Boats were often forced to wait in the harbor because of the weather conditions, usually an adverse wind direction. Contemporaries called this situation 'contrary' wind.[4] Although 18th century sailing boats were able to sail against the wind, this would take 'twice the distance, half the speed and three times the trouble' according to the traditional saying and was seldom tried. At times the wind would temporarily change direction, creating a short window of time for a packet boat to leave the harbor. However this was not always successful either. Boats were often forced to return because the wind had changed direction again. Presumably, the number of days a packet spent at sea was also related to weather conditions (*Rotterdamsche Courant*, passim).

Taking a closer look at the weather data available for the period reveals that the total sailing time between Harwich and Hellevoetsluys (time between scheduled and actual departure, plus the number of days at sea) was indeed determined by the wind direction.[5] Table 4.1 illustrates this point. The table presents the average wind direction for the days

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[4] 'Contraire wind', *Rotterdamsche Courant*, passim.

[5] Unfortunately is not possible to make a decomposition between the waiting time in Harwich and the actual number of days at sea. This information is not provided by the *Rotterdamsche Courant*.

following the scheduled departure of a packet boat from Harwich up to the day that it actually arrived in Hellevoetsluys. Every row presents these details for a different duration of the voyage across the North Sea. The second column presents the frequency of each different sailing time. For brevity I only report the sailing times up to 8 days, as voyages taking more than 8 days occurred only infrequently. Columns 3 to 10 report the average wind direction on each day of the voyage, with t+1 the first day of the trip, t+2 the second day of the trip, etc. The wind direction is reported in degrees, with the North being 360 or 0 degrees, and comes from the observatory of Zwanenburg, a town close to Amsterdam (KNMI).

Table 3.2 Sailing time and wind direction

| Sailing time (days) | Wind direction (degrees) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | t+1 | t+2 | t+3 | t+4 | t+5 | t+6 | t+7 | t+8 |
| 1 | 4 | 237 | | | | | | | |
| 2 | 148 | 244 | 244 | | | | | | |
| 3 | 315 | 246 | 246 | 246 | | | | | |
| 4 | 140 | 332 | 54 | 99 | 184 | | | | |
| 5 | 47 | 112 | 85 | 91 | 98 | 152 | | | |
| 6 | 15 | 101 | 77 | 80 | 79 | 67 | 104 | | |
| 7 | 8 | 106 | 101 | 95 | 96 | 112 | 117 | 187 | |
| 8 | 7 | 166 | 55 | 38 | 83 | 71 | 50 | 148 | 124 |

Different sailing times in rows — Day of voyage in columns

0/360 degrees: wind from the North — 180 degrees: wind from the South

90 degrees: wind from the East — 270 degrees: wind from the West

Position Hellevoetsuys with respect to Harwich: 100 degrees

Ideal wind direction for boats sailing to Hellevoetsluys: 280 degrees

Source: *Rotterdamsche Courant* and KNMI

Figure 2.1 shows that Hellevoetsluys is situated east-to-south (approximately 100 degrees) relative to Harwich. This implies that if the wind was blowing from this direction, the packet boats would have had serious difficulty in leaving Harwich and reaching Hellevoetluys. If, on the other hand, the wind was blowing from an opposite direction (west-to-north, or 280 degrees) the boats would have reached Hellevoetsluys very quickly. For any intermediate wind direction the boats were probably able to advance, but their speed depended on the exact wind direction.

Table 3.1 shows that this is indeed the case and that the direction of the wind can almost perfectly predict sailing times. Day t+1 presents the first day at sea. For short sailing times the wind direction is close to the optimal 280 degrees for all days. Take for example a sailing time of two days. On both sailing days (days t+1 and t+2) the wind was blowing from the South-West, making a swift passage to Hellevoetsluys possible. For longer sailing times this is not the case. Take a sailing time of 4 days for example. The average wind direction on day t+1 is close to North (not ideal, but not dramatic either), but for t+2 and t+3 the wind blows from the East, preventing the boats from advancing. Only when the wind turns south on the fourth day are the boats able to approach Hellevoetsluys. The same pattern can be observed for longer delays. During the first days wind is blowing from the East, only to change direction on the last day(s) of sailing. Note that the fit between sailing time and wind direction is particularly good considering that these wind directions were measured in Zwanenburg, 230 kilometers away from Harwich.

I have not found any instances of boats leaving behind schedule for any other reason than the weather. Sometimes the packet boats were used for official purposes and an official envoy would take a packet boat to get to Amsterdam London as fast as possible. The surplus of boats available for the service ensured that this never led to a delayed (or hasty) shipment of the English letters to Hellevoetsluys (*Rotterdamsche Courant*, passim).[6]

The number of days at sea also seems to have been completely determined by weather conditions. In theory it is possible that during times of international tension, dangers at sea (such a privateering, the presence of war ships, etc.) could have led to delays or may even have forced packet boats to return to port. If this would have been the case, the failure of a boat to arrive in Hellevoetsluys would have said something about international developments and could therefore have been relevant to asset prices. First of all it is important to note that the period under study, 1771-1777, featured no European conflicts and sailing at sea was therefore relatively safe. Second of all, the following example suggests that in general packet boats did not seem to suffer from international tensions.

On April 30 1777 a privateer sailing under the American Revolutionary flag (in 1777 the United States were still fighting the War of Independence against England) attacked a packet boat and captured the ship and the English letters. The privateers seem to especially have valued the latter as, according to an eye witness, they planned to send these letters to the US Congress[7]. Fortunately, this incident seems to have been a very rare event. The *Amsterdamsche Courant* reports that, as far as anybody can remember, this is 'only the third time a ship has been captured by enemies'[8]. At least for the years between 1771 and 1777 I did not find any evidence that this type of threats influenced the sailing times of packet boats at any time except for this incident. For most of the time the wind direction was far more relevant.

### 3.3 Possible alternatives to the packet boat

The previous sections have shown that, in all likelihood, all information relevant for British stocks originated from London. In addition the timing and frequency of packet boats seems to have been driven by the weather. The next important question is: did all new information from London reach Amsterdam through the packet boat system or were there alternative ways? This section will show that the mail packet boat was by far the most important way by which most recent information from England would be brought in.

The packet boats formed the only official mail service with England. Together with the City of Amsterdam, the British post was granted the monopoly to ship letters between Holland and England and any competition from other persons or organizations was deemed

[6] Between 1771 and 1777 this occurred quite infrequently. All results in this paper are robust to counting the cross-over of diplomats and other dignitaries as the arrival of news.

[7] 'Dat maal (de brieven) zal niet open gedaan worden voor dat het bij het congres komt', The same article mentions that an English official messenger managed to throw the letters he carried with him overboard. *Rotterdamsche Courant*, May 3, 1777.

[8] 'Zo ver men zig herinnerd is het de 3en paketboot die ooit door eenig vyand tusschen Harwich en Helvoet genomen is', *Amsterdamsche Courant*, May 6, 1777.

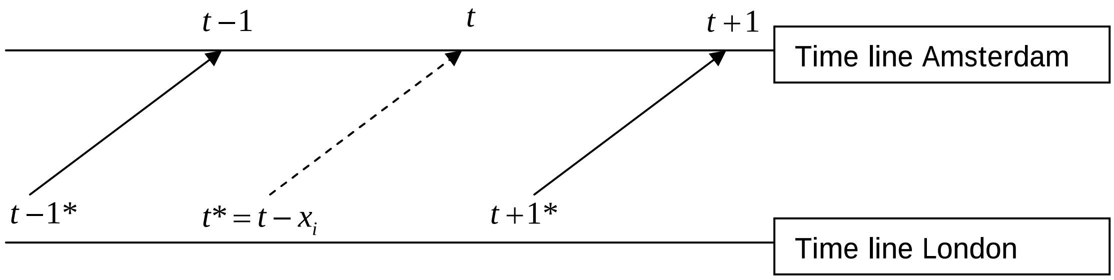
illegal (Ten Brink 1969, p. 24 and OSA 2599). Most evidence suggests that the English letters carried by the packet boats were indeed the main source of English information for the Dutch public. The Dutch newspapers' reports on England were based on the English letters and there is an example of an Amsterdam broker specializing in English shares that explicitly referred to them in the letters to his customers (Van Nierop 1931). The *Rotterdamsche Courant* was also dedicated in reporting the arrival of the packet boats, indicating the importance of the mail service for its readers.

Note that each week several ships (especially cargo ships and fishing boats) sailed between England and Holland. However none of them could have shipped English news to Amsterdam as quickly as the packet boats did. Figure 2.1 shows that Harwich – Hellevoetsluys was one of the most direct connections between London and Amsterdam, especially if one considers that boats could not reach Amsterdam directly but had to sail via the island of *Texel*, which would take several additional days. Moreover it was the City of Amsterdam that set up the packet boat service in 1668. The city government made sure that the news would take the fastest route possible (Ten Brink 1969 and Hogesteeger 1989). As mentioned before, the boats were specifically designed for their task and were quite quick. In addition the captains sailing the boats did so for decades, probably giving them great expertise adding to the efficiency of the system (Hemmeon 1911 and *Rotterdamsche Courant*). Once in Hellevoetsluys the English letters were quickly taken up in the Dutch mail system (for more details see appendix A). Coaches would wait for the boats to bring the letters to their respective destinations as quickly as possible. In short, the packet boat system was fast and efficient and organizing a similar or faster scheme would have been very costly.

I can test empirically whether the packet boat service was indeed the only way through which English news would reach Amsterdam. In order to do so I compare the returns on the British shares in Amsterdam and London. The null hypothesis is that Amterdam and London returns are only correlated when a mail packet boat had just arrived in Amsterdam.

Suppose there are three dates, $t-1$, $t$ and $t+1$ for which asset prices in Amsterdam are available. Further suppose that both at $t-1$ and $t+1$ news arrives from London containing the most recent share prices in London from a few days earlier at $t-1*$ and $t+1*$ (an asterisk indicates a date in London). If the packet boats were the only channel of information between England and Holland, there are two testable hypotheses. First of all the return in Amsterdam between $t-1$ and $t+1$ should be strongly correlated with the return in London between $t-1*$ and $t+1*$. Secondly, the return in Amsterdam between $t$ and $t-1$ should be uncorrelated with the return in London between $t*$ and $t-1*$. Essentially I test here whether English information from a certain date $t*$, that was not brought in by the packet boat, had an impact on Amsterdam prices or not.

Figure 3.3 Timing London and Amsterdam prices




Time indices without asterisk are dates in Amsterdam for which price information is available. Time indices with an asterisk are dates in London for which the public information set corresponds to the one in Amsterdam. Full lines indicate the sailing of a packet boat, the dotted lines indicates a, hypothetical, alternative way of transport.

These two hypotheses can be easily tested if the relevant dates in London are know. First of all, I need to know the exact dates when information in London was sent to Amsterdam using the packet boat service. These are date $t-1*$ and $t+1*$ from the above example. Fortunately these are straightforward to determine. Apart from reporting the arrival of packet boats, the *Rotterdamsche Courant* also gives information on the date on which the English letters brought in by the boats were sent. Secondly, I need to know at what date any alternative way of transportation would have left London to influence the Amsterdam price at date $t$. This is date $t*$ from the above example. By definition this date is unobservable as I only observe the arrival of the packet boat and not of any alternative hypothetical method of transportation. To determine this date in London I assume that any alternative way of transportation would take more or less the same time as the packet boat would. Because of the weather, this differed for each season. I therefore calculate the average number of days $x_i$ it takes for the official English letters to reach Amsterdam for each month separately, indexed by $i$. $t*$ is then defined for each month differently as $t-x_i$.[9] Figure 4.3 presents these timing issues graphically.

Figures 4-4a to 4-6b present the scatter plots testing the two hypotheses for each stock separately. The left hand panels present the relation between Amsterdam returns with news (between $t-1$ and $t+1$) and the corresponding returns in London (between $t-1*$ and $t+1*$). The right hand panel presents the relation between Amsterdam returns without news (between $t-1$ and $t$) and the hypothetical returns in London (between $t-1*$ and $t*$). The figures show that both hypotheses hold. Returns in Amsterdam and London are significantly correlated when news is coming in. However this correlation disappears and becomes strongly insignificant when no packet boat arrives.

Table 3.3 presents the same relations using formal regression analysis. I test whether the slope coefficients from figures 3.4 to 3.6 differ significantly when news is coming in or not. To test this, London returns are interacted with a news dummy (having a value 1 when news arrives) and then added to a regression of London on Amsterdam returns. If the packet boat truly is the only way through which news arrived in the Dutch Republic, the non-

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[9] I experiment with this definition by adding or subtracting a number of days from $X$. Results are robust to this.

interacted slope coefficient should be equal to 0 and the coefficient on the interaction term should be large and statistically significant. Table 3.3 shows that this is indeed the case.

Table 3.3 Co-movement returns Amsterdam-London: news – no news

| | EIC | SSC | BOE |
|---|---|---|---|
| London return | 0.0680<br>(0.4640) | -0.0240<br>(0.4970) | 0.0850<br>(0.5190) |
| London return x news | 0.3571<br>(0.0010)*** | 0.5100<br>(0.0000)*** | 0.2385<br>(0.0010)*** |
| News | 0.0810<br>(0.0610)* | -0.0150<br>(0.5790) | 0.0100<br>(0.6920) |
| Constant | -0.0450<br>(0.0800)* | 0.0030<br>(0.8710) | -0.0280<br>(0.1220) |
| R2 | 0.1520 | 0.0990 | 0.0670 |
| N | 814 | 814 | 814 |

Results from regressing Amsterdam on London returns. The interaction term between news and the London return captures the additional co-movement that can be explained by the arrival of news. London returns are lagged by the number of days it took for the English letters to arrive in Amsterdam. P-values based on bootstrapped standard errors (1000 replications) reported in parentheses. The total coefficient for London returns in the presence of news (London return + London return x news) is never statistically different from 1. Sources: see figures 3-1 to 3-3

*** significant at the 1% level *significant at the 5% level

Figure 3.4 EIC, co-movement London-Amsterdam

a) News b) No news

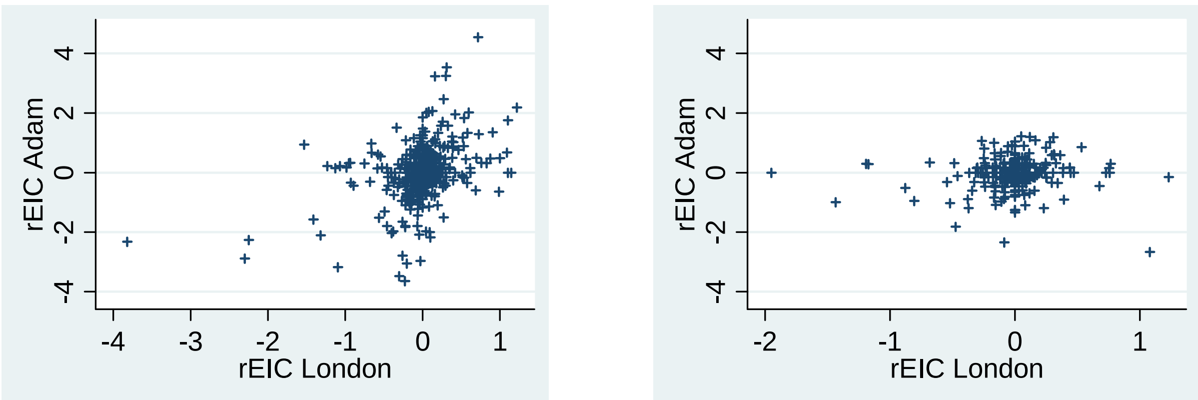


Figure 3.5 BOE, co-movement London-Amsterdam

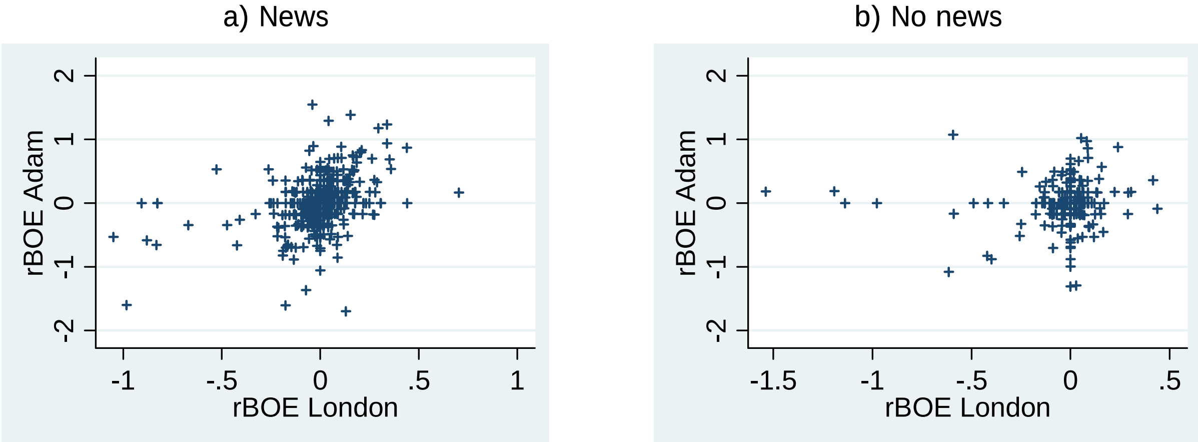
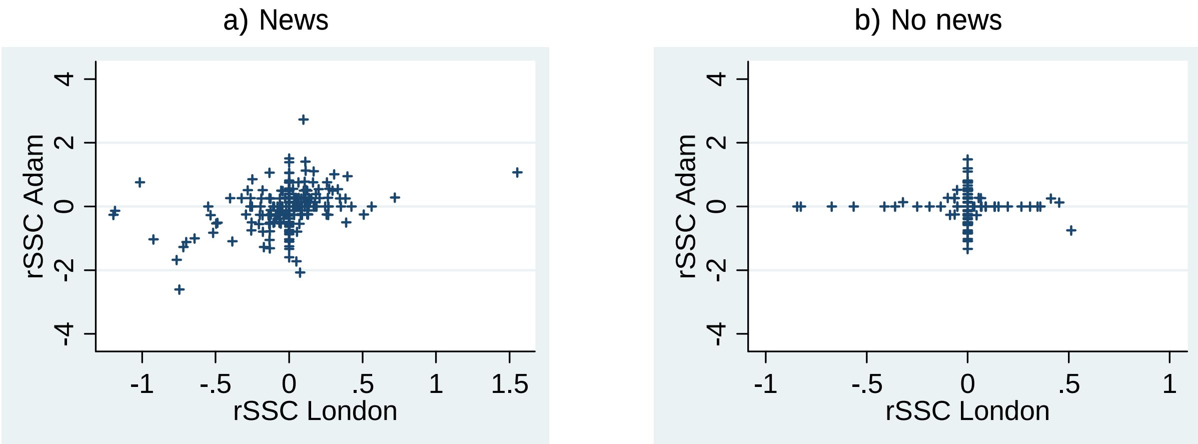



Figure 3.6 SSC, co-movement London-Amsterdam




Horizontal axis represents percentage returns in London, the vertical axis percentage returns in Amsterdam. Both are in percentages.
Sources: *Amsterdamsche Courant*, *Rotterdamsche Courant*, September 1771 – December 1777 and Neal (1990).

To summarize, the quantitative evidence supports the qualitative information: apart from the packet boat there does not seem to have been an alternative channel through which English news could have reached Amsterdam.

Although these results strongly point in the right direction, it is still possible that, although in general all English news arrived in Amsterdam trough packet boats, in some instances news did flow through alternative channels. First of all, one could argue that news did not necessarily have to come by boat. The telegraph was not in use yet, but post pigeons could have been used to get the news across the North Sea. Qualitative evidence indicates that it is unlikely that this could have played a big role. Although the use of post pigeons was already known in Ancient Greece, only around 1800 did people start to train them to make regular mail service possible (Levi 1977). The first pigeon post service in the

Netherlands I encountered in the literature was set up around 1850 to bring news from Antwerp to Rotterdam (Ten Brink 1957). It is interesting to note that during the winter months this post pigeon service did not operate. Apparently the birds did not cope well in bad weather.

A more relevant alternative may have been fisher boats. There are some hints that during the famous South Sea Bubble in 1720 investors hired private fishing boats to get news from England (Smith 1919, p. 107 and Jansen 1946, p. 168). During this episode share prices were far more volatile than during the 1770s (see Temin and Voth 2004) and consequently incentives to get the most recent information must have been greater. Something similar happened during the years of the Continental System (1806-1814). During this period sailing between Holland and England was officially forbidden, and some merchants chartered private fisher boats to get information from England. In this case, boats would dock at Katwijk aan de Zee, a fishing town closer to Amsterdam (Jonker and Sluyterman 2000, p. 136). It is possible that on occasion stock traders may have done the same during the 1770s. In section 5 I will address this concern in further detail.

## 4 The sources of asset price volatility

Information on the arrival of packet boats allows me to determine when news had reached Amsterdam. Adverse weather conditions could delay the arrival of the boats. In that case, stock prices in Amsterdam reflected only the news that had arrived with the previous boat. I compare stock returns for periods with and without news. This comparison allows me to determine the importance of news and trade-related factors for share price volatility.

### 4.1 Baseline results

The return[10] on asset $i$ ($R_{it}$) can be written as a function of two factors:

$$
\begin{aligned}
R_{it} &= \log P_{it} - \log P_{it-1} \\
&= f\left(I_{it} - I_{it-1}, T_{it} - T_{it-1}\right) = f\left(\Delta I_{it}, \Delta T_{it}\right)
\end{aligned}
\qquad (4\text{-}1)
$$

where $\Delta I_{it}$ denotes a change in the information set, and $\Delta T_{it}$ a change in market conditions. $\Delta I_{it}$ reflects the arrival of news from England and can be considered a change in the information available to investors on the value of the share. This can be news on the political or economic situation in England (a specific speech in Parliament relevant for the English debt position or the arrival of a fleet from India), or it can simply be the most recent price of a share on the English market. Note that there were always possibilities for arbitrage between London and Amsterdam (Van Nierop 1931). This implies that, considering that London was the dominant market for the British shares, Amsterdam prices would most likely

[10] Because the *Amsterdamsche Courant* reports shares prices with intervals of two or three days, these returns are either two day or three day returns. The three day return is between Friday and Monday. On Saturday trade was limited because of the Sabbath and the fact that a large number of brokers were Jewish (Spooner 1983, p. 21). Trade on Sunday was also likely to be thin, because of Christian brokers going to church. These two factors taken together imply that the three day return between Monday and Friday is comparable to the two days returns between Friday and Wednesday and Wednesday and Monday.

follow London prices, even if price changes in London were unrelated to the fundamental value of an asset. In other words, $\Delta I_{it}$ provides an upper bound for fundamental information.

$\Delta T_{it}$ reflects changes in the market environment. First of all, the micro structure of the market could lead asset prices to deviate from their true value. Risk aversion of investors with respect to a certain stock can vary (for example because of inventory risk), traders can face certain constraints (for example having to sell because of private liquidity shocks) and there can be other factors related to a change in the supply or distribution of an asset that affect its price (Ito, Lyons and Melvin 1998). In addition, investors' preferences for risk may vary over time. The stream of payments an asset promises may remain the same, but the rate at which these factors are discounted may vary. Campbell and Shiller (1988) argue that changes in the stochastic discount factor explain the bulk of asset prices movements with a monthly frequency. When, for some reason, some market participants have better (long lived) information than others, this can also make prices more volatile. The existence of private information will have the result that every buy or sell order will be approached cautiously by the market as a whole, because there is always a positive probability that a trade is informed. This asymmetry of information sets can make asset prices structurally more volatile than the underlying value of an asset (see Kyle 1985 and related literature). Finally behavioral factors could play an important part. Some market participants may not be fully rational and it may take time for rational investors to step in and bring prices back to fundamentals (Delong et al. 1990).

I differentiate between returns with and without news. Returns with news can be written as:

$$R_{it}^{NEWS} = f\left(\Delta I_{it}, \Delta T_{it}\right) \tag{4-2}$$

and returns without news as:

$$R_{it}^{NONEWS} = f\left(0, \Delta T_{it}\right) \tag{4-3}$$

I assume that the function $f(\ )$ is separable in $\Delta I_{it}$ and $\Delta T_{it}$ and that news is immediately reflected in prices. If $\Delta I_{it}$ and $\Delta T_{it}$ are uncorrelated, I can calculate the relative contributions of both factors to total return variances:

$$VI_i = \frac{V\left(R_{it}^{NEWS}\right) - V\left(R_{it}^{NONEWS}\right)}{V\left(R_{it}^{NEWS}\right)} = 1 - \frac{V\left(R_{it}^{NONEWS}\right)}{V\left(R_{it}^{NEWS}\right)} \tag{4-4}$$

and

$$VT_i = \frac{V\left(R_{it}^{NONEWS}\right)}{V\left(R_{it}^{NEWS}\right)} \tag{4-5}$$

with $VI_i$ the return variance that can be attributed to the arrival of news and $VT_i$ the return variance that can be attributed to factors related to the trading environment. Note that the assumption that news is immediately absorbed into prices is crucial. In section 5 I present ARMA tests on the return series that confirm this assumption. The assumption that correlation between $\Delta I_{it}$ and $\Delta T_{it}$ is zero is also crucial. If it is violated, the direction of the bias is unclear. If the correlation is negative, equations 4-4 and 4-5 would underestimate the significance of the market environment. If, on the other hand, the correlation is positive, the estimate of $VI_i$ would be biased downwards.

The above exercise was performed on the return data (three observations a week) of the EIC, the BOE and the SSC in Amsterdam between September 1771 and December 1777. Before moving forward to these results, let me first present the distributions of returns of the three companies in figures 4.1 to 4.3 to provide some intuition about the data.

Figure 4.1 Return (kernel) distributions EIC, news and no news

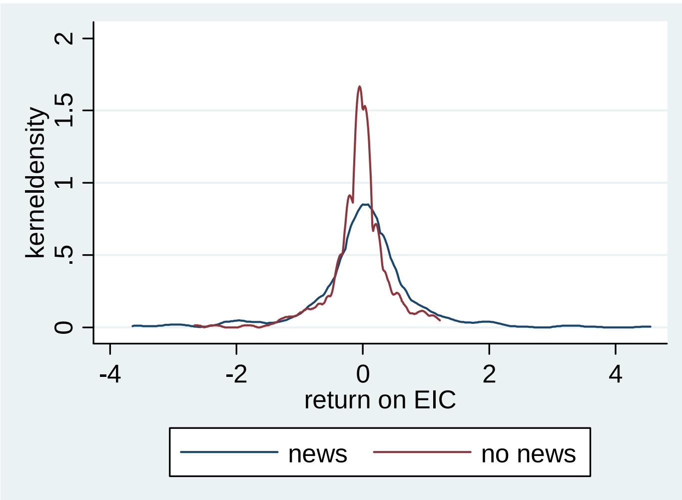



Figure 4.2 Return (kernel) distributions BOE, news and no news

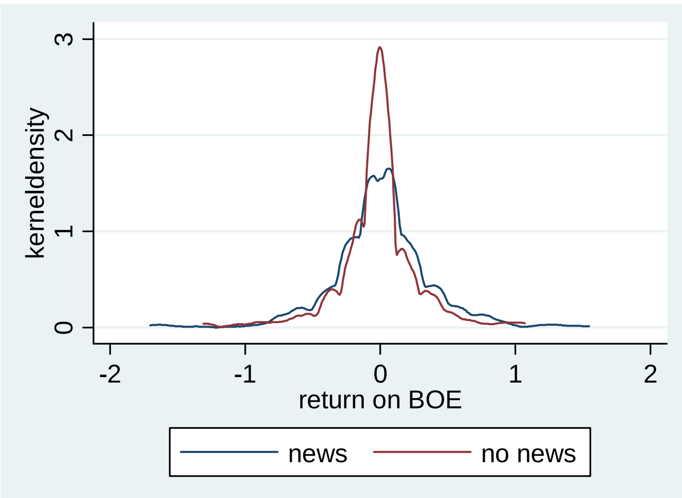
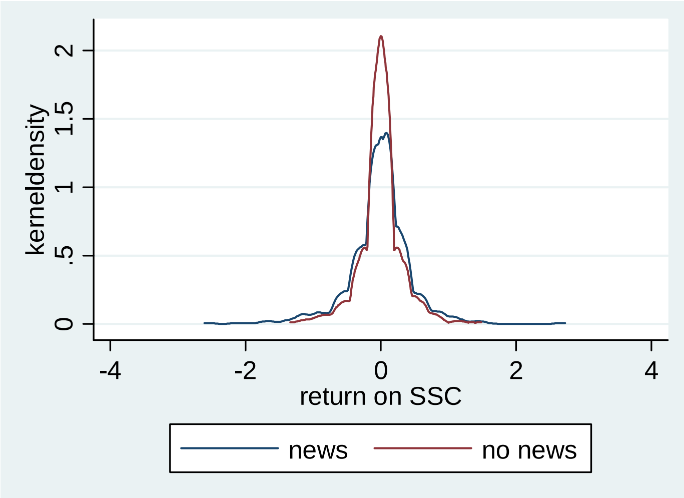


Figure 4.3 Return (kernel) distributions SSC, news and no news




Kernel distributions. Horizontal axis presents returns in percentages.
Source: *Amsterdamsche* and *Rotterdamsche Courant*, September 1771 – December 1777

The first thing to note from these graphs is that the distributions of the returns with news are wider than those without news. For example, most of the probability mass of the EIC returns with news lies between -1.5 and 1.5 percent, while most returns without news lie between -1 and 1 percent. In addition the fraction of zero returns is far lower for periods with news. Both observations point to the fact that the volatility of returns is higher with news than without it.

To test this more formally, table 4.1 presents statistical test on the equality of the return distributions in the presence or absence of news. As is usual with daily stock returns, the return distributions are non-normal. There is substantial mass in the tails (excess kurtosis) and relative to the normal distribution there are too many zeros. The standard F-test on the equality of the standard deviation relies on the normality of the distributions and can therefore not be used. Alternatives are the trimmed mean Brown-Forsythe test and the non-parametric Kolmogorov-Smironov test on the demeaned return series. Both of these tests perform well with non-normal distributions. The former directly tests the degree of dispersion, whereas the latter is more concerned with the overall shape of the distribution[11]. For all three stocks the null hypothesis that distributions are equal is strongly rejected.

Table 4.1 Tests on the equality of news/no news return distributions

| | B-F F test | p-value | K-S statistic | p-value | Obs. |
|---|---|---|---|---|---|
| EIC | 29.22 | 0.0000 | 0.1542 | 0.0001 | 882 |
| SSC | 20.48 | 0.0000 | 0.0828 | 0.0139 | 882 |
| BOE | 11.09 | 0.0009 | 0.1068 | 0.0124 | 881 |

In the table the equality of return distributions in the presence of absence of news are tested. First of all results from the trimmed mean Brown-Forsythe test are presented. Secondly, Kolmogorov-Smirnov test values are reported. Under the null-hypothesis of both tests the distributions of returns in the presence and absence of news are the same. Sources: see figures 4.1 – 4.3

[11] The Kolmogorov-Smironov test also looks at the position of the distribution. Since I demeaned the return series this does not affect the test results.

Table 4.1 shows that news matters, but by how much? Table 4.2 presents the variances of returns for the three funds, broken down for returns with and without news. In addition, the table presents estimates of the relative contributions of information and trade related factors to the total variance as defined in equations (4-4) and (4-5).

Table 4.2 Estimates of return volatility

| | $V\left(R_{it}^{NEWS}\right)$ | $N$ | $V\left(R_{it}^{NONEWS}\right)$ | $N$ | $VI_i$ | $VT_i$ |
|---|---|---|---|---|---|---|
| EIC | 0.76 | 518 | 0.26 | 364 | 0.66 | 0.34 |
| SSC | 0.24 | 518 | 0.11 | 364 | 0.55 | 0.45 |
| BOE | 0.17 | 518 | 0.10 | 363 | 0.39 | 0.61 |

Table presents the return variances in the presence and absence of news. Returns are calculated according to equation (4-1) and are in percentages. In the final two columns the relative contributions of news and trade related factors are calculated.
Sources: see figures 4.1 - 4.3

The table reveals that the relative contributions of information and factors related to the trading process to the overall variance differ for each stock. However, what stands out is that news contributes substantially (between 39 and 66%) to asset price movements. This stands in contrast to most contemporary studies that only find a minor role for news (see for example Mitchell and Mulherin 1994). The main reason for this strong result is that the arrival of news is precisely identified in this paper. This means that, again in contrast to most contemporary studies, the contribution of news is not biased downwards due to measurement problems. The second conclusion from table 4.2 is that although news dominates, the importance of the trading environment is far from negligible: the share of factors unrelated to news in overall volatility lies between 34 and 61 percent.

Existing papers like French and Roll (1986) and Ito, Melvin and Lyons (1998) also conclude that the trading process is very important for asset price movements. These papers compare normal trading periods with episodes where trading is restricted. However, it has been argued that in recent decades news is not a necessarily exogenous variable and could be responding to the trading process (Fleming, Kirby and Ostdiek 2006). This paper does not suffer from these problems. The flow of information between London and Amsterdam in the 18th century was exogenous and therefore the results presented here are most certainly not driven by endogeneity bias.

## 4.2 Robustness checks

There is a worry that these results could, to some extent, be driven by seasonal patterns. Mail boats usually faced smaller delays during the spring and summer. As a consequence boats arrived in Amsterdam in more regular fashion during these seasons and periods without news were in general shorter. This means that spring and summer observations are overrepresented in the news sample. This could be a problem, because it is likely that during the summer (especially August) relatively little happened in London. In other words, the volatility of news returns used in the analysis could be biased downwards. To correct for this, the volatility of returns can be conditioned on the month. Results are almost identical to the ones presented in table 4.2 (results available upon request).

The identification of the arrival of news in Amsterdam is based on a number of assumptions on how much time it took for postal coaches to travel between Hellevoetsluys and Amsterdam (see appendix A for details). If these assumptions are wrong it is possible that some of the returns I have identified as including no news, actually did reflect new information from London. Or alternatively, returns I identified as reflecting news may not do so in reality. Both identification errors could create an upward bias in estimating the fraction of return volatility that can be attributed to trading alone. To evaluate this potential bias I redo the calculations of table 4.2 with a more conservative identification strategy of the arrival of news. Table 4.3 only uses the returns of which I can be absolutely sure that they do or do not contain information brought in by the packet boats. Unfortunately, this stricter definition implies an effective reduction in the sample size (see appendix A for details). Results are reported in table 4.4.

Table 4.3 Estimates of return volatility, conservative definition

| | $V\left(R_{it}^{NEWS}\right)$ | $N$ | $V\left(R_{it}^{NONEWS}\right)$ | $N$ | $VI_i$ | $VT_i$ |
|---|---|---|---|---|---|---|
| EIC | 0.87 | 291 | 0.24 | 213 | 0.72 | 0.28 |
| SSC | 0.20 | 291 | 0.10 | 213 | 0.48 | 0.52 |
| BOE | 0.17 | 291 | 0.08 | 212 | 0.55 | 0.45 |

Table presents the return variances in the presence and absence of news. Returns are calculated according to equation (4-1) and are in percentages. In the final two columns the relative contributions of news and trade related factors are calculated. The sample is confined to returns of which it is absolutely certain that they contained news or not.
Source: see figures 4.1-4.3

From table 4.3 it becomes clear that using a more conservative identification strategy changes results quantitatively: now between 27 and 52 percent of volatility is unrelated to the arrival of news. Qualitatively conclusions are unaltered: news matters, but a large fraction of volatility is caused by factors unrelated to news.

Another possible worry is that the share prices reported in the Amsterdamsche Courant were in fact prices of future contracts. As I discuss in more detail in Appendix B, the futures market in Amsterdam was quite developed and most transactions took place in this market. In contrast, in London prices were always reported for spot contracts. The relation between the two prices is given by the following non-arbitrage condition:

$$FP_{it} = SP_{it} e^{r_t(\tau - t)/T} \qquad (4\text{-}7)$$

where $FP_{it}$ is the future price of asset $i$ at time $t$, $SP_{it}$ is the spot price and $\tau$ is the settlement date. This expression includes the short term interest rate $r_t$ that is charged for $T$ periods. The $e^{r_t(\tau-t)/T}$ component is usually called cost-to-carry.

Equation (4-7) implies that prices in Amsterdam were structurally higher than in London (Neal 1990), where the difference is given by the cost-to-carry element. Because I am looking at returns in this paper, and not at the differences between the two prices, the fact that Amsterdam reports future instead of spot prices is not a problem. To see this note that

$$\begin{aligned}\Delta FP_{it} &= \log FP_{it} - \log FP_{it-1} \\ &= \log SP_{it} - \log SP_{it-1} + (r_t - r_{t-1})\frac{(\tau - t)}{T} + r_{t-1}\frac{\Delta t}{T}\end{aligned} \quad (4\text{-}8)$$

If $r_t = r_{t-1}$ and $\Delta t$ is small, future returns almost equal spot returns.

There is one worry though, namely that return volatility in the absence of news could for some part be caused by fluctuations in the short term interest rate (so $r_t \neq r_{t-1}$). Unfortunately, no interest rate series is available for a frequency similar to the data on the share prices[12], so I cannot directly control for this. However, there is an indirect way to determine the influence of short term interest rates on volatility. The futures market was organized in a slightly different way than today. Similar to today a trader could enter into a transaction in which he promised to buy or sell an asset in the future, but this point in the future was restricted to clearing periods or *rescontres*. These *rescontres* were organized 4 times a year and their dates were fixed in advance. So essentially there were only a limited number of settlement dates available. The *Amsterdamsche Courant* always reported the price of a future contract to be settled during the next settlement period. This means that the time until settlement ($\tau - t$ in equations 4-7 and 4-8) of the future contracts reported was always between 1 day and three months.

I can make use of this variation in the following way. Equation (4-8) shows that the cost-to-carry component is the smallest when the time to settlement is the shortest. This implies that if interest rate fluctuations have a significant impact on overall volatility, the volatility of returns should on average be higher in periods further away from the settlement period. This can be easily tested. Table 4.4 reports the volatility of returns without news with a long time to settlement (between 2 months plus one week and 3 months, columns A) and with a short time to settlement (between 3 weeks and 1 day, columns B).

Table 4.4 Return volatility for different times to settlement

| | EIC | | BOE | | SSC | |
|---|---|---|---|---|---|---|
| | A | B | A | B | A | B |
| $V\left(R_{it}^{NONEWS}\right)$ | 0.19 | 0.21 | 0.08 | 0.14 | 0.05 | 0.14 |
| N | 81 | 92 | 81 | 92 | 80 | 92 |
| p-value B-F test | 0.51 | | 0.41 | | 0.16 | |
| p-value K-S test | 0.76 | | 0.98 | | 0.86 | |

Columns A reports the variance of returns taking place in the absence of news on future contracts with time until expiration of 2 months and one week or longer. Columns B reports the variance of no-news return on future contracts with time until expiration of three weeks or shorter. The final two rows report the p-values of Brown-Forsythe and Kolmogorov-Smirnov tests on the equality of the variance of columns A and B.

[12] See Flandreau et al. 2007 for interest data with a lower frequency extracted from bill of exchange data

Source: see figures 4.1-4.3

The table indicates that fluctuations in the short term interest rate had a negligible impact on the volatility of share prices. The difference between the variance of returns on futures with a short time to settlement and that on future contracts with a long time to settlement is not statistically significant. If anything, it seems that returns on future contracts with a shorter time to maturity actually had a higher instead of a lower variance.

A final concern regards the selection of the sample period. The analysis in this paper focuses on the period 1771-1777. One of the reasons for this choice is that during these years no continental wars took place that could generate price relevant information on the continent. In addition no financial crises took place during this period that centered on Amsterdam. The selection of the period was done with care to ensure that information flowed in one direction only (see section 3.1 for more detail on this point). It is clear to see that if news flowed in both directions, the identification strategy of this paper would break down. The downside of this selection procedure is that, from the perspective of the 18th century, the period 1771-1777 was relatively tranquil. In other words, relatively little information was generated. This means that the volatility generated by the arrival of news could be biased downwards through this sample selection bias. One way to check whether this sample selection bias has a big impact is to redo the calculations of table 4.2 with the most volatile stock during the most volatile period. Figure 3.1 shows that the price of EIC stock between September 1772 and December 1773 was especially volatile. Redoing the calculations for this stock, for this specific sub-period reveals that the fraction of volatility that can be attributed to news is 72%. This figure can be seen as the upper bound of volatility than could be attributed to news. To conclude, news is very significant in explaining price changes, but the market environment plays a large role in understanding why stock prices were as volatile as they were.

## 5 Robustness checks

### 5.1 Slipping through of news

Because of its efficiency and official status, the packet boat service was the most important channel for English news to reach the Dutch Republic. Nevertheless, it is not unthinkable that at times news reached Amsterdam through alternative channels, most importantly through the use of fisher boats. How important was this slipping through of news for share price fluctuations in Amsterdam? The variation in weather conditions on the North Sea and sailing times of packet boats allows me answer this question.

Sailing times were largely determined by the direction of the wind. Specifically, if the wind was blowing from the east, packet boats took longer to reach Hellevoetsluys. This means that I can isolate periods in which packet boats had trouble in getting across the North Sea. The main idea is that during these periods fishing boats (and even post pigeons) would have had similar problems. From the *Rotterdamsche Courant* it becomes clear that if the packet boat could not arrive, other boats from England did not arrive either. The packet boats even seem to have outperformed other boats: in storms or other types of bad weather, the packet boats were the first to get through.[13] Given that post pigeons could not be used in bad weather conditions (section 3.3), the same is likely to be true for pigeons.

Even under good weather conditions the Amsterdam market could have days without news coming in from England. The packet boat service allowed for only two crossings a week and regularly Amsterdam prices did not reflect any new information, even if the weather conditions would allowed for the crossing of the North Sea. This allows me to compare the volatility of 'no-news' returns under good and bad weather conditions. Under good weather conditions other boats would have been able to get across the North Sea to bring in news from England, whereas under bad weather conditions this would have been impossible or at least very difficult. If the slipping through of news was an important factor, there should be a significant difference between no-news returns taking place under good and bad weather conditions.

Figure 5.1 presents distributions of the returns on the EIC in Amsterdam. Distributions are drawn for three regimes: (1) returns taking place after the arrival of news, (2) returns in the absence of news and (3) returns in the absence of news, during bad weather conditions. Periods of bad weather conditions are defined as periods in which the packet boat had a sailing time bigger than the median sailing time of three days. The figure makes clear that the distribution of returns in the absence of news is largely the same whether the weather was bad or not. Unreported Brown-Forsythe and Kolgomorov-Smirnoff tests confirm that these two distributions do not differ significantly.

Table 5.1 redoes the volatility decomposition of table 4.2 but restricts the no-news data to periods of bad weather. Comparing table 5.1 with table 4.2 shows that the fraction of volatility that can be attributed to factors unrelated to the arrival of news hardly changes when this restriction is made. Only in the case of the BOE does the fraction of volatility that can be attributed to the arrival of news go up. In other words, the volatility of returns in the absence of news was the same regardless of the weather. This is a strong indication that alternative ways of getting news across the North Sea, even if the weather was favorable, were not used.

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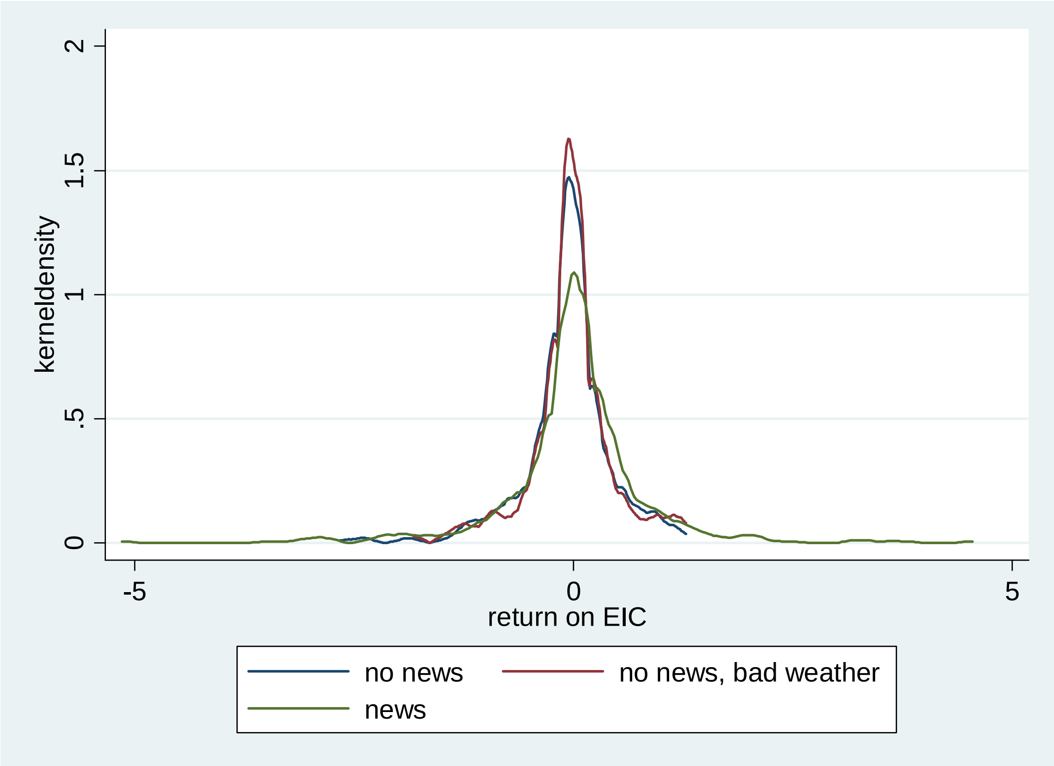
[13] Take for example January 1776, a month of very foul weather with wind blowing almost continuously from the east. Almost no ships managed to reach Holland. On February 4 1776 a certain Captain Gerbrands finally arrived in Hellevoetsluys, having departed London already on January 5. According to the newspaper, his ship had been blown completely of course all the way down south to Beachy Head (East Sussex, south of Dover) and it had taken weeks for it to fight its way back to Hellevoetsluys. In this period, the arrival of packet boats was highly irregular as well, but none of them took as much as 30 days to sail across the North Sea.

Figure 5.1 Kernel densities rEIC: news, no news and no news during bad weather




The figure presents kernel distributions of the EIC returns in Amsterdam. Kernel distributions are drawn for three different regimes: (1) returns taking place after the arrival of news, (2) returns in the absence of news and (3) returns in the absence of news, during bad weather conditions. Returns are calculated according to equation (4-1) and are in percentages.

Source: *Amsterdamsche* and *Rotterdamsche Courant*, September 1771 – December 1777

Table 5.1 Estimates of return volatility, no news bad weather only

| | $V\left(R_{it}^{NEWS}\right)$ | $N$ | $V\left(R_{it}^{NONEWS}\right)$ | $N$ | $VI_i$ | $VT_i$ |
|---|---|---|---|---|---|---|
| EIC | 0.76 | 518 | 0.24 | 163 | 0.68 | 0.32 |
| SSC | 0.24 | 518 | 0.11 | 163 | 0.56 | 0.44 |
| BOE | 0.17 | 518 | 0.08 | 165 | 0.50 | 0.50 |

Table presents the return variances in the presence and absence of news. Returns are calculated according to equation (4-1) and are in percentages. In the final two columns the relative contributions of news and trade related factors are calculated. No news returns are based on bad weather periods only (see text).

Source: see figure 5.1

## 5.2 The Amsterdam financial market as a source for information

Fluctuations in the discount rate (i.e. the expected return investors demand for holding a certain asset) are a key determinant for asset prices. A number of studies argue that, at least on a monthly frequency, fluctuations in discount rates are important for understanding asset price fluctuations (Campbell and Shiller 1988 and Vuolteenaho 2002). This could be true on a daily frequency as well.

Dutch investors held a substantial fraction of the English stocks (see section 2) and it is therefore plausible that changes in the Dutch discount rate were important for share prices. Depending on whether discount rates can change significantly from one day to the next, they could be a driver of the returns in Amsterdam in the absence of news. Their impact must have been small at most. Amsterdam returns on the English stocks had practically no predictive power for London returns, implying that Dutch discount news did not have an impact on London prices. Nevertheless, it is possible that discount rates can explain part of Amsterdam returns in the absence of news.

This argument can be tested using the following approach. Apart from trade in the English stocks, there was also an active trade in Amsterdam in shares of the VOC, the Dutch East India Company. If changes in the discount rate had an impact on the share prices of the English stocks, it is likely that they also influenced the share price of the VOC. The importance of fluctuations in Dutch discount rate can therefore be gauged by looking at the co-movement of the English stocks and the VOC on days when no news was coming in from England.

Table 5.2 presents the results from regressing the return on the English funds on the returns on VOC stock in the absence of news. The table shows that returns on the VOC and the English stocks behaved independently. This is an indication that either discount rate fluctuations had a very limited impact on day-to-day changes in share prices or that the Dutch discount rate was not important for the pricing of English stocks.

Table 5.2 Co-movement English stocks with VOC returns, no news

| | Amsterdam return | | |
|---|---|---|---|
| | EIC | SSC | BOE |
| Return on VOC | 0.0420<br>(0.4520) | 0.0070<br>(0.8540) | 0.0290<br>(0.2990) |
| Constant | -0.0010<br>(0.0400) | 0.0000<br>(1.0000) | 0.0000<br>(0.3000) |
| R2 | 0.00 | 0.01 | 0.00 |
| N | 330 | 330 | 329 |

Results from regressing Amsterdam returns of London stocks on VOC returns, in the absence of news.
P-values based on bootstrapped standard errors (1000 replications) reported in parentheses.
Sources: see figure 5.1

### 5.3 The speed of information absorption

An important assumption of the natural experiment presented in this paper is that news brought in from London was immediately absorbed into prices. If this were not the case, the distinction between returns taking place with or without news would lose some of its value. The assumption that prices immediately absorbed information seems a natural one. Part of the information investors in Amsterdam received was simple to process: the prices of the stocks in London. It seems likely that prices in Amsterdam would have reflected this immediately.

This assumption can be tested more rigorously. A standard test in the literature on the absorption of news is to look at the time series properties of the return series. If the return series exhibit serial correlation, this is an indication that news is not immediately absorbed by prices. Negative serial correlation would indicate that prices initially overshoot and are corrected later on. Positive serial correlation would indicate that prices slowly reflect changes in the return series.

A first pass at this issue is to look at the autocorrelation and partial correlation coefficients of the series of EIC returns. These are presented in figures 5.2 and 5.3

Figure 5.2 Autocorrelation coefficients rEIC

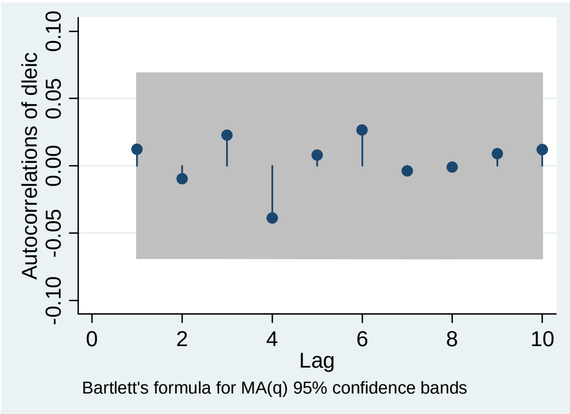
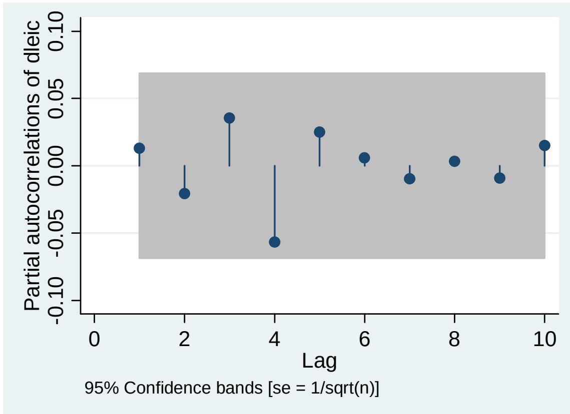



Figure 5.3 Partial Autocorrelation coefficients rEIC




Source: see figure 3.1.

Figures 5.1 and 5.2 clearly show that the evidence for autocorrelation in the return series for the EIC is weak. Autocorrelation coefficients are small and not significant at the 5% level.

A more formal test on the time series properties of the return series is a Portmanteau Q test on whether the series is white noise or not. These tests are performed on the return series for all three companies. All companies give the same result: the null hypothesis of white noise cannot be rejected at normal confidence intervals.

Table 5.3 Portmanteau Q test for white noise returns

| | Q statistic | p-value | Obs. |
|---|---|---|---|
| EIC | 49.04 | 0.1546 | 817 |
| SSC | 36.70 | 0.6198 | 817 |
| BOE | 28.12 | 0.9211 | 814 |

Under the null hypothesis of the Portmanteau test, returns resemble a white noise process. Source: see figure 5.1.

Finally it is possible to try to fit an explicit autoregressive process to the return data. Because the arrival of news may matter for the autoregressive process, the following model is fitted to the Amsterdam return series of EIC stock:

$$R_t = \rho^{news} \delta_{t-1}^{news} R_{t-1} + \rho^{nonews} \delta_{t-1}^{nonews} R_{t-1} + \delta_{t-1}^{news} + \delta_{t-1}^{nonews} + \varepsilon_t \qquad (5\text{-}1)$$

This equation captures the fact that returns that take place in the presence of news may have a different impact on subsequent returns than returns that occur in the absence of news. $\delta_{t-1}^{news}$ is a dummy variable taking the value of 1 if news arrived in the previous period,

$\rho$ is a regular autocorrelation coefficient and the coefficient $\rho^{news}$ allows the autocorrelation to differ when news arrived in the previous period.

The results of estimating equation (5-1) with OLS (with bootstrapped standard errors) and a Box-Jenkins model are presented in table 5.4. Both estimations give the same results. The two autocorrelation coefficients are not significantly different from zero. The impact of a previous news return is close to zero and slightly positive. This is an indication that a return that takes place after the arrival of news has no predictive power whatsoever for future returns. In this sense the market is efficient. The impact of a previous non-news return is somewhat negative. In other words, there is some evidence that a return that takes place in the absence of news has the tendency to mean revert. This effect is statistically insignificant though and a Chi-squared test confirms that the two coefficients are not statistically significant from each other.

Table 5.4 Autocorrelations in EIC returns

| | EIC returns | |
|---|---|---|
| | OLS | Box-Jenkins |
| $\rho^{news}$ | 0.0286<br>(0.5620) | 0.0286<br>(0.5710) |
| $\rho^{nonews}$ | -0.1310<br>(0.2550) | -0.1310<br>(0.2570) |
| $\delta_{t-1}^{news}$ | -0.0248<br>(0.4480) | -0.0248<br>(0.4450) |
| $\delta_{t-1}^{nonews}$ | 0.0206<br>(0.6250) | 0.0206<br>(0.6310) |
| Sigma | | 0.7217<br>(0.0000)*** |
| R2<br>N | 0.01<br>759 | <br>759 |
| Chi2-test on $\rho^{news} = \rho^{nonews}$ | 1.63<br>0.2011 | 1.6<br>0.2055 |

This table presents results from estimating equation 5-1 (see text). The first column presents estimates based on regular OLS estimation while the second column presents estimates based on Box-Jenkins estimation. P-values are presented in parentheses. The p-values of the OLS estimates are calculated using bootstrapped standard errors (1000 replications).
Source: see figure 5.1

To summarize, the evidence presented here seems to indicate that all information that was publicly available to investors was immediately absorbed into asset prices. Or in other words: on a day to day basis past stock returns could not predict future returns. From this perspective the Amsterdam market was efficient (Neal 1990).

## 6 Conclusions

How much of the short run volatility asset prices is due to news on the true value of a stock and how much can be accounted for by factors unrelated to the arrival of information like trading frictions, behavioral factors or asymmetric information? In this paper I have used a natural experiment provided by the 18$^{th}$ century Amsterdam equity markets to approach this question. In the 18$^{th}$ century a number of British stocks were traded on the Amsterdam exchange and all relevant price information from England reached Amsterdam through the use of mail boats. This paper identifies periods in which these boats could not sail because of the weather and analyzes what this lack of information implied for the volatility of the British stocks traded in Amsterdam. I show that asset price volatility during periods without news was between half and two thirds of the volatility that is observed during periods with news. This suggests an important role for factors unrelated to the arrival of news in the day to day movement of asset prices.

I present an array of empirical tests on the validity of the experiment. I show that, at least for the period under consideration, practically all news was generated in London. I find very little evidence that news was flowing in the opposite direction or could originate from a third center like Paris. The data is also consistent with the interpretation that most of this news, if not all, reached Amsterdam through the use of mail packet boats. Co-movement between Amsterdam and London prices was limited when the packet boats were not sailing. In addition, in the absence of official news the volatility of asset price movements was insensitive to the weather conditions on the North Sea. This suggests that practically no English news managed to slip through between official boats. Finally, I show that news was immediately absorbed into prices.

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## Appendix A: Identifying the arrival of news

### A-1 Benchmark identification

There are two sources available that allow me to infer when news arrived in Amsterdam: the arrival dates of the 'English letters' in Hellevoetsluys and the dates at which the news from these English letters was published in the *Rotterdamsche Courant*. Based on these two pieces of information it is possible to determine when news arrived in Amsterdam. To understand how both sources can be used I will first discuss some details of the transportation of letters from London to Amsterdam. Having explained this I will turn to the exact way in which I have used both sources to identify the arrival of news.

As mentioned in the main text, the mail packet boats that brought news from London sailed from Harwich to Hellevoetsluys. In this small harbor near Rotterdam the post bag with English letters was offloaded and from there was sent directly to Brielle. Only here the post bag was opened and the different packages were sent to the respective towns in Holland, among which were Amsterdam and Rotterdam. The reason for this somewhat strange construction was that this ensured that all Dutch towns, especially Rotterdam and Amsterdam would receive the English news at the same time, so that no town could extract any benefits from receiving the news any earlier than the others (Stitt Dibden 1965 and Hogesteeger 1989).

All transport within Holland took place by coach. This way of transport was relatively independent of the weather[14] and the time a coach took to go from one city to another was more or less constant (Knippenberg en de Pater 1988, p. 55)[15]. The information available indicates that it took less than a day for the letters from Hellevoetsluys to reach Amsterdam. A map from 1810 with the main mail connections in Holland indicates that it took around 10 hours for the mail to travel between Hellevoetsluys and Amsterdam (Knippenberg en de Pater 1988, p. 55)[16].

From the *Rotterdamsche Courant* there is information available on what day a specific packet boat arrived. Unfortunately the paper does not give an exact time of arrival in Hellevoetsluys. However, from 1774 onwards the newspaper does indicate whether a boat arrived in the morning or afternoon. Together with the average time it took for a coach to reach Amsterdam it is possible to get an approximate indication when the English letters arrived in Amsterdam.

Sometimes, this dating procedure leads to ambiguous results. Take the example of a boat that arrived on Monday. If the boat had arrived early in the morning the news would reach Amsterdam on the same day. If the boat arrived during the end of the morning, news would reach Amsterdam only on Tuesday, a day later. In order to determine more precisely when the English news arrived in Amsterdam, I use the dates of publication of the English news in the *Rotterdamsche Courant*. This newspaper appeared three times a week (on

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[14] The only exception is heavy snowfall. Going through the Amsterdamsche and Rotterdamsche Courant, I found that only very seldom coach services were seriously delayed by the weather.
[15] See also table of transport times of mail to European destinations in Ten Berg (1969, p. 21). While the time for a letter to reach London 'depended on the weather', the time to destinations reached by coach (like Antwerp and Brussels) was constant.
[16] Stitt Dibden (1965) mentions a transport time of 14 hours.

Tuesday, Thursday and Saturday) and was a morning paper that reported all news that had come in up to the previous day. Based on the editorials from *Rotterdamsche Courant* it seems that the newspaper was sent to the printers early in the evening the day before it came out. The English news reports in the *Rotterdamsche Courant* can be used to determine the arrival of the news in Rotterdam. Take the example of a boat that arrived in Hellevoetsluys on Monday. If the news it brought in was published in Tuesday's paper, this indicates that the news arrived in Rotterdam on Monday in time to be published in next day's paper. If on the other hand the news was published in Thursday's paper, this is an indication that the news must have arrived in Rotterdam Monday evening or on Tuesday.

Because the English letters arrived in Rotterdam more or less at the same time as they arrived in Amsterdam (see the discussion before), it is safe to assume that if news arrived in Rotterdam, it arrived in Amsterdam as well. Taking a closer (unreported) look at the data, I learned that when the English news had arrived early enough to be published in the *Rotterdamsche Courant*, the share prices of the English stocks in Amsterdam that were reported for that day also reflected this news. When, on the other hand, the news arrived too late to be published in newspaper, prices in Amsterdam also did not reflect this news. In short, this implies that the days of publication of the English news in the *Rotterdamsche Courant* allow me to time quite precisely when the English news arrived in Amsterdam. Together with the arrival dates of boats in Hellevoetluys, I can therefore determine which shares prices reflected news from England and which ones did not.

## A-2 Robustness checks

Although I believe that my identification strategy is quite precise, I do perform one robustness check. I redo the identification of the arrival of news in Amsterdam using the arrival dates of the packets boats in Hellevoetsluys only. In other words: I do not use any information provided by the publication of the English news in the *Rotterdamsche Courant*. Instead I assume that news that arrives in Hellevoetsluys on a certain day, can reach Amsterdam the same or next day. Consequently I only use the asset prices of which I can be completely sure that they contain new information or no information at all. This implies throwing away a large part of the data, making the estimates less secure, but I can be totally confident that these estimates will not be biased. Figure A-2 shows this more clearly.

Figure A-2: Identification robustness checks, dropping of observations

| Day | Arrival Boat | Arrival Amsterdam | Share prices | Prices with news? |
|---|---|---|---|---|
| Sun | A | A? | | |
| Mon | | A? | X | Yes |
| Tue | | | | |
| Wed | B | B? | X | Yes/No (dropped) |
| Thu | | B? | | |
| Fri | | | X | Yes/No (dropped |
| Sat | | | | |
| Sun | | | | |
| Mon | | | X | No |
| Tue | C | C? | | |
| Wed | | C? | X | Yes |

Letters indicate linked observations, grey colour indicates which days the newspaper appeared

## Appendix B: asset prices in 18th century Amsterdam

The exact character of the asset prices reported by the Amsterdamsche Courant is of great importance for this paper. Two important issues are at stake here: are prices spot or on time and do they reflect brokers' quotes or are they actual transaction prices?

### B-1 Spot or on time?

The main contributions that use the asset prices from the *Amsterdamsche Courant* mention that from 1747 onwards prices probably referred to 'prices on time' or future prices (Van Dillen 1931 and Neal 1987, 1990). This observation is based on the fact that the *Amsterdamsche Courant* reported, together with the price of the share, the month in which a transaction would be settled.

It is not immediately clear how these 18th century prices on time compare to the modern day definition of a forward or future and how these prices should exactly be interpreted. Smith (1919) gives a thorough description of the different type of time contracts that were used on the 18th century Amsterdam stock exchange. Together with a number of transaction contracts (see Neal 1987, p. 111, Dickson 1967, p. 335 and several examples in the Amsterdam City Archives N.12 collection) it is possible to figure out how the stock prices reported in the *Amsterdamsche Courant* should be interpreted.

In 18th century Amsterdam a transaction on time involved the following: party S would sell its shares to party B, but the actual transfer of the shares would only take place during the so-called periods of 'rescontre' (settlement). In the 18th century this process was entirely standardized. Settlement periods usually lasted two weeks which specialized 'rescontreurs' would settle all transactions. There were four of such rescontre periods in a year (during the 1770s in February, May, August and November). Just as today the payment for the delivery of an asset was also deferred to the future (Smith 1919). So far this closely resembles current day future contracts. The 18th century contracts differed only in one detail: all dividend or interest payments made before the day of settlement accrued to B and not to S. Any dividend or interest payments made in this period would be deducted from the price B would have to pay S on the day of settlement.

So even although the shares were still legally held by the seller, the parties acted as if the buyer was already the possessor of the stock. This has some implications for the way investors would have priced time contracts. Essentially an 18th century contract on time resembled the spot purchase of a share with the postponement of the payment to a certain (fixed) point in the future. The relation between a spot price and the price on time can therefore be expressed as:

$$FP_{it} = SP_{it} e^{r_t(\tau - t)/T} \tag{B-1}$$

where $FP_{it}$ is the future price of asset $i$ at time $t$, $SP_{it}$ is the spot price and $\tau$ is the settlement date. This expression includes the short term interest rate $r_t$ that is charged for a $T$ periods.

This expression closely resembles that of modern day futures and implies that different settlement dates coincide with different prices on time.

The most important difference between 18th century contracts on time on modern day futures regards the influence of dividend or interest payments on the price. After the payment of dividend or interest, the price the 18th century time contract would go ex-dividend. It can be shown that this not the case for modern day future contracts. These do not go ex-dividend, unless the date of dividend or interest payment coincides with the day of settlement (Hull 2005).

All this implies that there are two testable implications that should hold if this view on 18th century prices on time is correct:

(1) share prices should go ex-dividend

(2) when the date of the 'rescontre' changes from one quote to another (for example from May to August), this should coincide with a rise in the price roughly equal to the three month risk free interest rate (to see this compare equation (B-1) for a large and a small $T$).

Looking at the data both implications are confirmed for the three assets discussed in this paper. All price changes are statistically significant and their size is consistent with the general size of dividends and the level of the three month risk free interest rate.

### B-2 Quotes or market prices?

A second point of importance is whether the prices reported in the *Amsterdamsche Courant* reflected actual transactions or were quotes from brokers. The information from the literature on this is limited. The only thing we know is that prices were drawn up by a number of sworn brokers. In the correspondence between the Haarlem silk merchant Hennebo and his Amsterdam broker Bevel from the 1730s, references are made to official prices posted in the wall of the synagogue (Van Nierop 1931, p. 57). This service was commissioned and monitored by the City of Amsterdam and represented official prices that were used as a reference by investors and authorities alike (Smith 1919, p. 109 and Jonker 1996, p. 147).

There are a number of reasons to believe that the prices reported by the newspaper were not quotes given by market makers or specialists. The first thing to note is that the market did not operate through specialists or market makers. Rather buyers and sellers traded directly with each other (Polak 1924, p. 199-200). As a rule buyers and sellers themselves were not physically present on the exchange but used brokers to act in their interest. This implies that the market did not revolve around quotes made by market makers. Rather people wanting to buy or sell assets gave their broker a limit order and brokers must have coordinated amongst themselves to clear the market in the most efficient way possible. The correspondence between Hennebo and Bevel is a good example of how this system worked. Hennebo would give Bevel a limit order and he would only learn later on whether Bevel had been able to execute his order. Bevel would always point to the official price of the day to convince his master that it had really not been feasible to execute an order at a certain price limit (Van Nierop 1931, 64 and 66).

It is possible that some brokers in this market would take positions in the market to clear supply and demand. The official rules for the brokerage guild in the 18th century stated that stock brokers were allowed to trade on their own behalf (SAA 366: 1053). It is questionable however whether this had a big impact on the market. If certain brokers acted as *de facto* market makers to supplement the basic limit order market, this would imply that Hennebo should have transacted with the same counterparties. Or at least, certain brokers should have dominated. This is not the case. All transactions made by Bevel that can be reconstructed were with different brokers. In addition, the brokers he dealt with were always acting for their master, not on their own behalf (Van Nierop 1931, passim). This attests to the relative irrelevance of market makers and it makes it very unlikely that prices reported in the newspaper originated from brokers acting as specialists.

If prices did not reflect quotes from intermediaries, what did they reflect? Again the correspondence between Hennebo and Bevel gives us some hints about what these prices represented. As I said before, Bevel referred to official prices to explain why a limit order could not be filled. This is an indication that the official prices corresponded with market prices that were dominant during the trading day. Still, it is not clear what such a dominant price would have represented: the price of the last transaction, the average price during trading days, or something else?

Foucault et al. (2005) show that, just as in a specialist market, a limit order market will have a spread between bid and ask prices. Patient agents will issue limit orders and impatient agents decide whether they are willing to buy (or sell) against these prices. This means that limit orders determine the bid-ask spread of a market. The main difference with a specialist market is that in a limit order market there is a continuum of bid and ask prices, where each specific bid or ask price reflects a limit order of finite size. Which price will be used in a transaction depends on the exact match made between a patient and impatient agent. For the Amsterdam market this must have implied that there was a range of prices within which transactions were taking place. So, what did the official prices in the *Amsterdamsche Courant* represent?

It is most likely that these prices represented some kind of midpoint or average. This would have made most sense. To see this, consider what the main function of publishing prices in the *Amsterdamsche Courant* must have been. The newspaper would always be reporting prices of the previous day. This information would be of little value for at what price a transaction on the current day would be executed. For up to date information it would have been far more efficient to ask a broker (see Van Dillen 1931 for examples of brokers' private price slips). The function of the newspaper prices must have been a different one: monitoring (Polak 1924 and Hoes 1984). As I described, the market operated through investors giving limit orders to brokers. This implies that investors had a need to monitor their brokers. Brokers could cheat them in various ways. They could be lazy and not execute a limit order while the market price did allow them to do so. Alternatively they could execute a buying (selling) order at the limit price, while the market price had already changed to a lower (higher) level. The prices in the *Amsterdamsche Courant* were an official source of information, supervised by the City of Amsterdam, and could be used to monitor brokers. As I said before, Bevel referred to the official prices to convince his principal Hennebo that he had acted faithfully. From this perspective it would have made most sense if the official prices reflected something like a midpoint of all transactions taking place. This way both buyers and sellers could check up on the brokers acting in their interest.

Unfortunately there is no transaction data available to test this interpretation[17]. The only data I have available are on a limited number of transactions made by Bevel for his principal Hennebo. Foucault et al. (2005) argue that the person giving a limit order will never initiate the transaction. It will be always an impatient agent that decides to buy (or sell) at the limit price offered by a patient agent. This means that the agent giving the limit order will always sell at the (higher) ask price and buy at the (lower) bid price. If the prices in the *Amsterdamsche Courant* indeed reflected the midpoint of going market prices, this implies that (1) a sale made in Hennebo's name should be equal or exceed the official price and (2) a purchase made in Hennebo's name should be smaller or equal to the official price. For all transactions made by Bevel for Hennebo this is the case.

Another point to note is that if the *Amsterdamsche Courant* reported the mid-point of market prices, this should imply that there is no bid-ask bounce in the data. In section 5 I showed that there is no autocorrelation in the data and this consistent with the absence of a bid-ask bounce.

[17] Hopefully future research will uncover sources for transaction data.