The boats that did not sail.
News, trading and asset price volatility in a natural experiment[*]

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Abstract

How much of the short run volatility of asset prices is due to the arrival of news? How much can be accounted for by other factors like behavioral biases or frictions in the market microstructure? In today's markets these questions are difficult to answer because of the complexity of information flows. I use a natural experiment to answer them. During the 18th century a number of British stocks were traded on the Amsterdam exchange and all relevant information from England reached Amsterdam through mail boats. I reconstruct the arrival dates of these boats. This allows me to identify the flow of information directly. I then measure the effect of information on the volatility of the British stocks traded in Amsterdam. Stock prices moved significantly more after the arrival of news. Nevertheless in the absence of new, public information, price changes were still considerable. Volatility in "quiet" periods amounted to between 50 and 70% of that observed in periods with news.

I construct a model of share trading with frictions that explains why asset prices move in periods when no new public information reaches the market. The model analyzes how an insider trades on his private information. An informed agent unveils his information only slowly and information asymmetry, although decreasing, remains. Prices will be inherently

volatile even if no public news reaches the market. Private information also has an effect on uninformed trading. As information asymmetries gradually decrease, it becomes less costly for uninformed agents to trade. In consequence, uninformed trading increases over time. When the impact of private information on volatility becomes less dominant, a larger fraction of asset price movements is explained by uninformed trading. Empirical results for share trading in 18th century Amsterdam are consistent with the model's predictions.

JEL Codes: G14, N2, D82, F36
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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 only reflect the arrival of news about future cash flows or investors' discount rates. However, Cutler, Poterba and Summers (1989) argue that "many of the largest market movements have occurred on days when there were no major news events".[1] This finding is echoed by many other studies that find that public news has a limited impact on asset prices (e.g. Mitchell and Mulherin 1994). What explains this puzzling finding? DeLong et. al (1990) argue for a behavioral explanation in which irrational noise traders have a persistent impact on the volatility of asset prices.[2] An alternative explanation lies in the microstructure of financial markets. Trading frictions caused by asymmetric information or limited risk bearing capacity could lead to price movements in the absence of news (e.g. Romer 1993, see O'Hara 1997 for an overview).

So far no general consensus has emerged about the relative importance of public news and trading for asset price movements. A number of papers construct proxies that measure the intensity of news directly (e.g. Mitchell and Mulherin 1994 and Berry and Howe). These proxies only explain a small fraction of volatility. This finding is probably not due to the irrelevance of public news but to measurement problems. Today's information flows are so complex that it is difficult to identify the impact they have on prices (Kalev et al. 2004). Others compare asset price volatility for periods with and without trade (e.g. French and Roll 1986). They show that volatility is significantly higher in the presence of trading than when trade is restricted. However, trading and the flow of public information usually occur at similar moments in time. This makes it difficult to identify their independent contributions. In addition, the flow of

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[1] See also Fair (2002) who does a similar exercise with high frequency tick-by-tick data and Elmendorf, Hirschfeld and Weil (1996) who look at bond prices between 1900 and 1920.
[2] See also Shiller (2001) and Hong and Stein (2001).

information may not be exogenous and may respond to the trading process, further complicating identification (Fleming, Kirby and Ostdiek 2006).

In this paper I use a natural experiment from financial history to solve these problems. In 18$^{\text{th}}$ century Amsterdam an active trade existed in the shares of three English companies (the East India Company, the Bank of England, and the South Sea Company) (Van Dillen 1931; Neal 1990). The main market for these stocks was in London and most relevant information was generated here. The majority of developments that were relevant for the stock price took place in the English capital. In addition, English investors owned most of the stocks so that relevant discount rate news was also generated in London. English news reached Amsterdam through a mail packet boat service, which was operated by sailing boats especially equipped for this purpose, bringing in public newsletters and private correspondence. The boats were scheduled to leave twice a week, but because of 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 of new information for a number of days in a row, even up to two weeks. Trading in English stocks continued in the meantime and prices kept fluctuating. This setting provides the perfect environment to test the influence of the arrival of news and the trading process on the short run volatility of stock prices.[3]

This natural experiment solves most of the problems in the existing literature. First of all, the experiment allows for a precise identification of news. I will demonstrate that alternative ways by which English news could reach Amsterdam played a minor role. If relevant news did manage to reach Amsterdam through alternative channels, its impact was limited. I also show that news did not originate from Amsterdam or other places on the European continent. Secondly, the flow of information between London and Amsterdam during the 18$^{\text{th}}$ century was exogenous. It would be hard to argue that weather conditions on the North Sea were influenced by the sentiment on the Amsterdam exchange.

The specific historical setting allows me to study the reasons why asset prices move in the absence of the arrival of new information. For this purpose I develop a theoretical model which embeds the two most important frictions discussed in the micro market structure literature; namely asymmetric information (or insider trading) and limited risk bearing capacity. Anecdotal evidence from the 18$^{\text{th}}$ century indicates that both factors played an important role in the market. Because the flow of information is almost perfectly identified, the historical data provides a unique opportunity to test the model and determine the importance of market microstructure frictions for volatility.

During the 1770s and 1780's, the period studied in this paper, the Amsterdam equity market was at its pinnacle. Since the early 17th century an active trade had existed in shares of the Dutch East and West India Companies

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[3]This approach is only feasible in an historical setting with serious constraints on communication technology. Garbade and Silber (1978) show that national and international financial markets were already very well integrated after the introduction of the telegraph in the middle of the nineteenth century (see also Hoag 2006 and Sylla, Wilson and Wright 2006). Going all the way back to the 18$^{\text{th}}$ century is therefore a logical choice.

(Smith 1919; Gelderblom and Jonker 2004; Petram 2010). Around 1700, Dutch investors started to trade shares of the English companies on the Amsterdam exchange alongside the Dutch stocks. Trade in 'the English funds' was an integral part of the Amsterdam exchange (Smith 1919, p. 107; Neal 1987, p. 97). Neal (1990) shows that during most of the 18th century the London and Amsterdam equity markets were highly integrated. In addition, Neal documents that markets were efficient in the sense that return predictability was virtually absent.

I document the flow of information between these two integrated markets and I link it to asset price movements. The arrival of new information had a significant impact on volatility. However, an important component of return volatility of the English shares in Amsterdam can be attributed to other factors. I estimate that between 30 and 50% of total volatility is directly related to the arrival of news. The remainder (between 50 and 70%) was generated by the trading process. These findings indicate that, at least during the 18th century, the trading process itself is a key factor driving asset price volatility.

I argue that asymmetric information, or insider trading, is essential for understanding why the trading process is responsible for such a large fraction of volatility. In the presence of asymmetric information, prices are inherently volatile as every transaction is interpreted as potentially informed and prices move to reflect the (possible) informational content of trades. I develop a model of private information in which it is optimal for an insider to spread his trades over time (Kyle 1985). As a result, asymmetric information is persistent and prices remain volatile, independent of whether any new private information reaches the market or not. In the absence of new private information, informational asymmetries do fall over time as market participants slowly figure out the true informational content of trades. This is a noisy process but in the end the price of an asset does converge to its true value.

In the model the main function of a market is to allow uninformed agents to engage in risk sharing or trade for liquidity motives (Grossman and Miller 1988). This means that even in the absence of insider trading, asset prices will be volatile, as they move to compensate risk averse agents for taking on risky positions. These price movements are short lived and will be reversed when other agents enter the market with different trading demands (Campbell, Grossman and Wang 1993; Wang 1994).

The presence of asymmetric information changes the dynamics of the risk sharing process. The possibility of insider trading increases the implicit trading cost for uninformed agents and as a result there will be less trade for risk sharing motives. This effect is especially pronounced when a new private signal reaches the market and informational asymmetries are high. During periods without new information, these asymmetries will be smaller as the older private signals are already partly incorporated into prices. It thus becomes more attractive for uninformed investors to trade in such periods without new information and risk sharing becomes more prominent (Admati and Pfleiderer 1988; Foster and Viswanathan 1990).

Because of the almost perfect identification of news flows, it is possible to test this model with the historical data. Anecdotal evidence suggests that London insiders not only traded in their own city but also used the Amsterdam market to benefit from their private information. They sent their agents in Amsterdam instructions with the same packet boat service I described before. In this setting the model has two predictions. First of all, even in the absence of information flow, price changes in Amsterdam should be correlated with those in London. This reflects that the same private signal is incorporated into prices in both markets. The empirical results are consistent with this prediction. Secondly, the model predicts that trade for risk sharing motives should be more important during periods in which no new (private) information arrives from England. As said earlier, price movements induced by risk sharing will reverse themselves. The model therefore predicts that price movements that take place in the absence of new information should display a bigger reversal. This prediction is also confirmed by the price data. Additional evidence from a sample of individual transactions shows that markets were not thinner in periods without new information. The reversal of returns can therefore not be explained by the illiquidity of the market during such periods.

This paper is related to four strands in the existing literature. The first group of papers attempts to link the intensity of public information flow to return volatility in equity markets (Mitchell and Mulherin 1994; Berry and Howe 1994; Andersen, Bollerslev and Cai 2000; Kalev, Liu, Pham and Jarnecic 2004; Fleming, Kirby and Ostdiek 2006).[4] In general, the evidence for the relevance of public information flow has been mixed. Certain key events have a big impact on volatility, but in the aggregate the relation between news and prices seems weak. This is most likely due to the fact that news is measured with a large error. Not all news is relevant and not all relevant news has the same impact on prices (Kalev et al. 2004; Boudoukh et al. 2007). As a result, the fraction of daily volatility that can explained by public news lies around 0.01 (Mitchell and Mulherin 1994; Andersen, Bollerslev and Cai 2000). In a closely related paper, Chan, Fong, Kho and Stulz (1996) compare the intra-daily volatility patterns of US stocks with that of European and Japanese stocks that are dual listed in New York[5]. They show that volatility patterns are remarkably similar across the three type of stocks, even though the flow of public information is markedly different. Most notably, the volatility of European stocks in New York is only slightly higher when European markets are open. This points to a small role of public information.

The second group of papers takes the opposite approach and compares volatility between trading and non-trading periods to gauge the impact of trading. These papers analyze a number of instances in which trade is restricted but the flow of news remains constant (French and Roll 1986; Barclay, Litzenberger

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[4] For the link between news and bond prices and exchange rates see Ederington and Lee (1993), Elmendorf, Hirschfeld and Weil (1996), Andersen and Bollerslev (1998), Bollerslev, Cai and Song (2000), Melvin and Yin (2000), and Evans and Lyons (2008).

[5] See also Menkveld, Koopman and Lucas (2007)

and Warner 1990; Ito and Lin 1992; Ito, Lyons and Melvin 1998).[6] 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 argue that these studies do not truly solve the identification problem because the flow of news is not independent of the trading process.

Thirdly, this paper is related to the literature on the importance of private information for asset price movements. Most empirical work takes the price impact of transactions as evidence for the relevance of private information (Easley and O'Hara 1987; Hasbrouck 1991 and related papers). Recently this interpretation has been criticized (Duarte and Young 2009) with some papers calling for a different approach to study the impact of private information (Kelly and Ljungqvist 2009). There is also a theoretical debate about the time it takes for private information to get incorporated into prices. Some papers argue that this may take quite a while (Kyle 1985; Glosten and Milgrom 1985; Holden and Subrahmanyam 1992), while others point to reasons why this could happen very quickly (Holden and Subrahmanyam 1994; Foster and Viswanathan 1996; Chau and Vayanos 2008; Caldentey and Stacchetti 2010). Because private information is by definition unobservable, there is no empirical evidence on this point.

Finally, this paper is related to literature that tries to explain why asset price movements are partially reversed in the short run (e.g. Jegadeesh 1990). A number of papers argue that these reversals are the response to an initial overreaction to news (Cooper 1999; Subrahmanyam 2005). Other papers point to the importance of the limited risk bearing capacity of market participants and the need for prices to move in the short run to make markets clear (see above).[7]

Relative to this literature I make the following contributions. First of all I show that the arrival of news has a bigger impact on asset price volatility than initially thought. However, asset price movements in the absence of new information remain considerable. Secondly, I provide evidence that private information plays an important role in understanding these asset price movements. I show that private information is slowly absorbed into prices. Thirdly, the results in this paper indicate that the overreaction to news hypothesis is probably invalid, or at least does not apply to the 18th century. Return reversals are especially important for price movements in periods when no new information reaches the market. The limited risk bearing capacity argument appears to be more relevant. Finally, the results in this paper suggest that there is a relation

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[6] French and Roll (1986) observe that the NYSE restricted trading during some business days in 1968. They assume that the total flow of information is on average the same on any given business day and 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) apply a similar approach and use certain institutional features of the Tokyo exchange.

[7] Recent empirical work on this point includes Chordia, Roll and Subrahmanyam (2002), Avramov, Chordia and Goyal (2006), Hendershott and Seasholes (2007), Kaniel, Saar and Titman (2008), Andrade, Chang and Seasholes (2008), and Hendershott and Menkveld (2010).

between the degree of asymmetric information and the size of return reversals. Contrary to Grossman and Miller (1988) I therefore argue that large return reversals are not just the result of illiquid markets. They can also reflect a trading environment that is attractive for uninformed traders to engage in risk sharing.[8]

The rest of the paper is organized as follows. Section 2 discusses the historical background and context of this paper in more detail. I provide further details about how the English news reached Amsterdam and how, from a number of various sources, I can reconstruct when this information arrived in Amsterdam. In addition I provide anecdotal evidence about the relevance of private information and market participants' limited risk bearing capacity. Section 3 provides quantitative evidence about the news flows between London and Amsterdam. Section 4 presents estimates of asset price volatility in periods with and without the arrival of new information and forms the core of this paper. The theoretical framework is discussed in section 5. Section 6 provides empirical evidence supporting the model's predictions. Section 7 concludes.

2   Historical background and data

I examine three stocks that were traded in both London and Amsterdam: the East India Company (EIC), the Bank of England (BoE) and the South Sea Company (SSC).[9] The sample sub-periods are September 1771 – December 1777 and September 1783 – March 1787. This paper is not the first to analyze the share prices of these English companies in London and Amsterdam. Neal (1990) and Dempster et al. (2000) study the behavior of share prices on the Amsterdam exchange and compare it to the share prices in London.[10] Neal makes a strong argument for the efficiency of the two markets in the 18$^{\text{th}}$ century. He argues that the return series did not exhibit any return predictability. In addition, Neal and Dempster et al. show 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 archival records give the strong impression that an active trade existed on the Amsterdam exchange in these assets (Van Dillen 1931; Van Nierop 1931; Wilson 1941). 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; Wright 1999). These studies show that during the 1770's more or less one third of the shares in the British

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[8] Admati and Pfleiderer (1988), Foster and Viswanathan (1990) and George et al. (1994)

[9] In addition to these three stocks, two English annuities (the three and four percents) were actively traded in Amsterdam as well.

[10] Neal only had access to the Amsterdam price series from Van Dillen (1931) consisting of two observations a month. Demspter et al. use Neal's dataset.

companies were in the hands of Dutch investors. During the 1780's this fell to around a fifth.[11] 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; Wilson 1941). Nevertheless it seems reasonable to assume that, although the London market for British shares was most important, secondary markets in Amsterdam were not negligible.

2.1   Stocks and sample period

The three British companies analyzed in this study were concerned with a number of activities. The EIC was a trading company that held large possessions in what is today's India. The company's prospects were to a large extent determined by conditions in India. However, during the second half of the 18th century political developments in England started to become of key importance. There was a constant discussion inside and outside the British Parliament about the semi-private character of the company and its public function. In addition, the company required regular bailouts from the English government to stay on its feet. As a result, political gyrations had an important impact on the company's share price (Sutherland 1952).

The Bank of England (BoE) and the South Sea Company (SSC) both operated to help finance the British government debt. The BoE was set up in 1694 to function as the government's banker. In addition, it discounted commercial bills, but on a relatively small scale (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, these activities never really materialized and from 1713 onwards the company predominantly functioned as an investment vehicle in British government debt (Neal 1990). The prospects of both the SSC and the BoE were therefore tied to the British government.

The analysis of this paper rests on the assumption that all relevant information about the English stocks was generated in England. This is not necessarily true for the entire 18th century (Dempster et al. 2000). The period 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). In addition, during the 18th century Amsterdam was still the financial capital of the world. Financial crises like the one in 1763 were centered on the city. It is obvious that such developments were of key importance for the prices of the English stocks.

This has important implications for the selection of the sample period. From the perspective of this paper, one would like to look at periods in which no relevant information was generated outside England at all. These ideal circumstances can never be perfectly met, but for the periods 1771-1777 and 1783-1787 they are closely approximated.
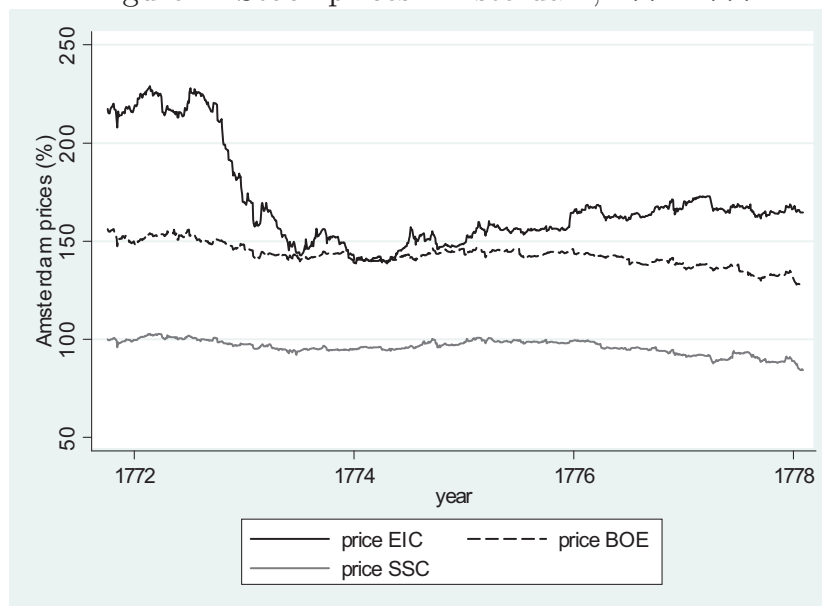
Both periods are characterized by peace on the European continent and the absence of severe financial crises. The starting point of the first period, Sep-

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[11] For the SSC these fractions are slightly higher

Figure 1: Stock prices Amsterdam, 1771-1777

tember 1771, is determined by data limitations. The period stops in December 1777 as tensions between France and England increased, eventually leading to outright naval war in July 1778. The second sample period starts in September 1783, right after the signing of an official peace treaty between France and England. There had been an armistice between France and England since January 1783 and the official peace treaty meant the return to normality. The second sample period stops in March 1787 when domestic tensions in the Netherlands rose, eventually leading to minor skirmishes in May 1787 and an intervention by the Prussian army in September 1787.

Figures 1 and 2 present the developments of share prices during the two periods and illustrate the main developments. The first striking feature of figure 1 is the sharp fall in the EIC price after July 1772. For years the directors of the EIC had paid out dividends that were far too high considering the worrying financial situation the company was in. In 1772 the bomb finally burst. In the spring of that year the EIC had to suspend payments on a loan obtained from the BoE and the bad state of the company was finally revealed (Sutherland 1952). Another event influencing share prices in this period was the American War of Independence that started in 1775. This war had an important impact on the financial situation of the English government. As a consequence the price of English debt (and related stock like the BoE and the SSC) fell from 1775 onwards. An important point here is whether news from America would reach Amsterdam directly or 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, a closer inspection of the Dutch newspapers of the period indicates that all America-related information came from London.

Figure 2: Stock prices Amsterdam, 1783-1787
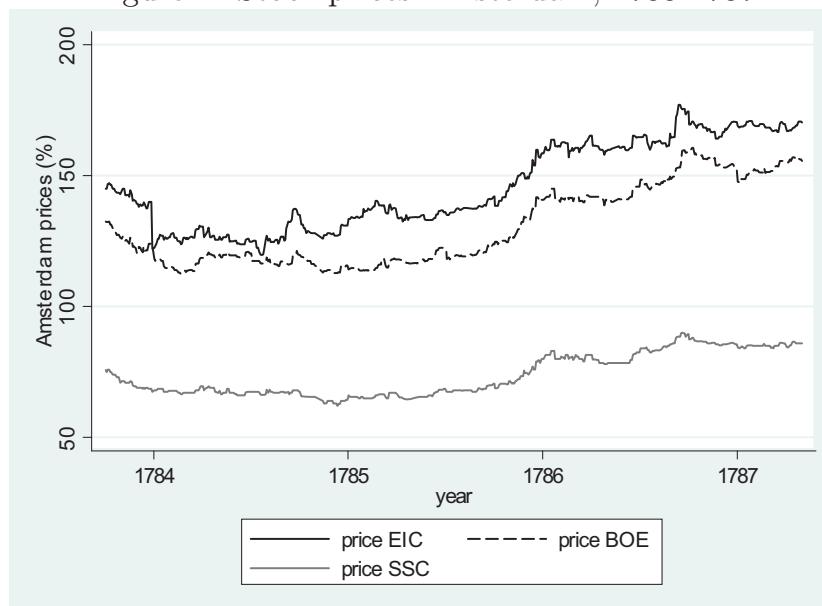
The second period between September 1783 and March 1787 shows a steady increase in all stock prices due to the relaxing international environment after the conclusion of the American War of Independence, which had also implied war between England and European countries like France and the Dutch Republic. One episode jumps out, the dramatic fall in the EIC stock after 18 November 1783. That day Prime-minister Fox gave a speech in the House of Commons in which he revealed the dire straits the EIC was in at that moment and most importantly, stated that the EIC would receive no government bailout. (Sutherland 1952, p. 375).

2.2 The flow of information between London and Amsterdam

How exactly did the English news reach Amsterdam? England and the Dutch Republic were connected through a system of sailing ships, at the time referred to as packet boats. The system was organized between Harwich and Hellevoetsluys, a important harbor close to Rotterdam (see figure 3). Since Amsterdam did not have a direct connection with the North Sea (boats had to sail across the isle of Texel), this was the fastest way information from London could reach Amsterdam (Hemmeon 1912; Ten Brink 1969; Hogesteeger 1989; OSA 2599).

Each packet boat brought in papers and other newsletters with information about the recent developments in London, including the most recent stock prices. In addition, the packet boats brought in private letters from London correspondents filled with political and economic news and updates about stock market conditions[12].

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[12]Wilson (1941, pp. 74-75) gives a number of examples where people with an interest in

Figure 3: Map of the North Sea

This service had existed since 1660 and was set up by the City of Amsterdam to ensure a swift and regular information flow from England. Two boats per week were scheduled to leave Harwich on Wednesday and Saturday afternoon. Letters were collected in London at the end of the previous day, to be sent to Harwich by horse drawn coach in the early morning. Throughout the entire sample period I found no deviations from this schedule. On the other side of the North Sea, similar horse drawn coaches were waiting for the letters to transport them to their final destination. Once the letters had arrived there, they were uniformly distributed (Van Nierop 1931). The same service existed in the opposite direction to transport news from Amsterdam to London.

Steam power was 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 Great Britain 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. The captains sailing the boats did so for decades, probably giving them great expertise which added to the efficiency of the system. (Hemmeon 1912, p. 115-116).

the English stocks received private correspondence from London. For other examples of such letters see the correspondences the Amsterdam broker Robert Hennebo and the bankers Hope & Co maintained with their agents in London (Van Nierop 1931, passim and SAA 734; 78,79, 115 and 1510) and the estate of the Jewish broker Abraham Uziel Cardozo (SAA 334; 643).

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 two 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.

Despite these precautions the packet boats still depended on the wind to get across the North Sea. 18$^{\text{th}}$ century sailing boats were able to sail against the wind, but this would take 'twice the distance, half the speed and three times the trouble' and was seldom tried. Boats frequently encountered adverse winds and as a result there was considerable variation in the time it took for the packet boats to reach Hellevoetsluys. This could take anything between one and twenty days, with a median sailing time of two days (see table 1 for the exact distribution of sailing times on page 19). As a consequence English news reached Holland with varying intervals.

The packet boat system was the main source of English information for investors in Amsterdam. The Dutch newspapers of the time all relied on the packet boat service to get news from England (*Amsterdamsche Courant*; *Opregte Haerlemsche Courant*; *Rotterdamsche Courant*). During the sample period, all articles in the *Amsterdamsche Courant* with new information from London can be retraced to the arrival of a specific packet boat, except for a number of exceptions I discuss below. Furthermore, evidence points out that private letters were sent through the packet boat system as well.[13]

At times, during periods of particularly bad weather, the English news could arrive in Amsterdam through the harbor of Ostend in today's Belgium, which had a regular packet boat service with Dover in England. During such episodes it was impossible for the packets to sail between Harwich and Hellevoetsluys but other packets seem to have managed to get across to Ostend. With a total of nine times this happened only infrequently during the entire sample period. These episodes were meticulously reported by the Dutch newspapers and I account for them in the empirical analysis.[14]

The packet boats were of course not the only ships that sailed between London and Amsterdam. Each week ships coming from England would dock in the Amsterdam harbor. However in terms of keeping up with current affairs these ships were always behind the packet boats. As said, they had to sail via the isle of Texel which would take a number of additional days. It therefore comes as no surprise that both individuals and the public newspapers had to

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[13] I analyzed the English correspondence from Hope & Co during the sample period. Hope was one of the biggest Dutch banking houses of the periods with strong connections in England. Most English letters in the Hope archive mention both the date a letter was written in London and the date it was received in Amsterdam. All the dated letters in the archive can be linked to the sailing of a specific packet boatHope & Co, SAA 734; 78,79, 115 and 1510, see also the correspondence in Van Nierop 1931, passim

[14] I did not find a single reference to English letters received over Calais. Apparently, from a Dutch perspective, the Ostend connection always beat the Calais one.

rely on the packet boat service to get the most recent news from London.

Although the packet boat service seems to have been the most important source of information for Dutch investors, the flow of news through alternative channels can never be completely ruled out. It is possible that investors set up private initiatives to get information from London. For example, there are rumors from the South Sea bubble in 1720 that Dutch investors chartered their own fishing ships to get the most recent information from London (Smith 1919; Jansen 1946). Jansen however could not find any evidence supporting these rumors. Finally, in theory it is possible that market participants used post pigeons to get information from London. The use of post pigeons can be retraced to antiquity. However the historical record suggests that people started to use them intensively after 1800 only (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 when there was no telegraph connection yet between the two cities (Ten Brink 1957).[15] 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.

Notwithstanding these possible alternatives, it seems reasonable to assume that if the official packet boats could not sail because of adverse weather conditions it would have been extremely difficult for others (be it boats or post pigeons) to cross the North Sea. Later on in the paper I will use this logic to perform a number of robustness checks on the main results.

The Rotterdamsche Courant gives some details about conditions at sea during such episodes of bad weather. It seems to have been consistently the case that if the packet boats could not sail, no other boats from England arrived in Hellevoetsluys. In addition, a close reading of the newspaper shows that the packet boats were the first to emerge from bad weather.[16]

These points can be illustrated by studying the developments around the dramatic price fall of the EIC stock after Prime-Minister Fox' speech on November 18, 1783 (see p. 2.1). This price fall constitutes the single largest price change recorded during the sample period. Figure 4 presents the development of the EIC stock price in London and Amsterdam between November 14 and December 15 of 1783. After Fox held his speech, in which he spoke of "the deplorable state of the EIC's finances" and the risk of bankruptcy (London Chronicle, November 18, 1783), the EIC stock price in London fell dramatically from 136 to 120. In the following days, weather conditions were unfavorable and the packet boats could not get across the North Sea. Amsterdam prices remained virtually unchanged for over a week. Finally, a packet boat managed

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[15] Similarly in the 1850's Reuters used post pigeons to get news from Aachen to Brussels before the telegraph line between the two cities was finished.

[16] 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 on January 5. According to the newspaper, his ship had been blown completely off 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 many as 30 days to sail across the North Sea.

Figure 4: EIC stock price London and Amsterdam, Nov/Dec 1783

Solid lines indicate the flow of news between London and Amsterdam
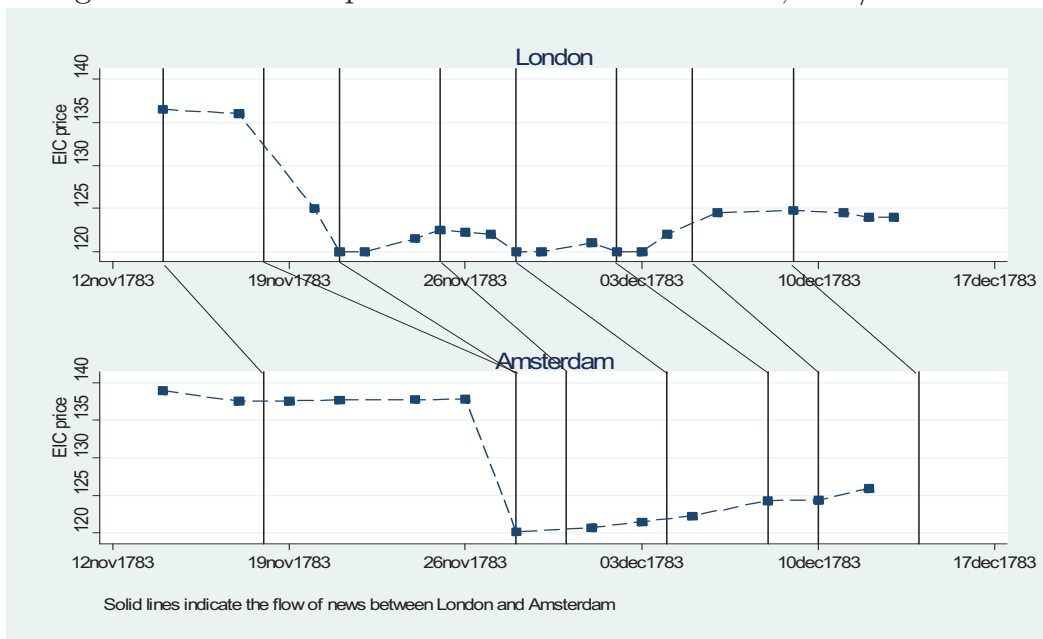
to reach Hellevoetsluys and on November 28 Amsterdam investors heard about the recent news from London. The Amsterdam price adjusted immediately to 120.

2.3   Market microstructure

One thing that was not affected by any weather conditions was the trade in equity in Amsterdam. During the 18th century this trade took place in a decentralized fashion. Around noon there were two official trading hours in front of the Exchange building (Spooner 1983; Hoes 1986). However, trade continued outside these official hours in coffee shops and even in front of Jewish synagogue. Trading seems to have continued into the evening. A central clearing mechanism for the stock trade was missing and most trades took place through the direct matching of buying and selling parties (Van Nierop 1931).

This matching was done by a relative small group of brokerage firms. Smith (1919) argues that in 1764 41 brokerage firms were dominating the market. This relatively small scope seems to have ensured that the decentralized setup of the market did not degenerate into chaos. The correspondence of broker Robert Hennebo published in Van Nierop (1931) indicates that the market was driven by limit orders. Principals would transmit these orders to their brokers, who then tried to execute these orders to the best of their ability. Interestingly, limit order were often made conditional on specific market conditions. For example, a broker would cancel certain sell orders after the arrival of positive news (Van Nierop 1931, p 64).

By the second half of the 18th century, a significant fraction of trade in the English stocks in Amsterdam was concentrated in the futures market (Van

Dillen 1931). As a result all available price data for the Amsterdam market refers to futures prices[17]. This has two important implications. First of all, it was relatively easy for market participants to take in considerable short positions.[18] Secondly, this has an important implication for the interpretation of the price data available in Amsterdam. Spot and future prices are linked through the cost-to-carry component. This means that fluctuations in the short term interest rate could have an impact on stock returns in the Amsterdam market. Fortunately, the future contracts in Amsterdam only had limited running periods (up to three months, see footnote on page 15), so the impact of interest rate fluctuations is likely to be small.

The stock prices I use in this paper were collected from newspapers. The prices the papers published were supplied at the end of the afternoon by a committee of so-called sworn brokers who were officially responsible for the reporting of these prices (Smith 1919, p. 109; Jonker 1994, p. 147). The prices functioned as an official reference, both for the city authorities and for investors who used these prices as an ex post control of their brokers (Polak 1924). As said, the Amsterdam market was a decentralized limit-order driven market. The prices that were reported therefore most likely reflected the equilibrium price at which most limit orders could be cleared. The correspondence in Van Nierop (1931) suggests that prices were indeed interpreted this way.

2.4 Private information and limited risk bearing capacity

What can the historical record tell us about the inefficiencies or frictions in this trading process? Going through the archival evidence two important characteristics of the Amsterdam market stand out: the presence of private information and the constant threat of insider trading, and a limited capacity to deal with short run liquidity shocks.

There is ample anecdotal evidence that London insiders used the Amsterdam market extensively to benefit from their private information. Insider trading in London and Amsterdam wasn't banned until the 1930's and especially EIC stock featured frequent insider trading. In a letter to one of his clients from January 1731 Amsterdam broker Robert Hennebo mentioned that there had been some active buying of EIC stock on the exchange and that

> 'if I am not mistaken, these orders came from London, from one of the directors of the EIC, John Bance (...), making it likely that the share price will rise some more'.[19]

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[17] Compared to today, the future contracts of the 18th century had one distinguishing characteristic. Rather than the running period of a contract, the end date of that contract was standardized. A future contract could have 4 possible end dates: February 15, May 15, August 15, or November 15. This implied that a future contract traded today had a slightly different running period than a contract traded tomorrow.

[18] For example, in the beginning of 1772 Alexander Fordyce, a London investor, had built up a considerable short position in EIC stock through the Amsterdam future market. When prices continued to rise, this created a spectacular bankruptcy. Wilson (1941) and Archive Hope & Co., SAA, 735-1510

[19] Hier is gisteravont veel premy voor de reysing gegeven, en vandaag waren hier koopers

There is also evidence that EIC directors James Cockburn and George Cole-brooke were 'bulling' the Amsterdam market during 1772 (Sutherland 1952, p. 228; SAA Hope, Journal 1772). One of his contemporaries would later describe Colebrooke as he, 'who was in the secret, knowing when to sell for his own advantage' (quoted in Sutherland 1952, p. 234). Such practices were not restricted to directors of the EIC. At times, political developments had a profound impact on the Company's prospects and as a result British politicians would engage in insider trading as well. During the 1760's a group of MP's, amongst which Lord Shelburne, a later prime-minister, and Lord Verney, member of the Privy Council, speculated in EIC stock on the Amsterdam exchange. The big advantage of trading in Amsterdam was that the risk of reputation loss due to insider trading would be minimized. Profiting from Amsterdam investors was far less of a sin than taking advantage of fellow countrymen (Sutherland 1952, pp. 206-8).

The clearest example of informed trading in Amsterdam originates from the archives of Hope & Co. In the fall of 1772 Hope went into business with Paul Wentworth, an envoy for New Hampshire in London to speculate on EIC stock. The British government had recruited Wentworth to spy on other agents of the American territories and not surprisingly Wentworth was well versed in the vagaries of political life in London.[20] On the 22nd of December 1772 Hope received a letter from Wentworth dated the 18th which was labeled 'private' and read:

> 'A report is made [on the poor state of the EIC] and we shall soon judge of its effect upon the stock. Those who know most think the stock will fall and we are of that opinion. You may therefore resume your sales to such extent as you think proper and with the usual dex[t]erity. (...) There appears no risk in selling from 170 to about 166. One wouldn't go lower, for though it is probable the stock will fall to 150, yet at that price or higher people may begin to speculate for the rise which will undoubtedly take place when any plan shall be fixed for the relief of the company. Whenever therefore the price falls to 154 or thereabouts, we should not only settle our positions but purchase more with a view to the rise as circumstances may make it advisable'.[21]

Wentworth's intelligence proved to be accurate. On January the 14th of 1773 the Directors of the EIC asked for a government loan and concessions on the export of tea to all British colonies, both of which were granted (Sutherland 1952, pp. 249-251). Most importantly, Wentworth's prediction on the price trajectory largely came true. The price of EIC stock in Amsterdam fell from 169.5 to 161 on December 30, reaching its lowest point on January 4, 1773 at

tot 169. So ik niet mis heb komt die order van London, van een der directeurs, Mr. John Bance, sodat, gelyk ik Ued meermaals gesegt en geschreeven heb, de apparentie grooter voor een reysing dan voor een daling is'. Van Nierop (1931), p. 68.

[20] http://www.fas.org/irp/ops/ci/docs/ci1/ch1c.htm

[21] Private letter from Wentworth to Hope, SAA 735, 115.

157.50[22]. After that, the price of EIC rose back to 169.5 on January 29, 1773.

Another interesting point is the reference to 'the usual dex[t]erity' Hope had to apply when executing the transactions. Most likely Hope had to be careful not to trade too conspicuously and reveal the information to other market participants. Hope probably did this by going through intermediaries. Hope's bookkeeping indicates that all share transactions on the Amsterstam exchange were handled by the firm David Pereira and Sons (SAA 734).

Just as today (see inter alia Hendershott and Seasholes 2007), Amsterdam market participants seem to have had a limited capacity to accommodate significant trading flows and to bear the (short run) risk on large stock positions. Order flow imbalances could move prices in the short run, even though no new information about the true value of the stock was available.

For example, in June 1735 the prices for the English stocks in Amsterdam fell strongly within a couple of days. Broker Robert Hennebo told his principal Simon Bevel on June 21st 1735 that

> 'The true reason for the fall in prices is that some people who have lend considerable amounts of money on the collateral of stock, have become pessimistic. They called in their loans. The borrowers, not having the time to raise cash elsewhere, were forced to sell the stock hastily for whatever price they would fetch. In this fury the prices of EIC and BoE stock fell to 144.25 and 133 respectively. However, when the fire sale came to an end, the stocks suddenly started to rise again'.[23]

2.5 Data

The empirical analysis of this paper is based on detailed price data from the Amsterdam and London markets and information about the arrival of packet boats in Hellevoetsluys. Data on Amsterdam stock prices were hand collected from the *Amsterdamsche Courant* and where necessary supplemented by the *Opregte Haerlemsche Courant*. For each stock three prices a week are available for Monday, Wednesday and Friday. I collected data for the three mentioned English stocks (EIC, SSC and BoE), two English bonds (3 and 4% annuities) and two Dutch stocks (VOC and WIC). The Amsterdam market traded English stocks in Pounds Sterling and prices were therefore reported in Pounds (as the percentage of nominal value)[24]. Price data from London are available on a daily frequency and are taken from Neal (1990).

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[22]In London the EIC stcok price did fall to 154 on January 16th.

[23]De waare oorzaak van de daling is (..), dat eenige menschen swaarhoofdig geworden zyn die veel geld op allen soorten van fondsen ter leen had geschoten had. Zy eysten hun geld op en de beleenders niet aanstonds paraat zijnde, wierden die partyen hals over kop, wat zy gelden mogten, contant verkogt. In die fury viel de Bank op 133 en de Oost-Indische Compagnie op 144.25%. Maar so haast de verkoopen ophielden reezen de fondsen eensklaps. Van Nierop (1931), p. 59

[24]Previous research by Neal (1990) and Dempster et al. (2000) use Amsterdam prices with a frequency of 2 observations a month. See footnote on p. 7.

The arrival dates of boats in Hellevoetsluys were hand collected from the *Rotterdamsche Courant*. The newspaper reports on what day a specific boat arrived and whether it arrived in the morning or afternoon. This data can be used to determine when news from England must have arrived in Amsterdam. It took approximately 10 hours for news from Hellevoetsluys to be transported to Amsterdam (Knippenberg en de Pater 1988, p. 55). This generally means that the information brought in on a certain day was only available for Amsterdam investors during the next day.[25] The *Rotterdamsche Courant* not only mentions the day a specific boat arrived but also the date of the news it carried. This information can be used to determine the contents of a specific shipment of news.

Finally I use data on weather conditions from the observatory of Zwanenberg, a town close to Amsterdam. This data provides three observations a day on the wind direction and other weather variables. This data comes from the KNMI.

3 Quantitative evidence on news flows

The empirical analysis of this paper rests upon two important assumptions. First of all, I assume that the flow of information was exogenously determined and in no way related to developments on the market or in the wider economy. Secondly, I assume that all information relevant for stock prices was generated in England. In the historical overview of the previous section I argued that both assumptions are at least approximately correct. In this section I will provide more formal evidence for their validity. Finally, I will discuss to what extent the extensive information flow between London and Amsterdam led to integrated markets.

3.1 Exogeneity of the arrival of information

What determined the arrival of packet boats in Hellevoetsluys? In the newspapers of the time I have found no evidence that international tensions affected the sailing of the packet boats during the sample period. Taking a closer look at the weather data available for the period confirms that the total sailing time between Harwich and Hellevoetsluys was determined by the wind direction. Table 1 illustrates this point. The table presents the average wind direction on the days packet boats were at sea. Every row represents this information 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 7 days, as voyages taking more than 7 days occurred only infrequently. Columns 3 to 9 report the average wind direction on each day of

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[25]There are some exceptions, if a boat arrived in Hellevoetsluys very early in the morning, it sometimes happened that the information from London was already available in Amsterdam on the same day. I used the publication of English news in the *Amsterdamsche Courant* to identify these cases.

Table 1: Sailing time and wind direction

Total days at sea		Wind direction while at sea						
days	N	t+1	t+2	t+3	t+4	t+5	t+6	t+7
1	338	↘						
2	489	↘	↘					
3	215	↘	↗	↗				
4	84	↖	↖	↖	↙			
5	37	↖	↖	↖	↖	↘		
6	16	↖	←	←	↙	↙	↙	
7	13	↖	←	←	↖	↖	↙	↙

Direction Harwich - Hellevoetsluys: →
Columns: day of the voyage   Rows: average wind direction
Source: Rotterdamsche Courant and *KNMI*

the voyage, with t+1 the first day of the trip, t+2 the second day of the trip, etc.

Figure 3 shows that Hellevoetsluys is situated east of 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 the west 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 1 shows that this is indeed the case and that the direction of the wind can almost perfectly predict sailing times. For sailing times up to two days the wind direction is close to west, the optimal direction. For longer sailing times this is not the case. Winds mainly blow from the east, slightly changing direction on the last day of the voyage. Note that the fit between sailing time and wind direction is particularly good considering that these wind directions were measured in Zwanenburg, 250 kilometers away from Harwich.

3.2   Direction of news

In the historical overview of the previous section I argued that most relevant developments during the sample period were centered on London. In addition, the historical evidence on stocks holdings suggests that between 65 and 80% of the English stocks was held by English investors. This suggest that the bulk of discount rates news (Campbell and Shiller 1988) came from England. I will use VAR analysis and Granger causality tests to look at this more carefully.

Figure 5: VAR analysis: EIC
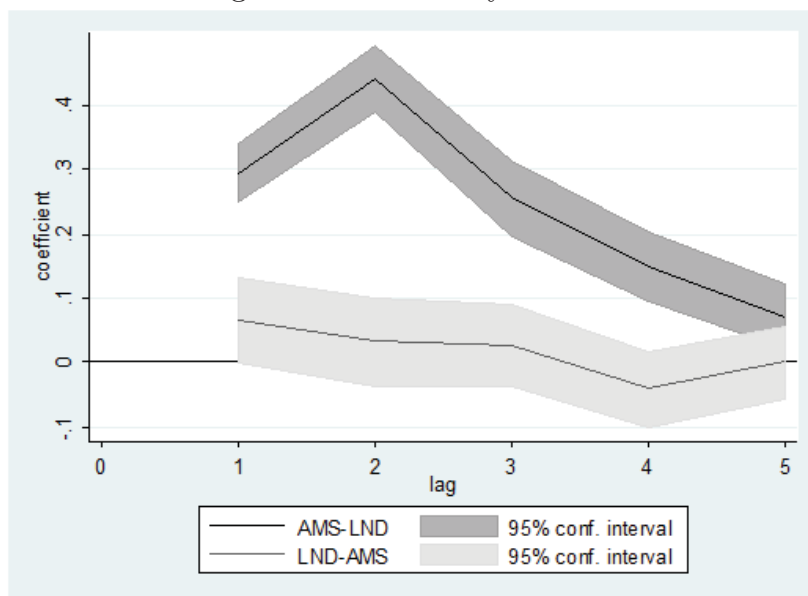
If all relevant news originated from London, Amsterdam prices should have lagged London prices with a delay consistent with the time it took for the English letters to reach Amsterdam: on average a period of four days (a median sailing time of two days plus two additional days to transport the news from London to Harwich and 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 periods September 1771 – December 1777 and September 1783 – March 1787 and looking at returns instead of prices.

For the Amsterdam market three prices per week are available: 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).[26] Prices in London are available on a daily frequency, but to make the empirical testing consistent I only use price data of the same days this information is available for Amsterdam.

Based on these two or three day returns I estimate an unstructured VAR model with a total of 5 lags. Note that in a two variable VAR model, the variables are regressed on their own lags and on the lags of the other variable in a single system. Also note that (because of the structure of the data) each lag represents either two or three days. In figures 5 and 6 I plot the VAR coefficients from this analysis for the EIC and BoE return series. Unfortunately I cannot use the English data on SSC stock returns since English price notations for SSC were very irregular during the sample period (Neal 1990).

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[26] Note that the three day period includes the weekend. During the 18th century, trading continued during the weekend. However, trade on Sunday was limited due to the absence of Christian traders. Likewise, Jewish traders did not participate on Saturdays. Spooner (1983), p. 21

Figure 6: Var analysis: BoE returns
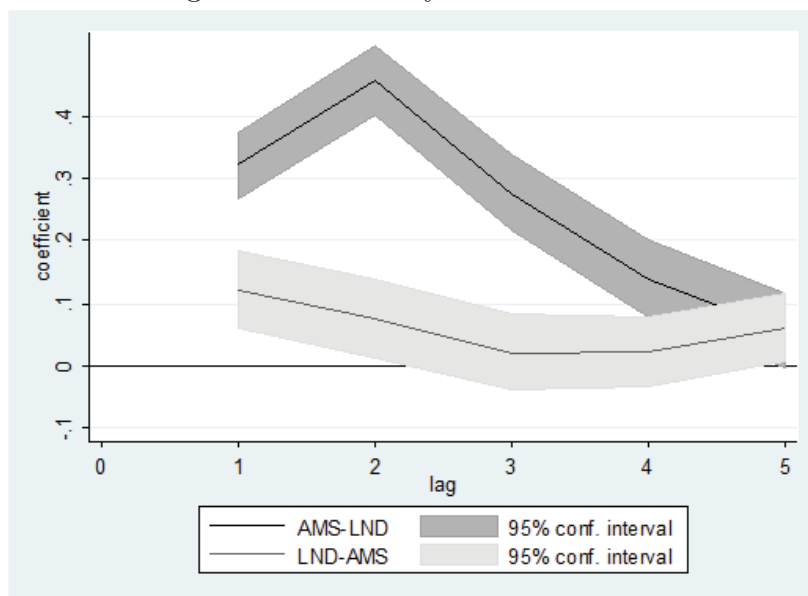
The two figures present two sets of coefficients, one for the relation between Amsterdam returns and lagged London returns (AMD-LND) and one for the relation between London return and lagged Amsterdam returns (LND-AMS). The figures unequivocally show that lagged London returns had a very strong predictive power on price changes in Amsterdam. The strongest effect is found at a lag length of two, implying an effective lag of four to five days. This is fully consistent with the historical context. In contrast, lagged Amsterdam returns have almost no effect on London returns. In other words, the two figures suggest that almost all news relevant for the English stocks was indeed generated in London.[27]

This statement can be tested more rigorously with Granger causality tests, which are reported in table 2. For the EIC the test strongly rejects causality from Amsterdam to London, whereas causality from London to Amsterdam is strongly accepted. For the BoE results are slightly more nuanced, with some evidence for causality running from Amsterdam to London. However, evidence for causality running from London to Amsterdam is far stronger. In addition, to the Granger causality tests I calculate Hasbrouck's (1995) information shares of the two markets. I estimate the common random walk component of the EIC and BoE price series in both cities and I calculate what fraction of its variance can be attributed to each market. The results in the final column of table 2 indicate that around 98% of all relevant information was generated in London.

It is possible that news originated from a third place, like France or the East Indies. France played an important role in the international politics of the time and developments in Paris could have had an important impact on the prices of

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[27] This finding can not be generalized to the entire 18$^\text{th}$ century. Dempster et al. (2000) argue that for the entire century some price discovery was taking place in Amsterdam.

Table 2: Granger causality and information shares

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		F-stat	p-value	Information shares
EIC	LND $\rightarrow$ AMS	96.23	0.0000	0.977
	AMS $\rightarrow$ LND	1.50	0.1869	0.023
BOE	LND $\rightarrow$ AMS	81.64	0.0000	0.990
	AMS $\rightarrow$ LND	4.49	0.0005	0.010

This table tests for Granger causality between the Amsterdam and London return series for EIC and BOE stock. In addition the information shares of Amsterdam and London (Hasbrouck 1995) are presented in the final column.

the English stocks. I focus on two periods in which developments in France were relatively unimportant (see the discussion on page 9). Nevertheless, they could have still played a role. To test this I look at the contemporaneous correlation between London and Amsterdam returns. News from Paris would arrive in London and Amsterdam at more or less the same time. The VAR framework used above cannot accommodate contemporaneous correlations and I therefore estimate univariate regressions. Results indicate that there was virtually no contemporaneous correlation between London and Amsterdam. The regression coefficients for the EIC stock and BoE were 0.0421 and 0.0054 with bootstrapped standard errors of 0.0398 and 0.0367.

There is an additional complication for EIC stock. A significant fraction of relevant news for this company came from Asia. The Dutch had an important presence in Asia as well through their own East India Company (VOC). It is therefore possible that news from Asia may have reached Amsterdam through Dutch VOC ships before it reached London. A closer examination of the *Amsterdamsche Courant* suggests that this worry is of minor importance. First of all, there were more English ships sailing between Asia and Europe than Dutch ones. As a result, the *Amsterdamsche Courant* often mentioned news from the Dutch Indies that was brought in by English ships. The reverse (news from British India brought in by Dutch ships) happened only very seldom. Secondly, Dutch boats from the East Indies often docked in Dover before sailing to Amsterdam. As a result, news from the Dutch East Indies often reached England first. To provide a final check I collected data on the arrival of news from Dutch East India from the Amsterdamsche Courant, aided by the work of Bruijn et al. (1979-1985). Later on in the paper I will show that all results are robust to the exclusion of trading days on which news from Asia was brought in by Dutch ships.

Figure 7: Return distributions EIC, news vs no-news
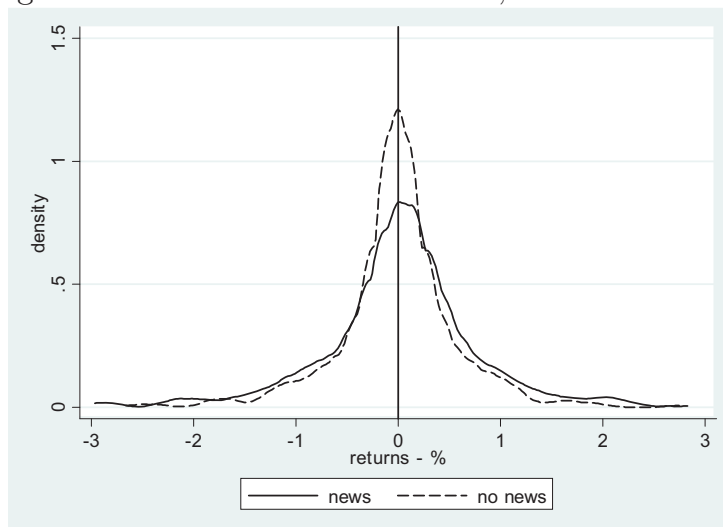
4 Volatility and the arrival of information

4.1 Benchmark results

Information on the arrival of packet boats allows me to determine when information reached Amsterdam. In case no boat arrived due to adverse weather conditions, stock prices in Amsterdam reflected only the information that had arrived with the previous boat. I compare stock returns between periods with and without the arrival of new information. This comparison allows me to determine how important the arrival of news and other, trade related factors are for the volatility of share prices.

There are three prices a week available for the Amsterdam market (for Monday, Wednesday and Friday). I calculate returns based on two (Fri-Wed and Wed-Mon) or three day periods (Mon-Fri).[28] For each return I determine whether it occurred after the arrival of new information from England. The returns that did are labeled 'news returns', those that did not as 'no-news returns'.

As a first step I present the distributions of these news (solid line) and no-news returns (dashed line) in figures 7 to 9. At first glance it becomes clear that for all three stocks, returns are more volatile after the arrival of new information. The distribution of news returns has considerably more mass in the tails and compared to the distribution of no-news returns there are far less zeros in the distribution. In other words: the arrival of new information matters.

By how much does news matter? Suppose that return innovations R are a function of new information (N) and other factors related to the trading process (T)

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[28]See footnote on page 20.

Figure 8: Return distributions SSC, news vs no-news
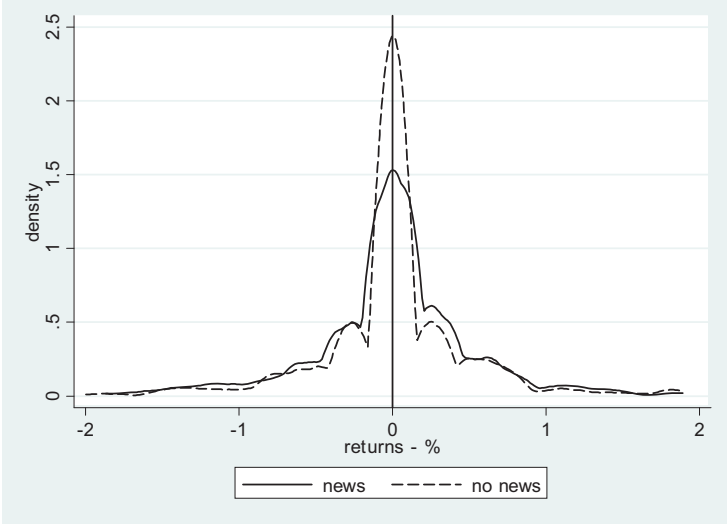
Figure 9: Return distributions BoE, news vs no-news
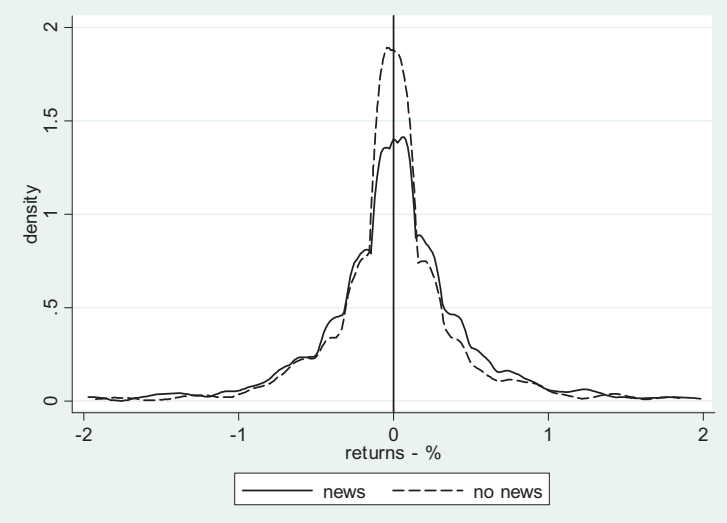
Table 3: Benchmark results

		Returns					Variance no-news/news (BF stat)
		mean	var	skew	kurt	N	
EIC	news	0.03	0.7723	0.05	8.65	752	0.4746
	no-news	-0.01	0.3665	-0.30	8.26	584	(28.12)****
SSC	news	-0.01	0.3595	-0.51	9.09	753	0.7222
	no-news	0.02	0.2597	0.55	8.36	584	(8.06)***
BoE	news	0.01	0.2731	-0.09	7.99	753	0.7361
	no-news	0.01	0.201	0.51	9.96	584	(12.14)***

*** indicates statistical significance at the 1% level. In the final column Brown-Forsythe test statistics on the variance ratios are in parentheses ($H_0 : ratio = 1$). This table presents descriptive statistics of Amsterdam returns on EIC, SSC and BoE stock in the presence and absence of news from England. Data are for the periods Sept. 1771 - December 1777 and September 1783 - March 1787. In the final column tests are resported for the equality of the variance of the news and no-news samples.

$$R = f(N) + g(T)$$

Further suppose that the covariance between return innovations due to the arrival of new information and innovations due to trade related factors is zero.[29] In this case I can apply a simple variance decomposition. In periods k new information becomes available and prices will move to reflect both factors, formally $R_k = f(N_k) + g(T_k)$. In periods $\widetilde{k}$ no news reaches the market and prices only move to reflect trade-related factors, $R_{\widetilde{k}} = g(T_{\widetilde{k}})$. The fraction of the variance that can be attributed to trade related factors N can therefore be estimated as

$$\frac{var[g(T)]}{var[R]} = \frac{var[R_{\widetilde{k}}]}{var[R_k]}$$

and $1 - \frac{var[R_{\widetilde{k}}]}{var[R_k]}$ provides an estimate of the fraction of the variances that can be attributed to the arrival of news.

Details are provided by table 3. The table presents the first four moments of the return distributions for periods with and without new information. Most importantly, and consistent with figures 7 to 9, the variance of returns is higher for periods with news. This is consistently true for all three stocks. The results in table 3 show that $\frac{var[R_{\widetilde{k}}]}{var[R_k]}$ lies between 0.48 and 0.73, depending on the stock.

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[29] This assumption cannot be tested in this framework. If the covariance between return innovations due to news and other factors is positive (negative), the fraction of the variance that can be attributed to the arrival of news will be biased upwards (downwards).

This suggest that the fraction of return volatility that can be ascribed to the arrival of information from England is responsible for 27 to 52 % of volatility. The remainder must be caused by trade-related factors.

Is the contribution of news statistically significant? The table shows that the return series are non-normal. As is usual with daily stock return data, the kurtosis of the series is considerably bigger than 3. In other words, compared to a normal distribution, there is more weight in the tails. A standard F test on the equality of variances can therefore not be applied here. I follow Boos and Brownie (2004) who argue that under these circumstances it is best to use a non-parametric test based on mean absolute deviation from the median. The most widely used test in this respect is the Brown-Forsythe (B-F) test. The B-F statistics in table 3 indicate that the differences in variance between news and no-news returns are highly statistically significant for all three stocks.

Simply taking the ratio of the variances effectively ignores any time series properties present in the data. To address this point I estimate ARCH(1) models on the return series to control for the spilling over of volatility from one period to the other. In addition, I include an AR(1) term in the mean equations of the ARCH models to control for any auto-correlation that might be present in the series. The results of these estimations are reported in table 4.

The resulting estimates indicate that ARCH effects are present in the return series for all three stocks. These effects are considerably weaker for the EIC than for the SSC and BoE. The evidence for auto-correlation in the return series is weak. Only in case of SSC stock is the AR(1) coefficient statistically significant. The variance-ratio's of no-news and news returns are very similar to before. When the return series are corrected for ARCH effects and auto-correlation, the fraction of volatility that can be ascribed to the arrival of information lies between 30 and 53%.

To sum up, the first important conclusion from this analysis is that the arrival of information is an important factor in explaining short run asset price movements. This contrast with 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 information 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 the analysis is that although information is important, the impact of the trading process is far from negligible. Factors unrelated to the arrival of new information account for 47 to 70 % of overall volatility. This result is consistent with papers like French and Roll (1986) and Ito, Melvin and Lyons (1998) who compare asset price volatility in periods with and without trading and who conclude that the trading process itself generates considerable volatility. In today's markets, it is possible that the availability of new information responds endogenously to trading activity (Fleming, Kirby and Ostdiek 2006). The results in this paper do not suffer from this potential problem. The flow of information between London and Amsterdam in the 18th century was exogenous and the results presented here are therefore not affected

Table 4: Results from ARCH model
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	EIC	SSC	BoE
AR(1)	0.0100	-0.0929	-0.0044
	(0.0334)	(0.0472)**	(0.0624)
ARCH(1)	0.1112	0.2700	0.3660
	(0.0363)***	(0.0627)***	(0.0814)***
news	0.6793	0.2661	0.1934
	(0.0731)***	(0.0296)***	(0.0205)***
no-news	0.3192	0.1875	0.1317
	(0.0490)***	(0.0267)***	(0.0220)***
no-news / news	0.4699	0.7046	0.6808
	[4.1868]***	[2.0053]**	[2.1172]**
Log-likelihood	-1488	-1049	-869
N	1336	1336	1336

***, **, * indicates statistical significance at the 1 and 5 and 10% level.
Bollerslev-Wooldrige robust standard errors are reported in parentheses. In
brackets a Z-test is reported on the ratio of the no-news and news dummies
($H_0 : ratio = 1$).
This table present estimates from an ARCH(1) model on the return series. An
additional AR(1) terms is included in the mean equation. The news and no-
news coefficients are based on news and no-news dummies that are included in
the variance equation, which was estimated without a constant.

by endogeneity bias.

4.2   Robustness checks

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 in alternative ways.
How important was this slipping through of news for share price fluctuations in
Amsterdam and does this bias the previous results? The variation in weather
conditions on the North Sea and the sailing times of packet boats allows me to
answer this question.

The idea is to identify periods in which packet boats had trouble in making
their way across the North Sea. During these periods other boats (or even post
pigeons) would have had similar problems. The packet boat service allowed for
two crossings a week. This means that even under good weather conditions
the Amsterdam market featured trading days in the absence of new information
from England. This allows me to compare the volatility of no-news returns under

Table 5: No-news, bad weather sample

	Returns					Variance	
	mean	var	skew	kurt	N	no-news/news	no-news: bad weather/all
						(BF stat)	(BF stat)
EIC	0.02	0.3270	-0.79	8.60	261	0.4234 (14.82)***	0.8921 0.13
SSC	0.01	0.2019	-0.24	8.47	261	0.5615 (10.16)***	0.7774 (3.02)*
BoE	0.03	0.1565	0.94	8.55	261	0.573 (14.21)***	0.7785 (3.55)*

***, * indicates statistical significance at the 1 and 10% level. In the final columns Brown-Forsythe test statistics on the variance ratios are in parentheses (H_0 : $ratio = 1$).

This table presents descriptive statistics of Amsterdam returns on EIC, SSC and BoE stock. The sample is restricted to no-news returns taking place during bad weather episodes. Data are for the periods Sept. 1771 - December 1777 and September 1783 - March 1787. The penultimate column presents tests for the equality of the variance of the news and the no-news, bad weather samples. The final column presents tests for the equality of the variance of the bad weather and the full no-news samples.

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. In addition, restricting the analysis to the bad weather sample should remove most concerns that no-news returns were driven by the slipping through of news.

In table 5 I present the summary statistics of no-news returns that took place during periods of bad weather (defined as periods in which packet boats had a sailing time larger than the median of two days). In general, the variance of no-news returns was slightly lower during these bad weather episodes. As a result the fraction of volatility that can be ascribed to the arrival of news increases. According to table 5 between 43 and 58% of volatility can be attributed to the arrival of news. However, the B-F tests indicate that the difference in the variance between good and bad weather episodes only borders on statistical significance for the SSC and BoE with p-values of 0.08 and 0.06, and is altogether insignificant for the EIC with a p-value of 0.72.

For the EIC relevant information did not only originate from London, but could also come from India. As said it is possible that Dutch ships from Asia

Table 6: No news from Asia

| | | Returns | | | | | Variance |
		mean	var	skew	kurt	N	no-news/news (BF stat)
EIC	news	0.02	0.727	0.00	9.33	661	0.5277
	no-news	-0.01	0.3837	-0.29	8.27	521	(20.45)***

*** indicates statistical significance at the 1% level. In the final column Brown-Forsythe test statistics on the variance ratio are in parentheses ($H_0 : ratio = 1$). This table presents descriptive statistics of Amsterdam returns on EIC stock in the presence and absence of news. Data are for the periods Sept. 1771 - December 1777 and September 1783 - March 1787. Periods during which news from Asia either reached Amsterdam or was officially published are excluded from the sample. The final column tests for the equality of variance between the news and no-news samples.

brought in news relevant for the EIC. This could drive part of the volatility of the EIC stock in Amsterdam in the absence of news.

I check for this possibility in table 6. I focus on EIC stock and I exclude all returns that took place over periods in which news from Asia arrived in the Dutch Republic. Results remain virtually unchanged. If anything, the fraction of the variance in EIC returns that can be ascribed to the arrival of news from London falls from 53 to 47%.

Possibly, the previous results could be biased against the importance of news because of the use of simple return data instead of abnormal returns in which the development of the market as a whole is taken into consideration. The market could have influenced prices in Amsterdam and accounted for part of volatility in the absence of news. The European market for products from the East-Indies may for example have changed or there may have been developments in the general economic conditions. The VAR analysis of the previous section suggests that such general European developments had limited impact on stock prices in London. Nevertheless the impact of these market-wide factors can be easily checked.

In order to do so I estimate a simple CAPM model with a market portfolio that consists of all the English and Dutch stocks traded on the exchange.[30] From this CAPM model I extract abnormal returns with which I redo the previous analysis. Results are presented in table 7. The findings show that the fraction of volatility that can be ascribed to the arrival of news even falls to between 0.13 and 0.48. This finding suggests that most news about the market originated from England and is consistent with the VAR analysis in the previous section.

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[30] The beta's of the EIC, SSC and BoE in Amsterdam were 1.00, 0.78 and 0.76 respectively, all significant at the 1% level with adjusted R^2s of 0.29, 0.36 and 0.46.

Table 7: Abnormal returns

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		Returns					Variance no-news/news (BF stat)
		mean	var	skew	kurt	N	
EIC	news	0.03	0.5287	-0.12	8.58	751	0.5163
	no-news	-0.03	0.2730	-0.78	8.34	583	(26.43)***
SSC	news	-0.01	0.2218	-0.26	8.16	751	0.7844
	no-news	0.01	0.1740	0.29	8.93	583	(7.27)***
BoE	news	0.01	0.1384	0.33	7.99	751	0.8725
	no-news	-0.01	0.1207	-0.16	10.89	583	(3.98)**

***, ** indicates statistical significance at the 1 and 5% level. In the final column Brown-Forsythe test statistics on the variance ratios are in parentheses ($H_0 : ratio = 1$).

This table presents descriptive statistics about Amsterdam abnormal returns on EIC, SSC and BoE stock in the presence and absence of news. Abnormal returns are generated from a standard CAPM model using the total market return. Data are for the periods Sept. 1771 - December 1777 and September 1783 - March 1787. The final column tests for the equality of variance between the news and no-news sample.

5 Model

5.1 Introduction

In this section I introduce a rational expectations model that is able to generate asset price volatility in periods when no new information reaches the market. The model incorporates the two most important frictions discussed in the market microstructure literature: asymmetric information about the value of the stock and limited risk bearing capacity of the market as a whole. I will first discuss the model's intuition and then move to a more formal discussion of the model's solution and precise predictions.

The first building block of the model is the presence of private information. In London there is an insider like Paul Wentworth with privileged information who sends this information to a trusted agent in Amsterdam (see the historical background on page 16). What impact does the presence of private information have on the movement of share prices?

I assume that the insider is a monopolist with regard to his private information. In addition, I assume that insider can hide his trades in the market's total order flow, i.e. the market cannot identify the insider. Following the literature on insider trading (Kyle 1985)[31] the insider will spread out his trades over time

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[31] See also Glosten and Milgrom (1985) and Holden and Subrahmanyam (1992).

to optimally benefit from his informational advantage. His trading activity will reveal some of his information and the private signal is slowly incorporated into prices. This noisy adjustment process will continue into periods in which no new information reaches the market.

This element of the model has an additional implication. Note that the same private signal gets incorporated into prices in both London and Amsterdam. This implies that, even in the absence of news flows, price changes in Amsterdam should be correlated with those in London. I will present evidence consistent with this prediction.

In addition to the presence of private information, I assume that market participants have a limited risk bearing capacity in the short run. This means that if an investor has certain liquidity needs and wants to go long (short) in the stock, he will have to offer a premium (discount) to compensate his counterparty for the risk that the latter has to take on. As a result the equilibrium price will have to move to accommodate these trading demands (Grossman and Miller 1985; Campbell, Grossman and Wang 1993)[32]. This feature also closely resembles the situations such as described by Robert Hennebo (see page 17). As long as the motives behind these trading demands do not depend on the arrival of news, this will generate additional volatility in the absence of new information.

This feature of the model also predicts that short run returns are partially reversed during the next trading period. If liquidity shocks are uncorrelated over time, their effect is transitory and today's premium (discount) that is offered to make markets clear will be uncorrelated with tomorrow's. The resulting price changes will be reversed during the next trading period. I will provide empirical evidence for this in section 6.

I explicitly model the interaction between the presence of private information and liquidity trading. I specify the motives for liquidity trade and I show how these are related to the degree of asymmetric information. The key result is that the willingness of uninformed agents to trade is decreasing in the degree of asymmetric information (Admati and Pfleiderer 1988; Foster and Viswanathan 1990; George et al. 1994).[33]

Finally, I introduce a key feature of historical experience: uncertainty about the arrival of news. Because of changing weather conditions on the North Sea, it was uncertain when the next boat from London would arrive. This was an important issue for the informed agent in Amsterdam because news updates from London (partially) revealed the private signal to the wider public. If the boat from London arrived earlier than expected, the insider would lose a significant part of his profits.

This risk of revelation will lead the insider to trade relatively aggressively

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[32]Examples of other papers who combine informed trading with limited risk bearing capacity include Subrahmanyam (1994), Holden and Subrahmanyam (2002), Chordia and Subrahmanyam (2004) and Gabaix et al. (2006). In these papers private information is short lived.

[33]See also Spiegel and Subrahmanyam (1992), Massoud and Bernhardt (1999), Baruch (2002) and Mendelson and Tunca (2004).

early on when he has just received the private signal. As time progresses and the informed agent exhausts most of his informational advantage, informed trading will become less important. Under these conditions the willingness of uninformed agents to trade increases over time. As a result, insider trading will dominate right after the arrival of news from London while in subsequent periods without news uninformed liquidity trading will be more prominent.[34]

The model has two important consequences for the dynamics of price changes. Because all trading periods feature informed trading, price changes always reveal a part of the private signal. However, this revelation of private information will be particularly strong in periods taking place right after the arrival of news. Secondly, the importance of liquidity trading increases in the subsequent periods when no new information reaches the market. The degree to which price changes are reversed later on is therefore also higher in periods without news.

The model I develop in this paper is based on the limit order framework developed by Kyle (1989). Relative to the existing literature, the model makes two contributions. First of all, to the best of my knowledge the model is the first to combine long lived private information with limited risk bearing capacity. Secondly, the model endogenizes uninformed trading and has the feature that uninformed trading becomes more important over time because the uncertainty about the revelation of the private signal forces the insider to use his information early on. With the exception of Baruch (2002) existing models that combine insider trading with endogenous liquidity trade do not have this feature.

5.2   Setup

The model features the trade of a single asset in two different markets, London and Amsterdam. The full model consists of a infinite number of episodes, indexed with k. Each individual episode k is represented in figure 10. At the beginning of episode k nature determines the true value of the asset v_k, where v_k behaves as a martingale, i.e. $v_k = v_{k-1} + \varepsilon_k$ with $\varepsilon_k \sim N\left(0, \sigma_\varepsilon^2\right)$. ε_k is not known to the wider public but is privately observed by a single agent, the London insider, at the beginning of the episode. At the end of the episode, v_k is publicly revealed in London and the next episode $k + 1$ begins.

The model is focussed on developments in Amsterdam. I assume that right after the moment nature decides on ε_k, the London insider sends this signal to a trusted agent in Amsterdam. At the same time the revelation of ε_{k-1} is also transmitted to Amsterdam. Likewise, when ε_k is revealed and a new signal ε_{k+1} is generated, this information is also sent to Amsterdam immediately. Depending on the weather conditions, this news can take one or two periods to arrive in Amsterdam, indexed as $t = 1$ and $t = 2$. The probability of the news

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[34]I am not the first to introduce the risk of the revelation of private information in a model of insider trading (Back and Baruch 2004 and Caldentey and Stacchetti 2010). However, the model developed in this paper is the first to trace its effects on liquidity trading.

Baruch (2002) develops a market maker model with similar features. In his model the insider is risk averse (as in Holden and Subrahmanyam 1994) and this causes him to trade relatively aggressively early on. Liquidity trading is partly endogenous and increases over time as adverse selection costs fall.

Figure 10: Setup model
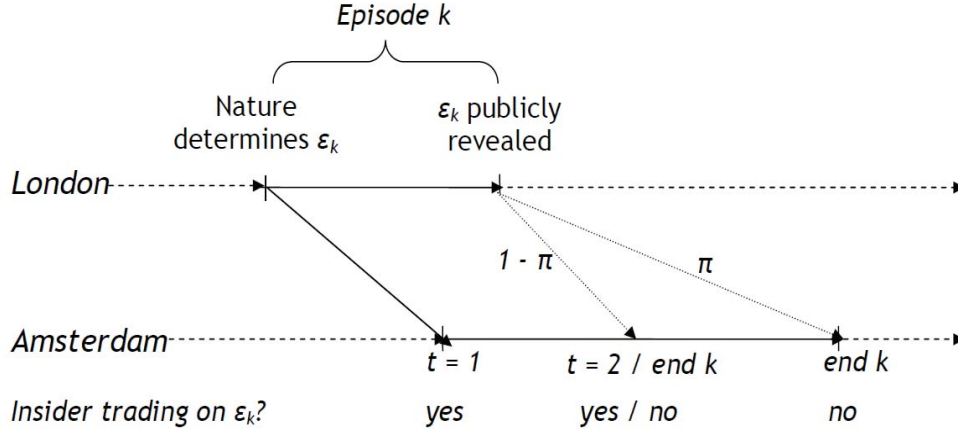
arriving right after $t = 1$ is $1 - \pi_k$. The probability of it arriving after $t = 2$ is π_k. If news travels fast, there is only one period to trade on information ε_k, whereas if news travels slowly there are two periods.[35] The price that results after trade in $t = 1, 2$ is given by $p_{k,t}$. I use $p_{k,0}$ to denote the last price observed before the arrival of boat k.[36]

5.3 Agents

There are two types of agents in Amsterdam. First of all in every episode there is a single privately informed agent who knows ε_k and who trades in $t = 1, 2$. The privately informed agent is risk neutral and maximizes profits.

Secondly, in every period $t = 1, 2$ there is a different group of M_t risk averse agents who only observe public information v_{k-1}, and, if in $t = 2$, also the equilibrium price of period $t = 1$. I assume that $M_1 = M_2 = M$. I use subscript m to indicate an individual agent of this class. Every uninformed agent receives an endowment in the stock $u_{k,t,m}$. The $u_{k,t,m}$ are identically and independently distributed as $N\left(0, \sigma_u^2\right)$. The uninformed agents maximize an exponential utility function with coefficient of absolute risk aversion A.

The endowments in the risky asset give the uninformed agents a motive for trade. Since ε_k, the innovation in the value of the asset, is unknown, the uninformed agents face risk σ_ε^2 on the endowments they receive. As a result of this risk they want to engage in risk sharing and rebalance their portfolios. For simplicity and following Massoud and Bernhardt (1999) and Mendelson and Tunca (2004) I assume that each uninformed agent only trades in the period that he receives the endowment.

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[35] Note that the probability that a boat arrives after $t = 1$ or $t = 2$ also depends on the speed of the previous boat (the first solid line in figure 10 pointing to $t = 1$). This can be accommodated in this framework by changing probability π_k.

[36] Depending on whether boat $k - 1$ arrived after $t = 1$ or $t = 2$, $p_{k,0}$ equals $p_{k-1,1}$ or $p_{k-1,2}$.

At the end of episode k, the moment ε_k is revealed and transmitted to Amsterdam, all outstanding claims in Amsterdam are settled at v_k. This means that both the informed agent's profit and the uninformed agents' utility are valued at v_k. This assumption has the nice implication that claims from episode k have no impact on the trading environment in episode $k+1$. This assumption is crucial for obtaining a closed form solution and is applied in most of the existing literature.[37] As a result I can drop subscript k in most of the analysis. From the perspective of individual episode k, v_{k-1} forms the ex ante expectation of v_k and is denoted as v_0. Similarly, again from the perspective of an individual episode, the asset's true value v_k is written as $v = v_0 + \varepsilon$.

5.4 Market micro structure

It is important to define the market mechanism in this model. How exactly does trade take place? The historical overview suggests that the Amsterdam equity market in the 18th century functioned as a decentralized limit order market. Such a situation can be modelled as a Walrasian auction. In such a model agents submit their demands curves (how much is each agent willing to buy/sell at a certain price) to a Walrasian auctioneer. Prices and quantities are set at that point where all individual demand curves intersect.[38] I effectively follow the seminal model in Grossman and Stiglitz (1980).

Both the informed and the uninformed agents submit their demand curves to maximize their respective objectives. Note that the price at which an uniformed agent is willing to sell or buy depends on his expectation of ε. The trading process provides information about the true value of ε. I assume that each agent observes the sum of the demands of all other traders. This aggregate includes the demand submitted by the informed agent and therefore provides a noisy signal about ε. For example, when the rest of the market is willing to buy a lot of the asset at price v_0 (the ex ante expected value) this could be an indication that the informed agent has positive information about ε. This implies that in the Nash equilibrium that I derive, the optimal demand curve of uninformed agents depends on the realization of all other demand curves.

The Amsterdam market featured a relatively small number of participants. I therefore deviate from Grossman and Stiglitz (1980) and follow Kyle (1989) in assuming that agents act non-competitively. In other words, each agent takes his own actions' impact on the equilibrium into consideration.

5.5 Definition of equilibrium

I solve for the Nash equilibrium in pure strategies. The equilibrium is determined by the optimal demand curves submitted by the agents. A Walrasian

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[37] See Holden and Subrahmanyam (2002) for a discussion

[38] Although this is not a model of a full fledged limit order market (see Foucault et al 2005), it is a useful abstraction. An important issue is the absence of a centralized clearing mechanism in the Amsterdam market. In applying a Walrasian framework I therefore implictly assume that 18th century brokers effectively managed to match all clients' demand curves. Since the total amount of brokers was relatively small, this assumption seems to be realistic.

auctioneer aggregates these and sets an equilibrium price. The optimal demand curve of an uninformed agent has to fulfill four requirements. (1) The equilibrium demand schedule must lead to a **optimal position** in the stock, given the risk of the stock and the price at which transactions are concluded. (2) The uninformed demand curves must be conditional on the aggregate demand curve that is observed, since this provides information about ε. Put alternatively, the **position** of an uninformed demand curve depends on aggregate trading activity and the initial endowment in the stock (Grossman and Stiglitz 1980). (3) Uninformed agents are risk averse and their demand curves are therefore **downward sloping** because they need to be compensated for the risk they take on their books. The slope of the demand curves depends on the degree of risk aversion (Grossman and Miller 1988). (4) All agents act **non-competitively** and take their individual impact on the equilibrium price into consideration when submitting their demand curves (Kyle 1989). This price impact is determined by the demand curves of other uninformed agents given by (1) - (3). For example, when an individual agent wants to sell, prices will fall to reflect a lower expected value of ε and to compensate counterparties for taking a long position on their books.

The demand curve of the informed agent is more straightforward. (1) It has to fulfill **profit maximization**. (2) The informed agent is a **monopolist** over his signal and realizes he has an effect on the equilbrium price. In a competitive setting, the risk neutral insider would set would submit a flat demand curve at $v_0 + \varepsilon$. This would fully reveal his signal, thereby destroying his profits. In a monopolistic setting, the insider limits the revelation of information and submits a downward sloping demand curve. The slope of this demand curve depends on the price impact he faces (Kyle 1989).

The Nash equilbrium of the problem can be formalized as follows. Let x_t and $y_{t,m}$ be the demand curves submitted by the informed and uninformed agents in period $t = 1, 2$. A positive (negative) value of x_t or $y_{t,m}$ indicates that the agent goes long (short) in the stock.

First of all note that the equilibrium price p_t depends on the sum of all individual demand curves.

$$p_t = p \left(x_t, \sum_m y_{t,m} \right)$$

Let $U_{t,m}[y_{t,m}, p_t]$ be the utility function of uninformed agent m in period $t = 1, 2$. Remember that each uninformed agent is only allowed to trade in the period that he receives the endowment. $y_{t,m}$ is uninformed agent m's equilibrium demand curve if, for all alternative demand curves $y'_{t,m}$ and equilibrium demand curves x_t and $y_{t,k}$ for $k \neq m$ (all other uninformed agents in t), the following

holds

$$U_{t,m} \left\{ y_{t,m}, u_{t,m}, p \left(y_{t,m}, x_t, \sum_{k \neq m} y_{t,k} \right), E\left[\varepsilon \mid p_t\right] \right\}$$

$$> U_{t,m} \left\{ y'_{t,m}, u_{t,m}, p \left(y'_{t,m}, x_t, \sum_{k \neq m} y_{t,k} \right), E\left[\varepsilon \mid p_t\right] \right\}$$

(1)

In words, the optimal uninformed demand curve $y_{t,m}$ depends on the endowment received by the uninformed agent $(u_{t,m})$, all other agents equilibrium demand curves $(x_t, \sum_{k \neq m} y_{t,k})$, the expected value of ε, and the fact that an uninformed agent has an impact on the equilibrium price $(p_t = p(y_{t,m}, \cdot, \cdot))$.

Let $\Pi_2 = \Pi_2[x_2, \varepsilon, \bar{p}_1, p_2]$ be the informed agent's profit function in period $t = 2$. x_2 is the informed agent's equilibrium demand curve in $t = 2$ if, for a given price $\bar{p}_1$, all alternative demand curves x'_2 and equilibrium demand curves $y_{2,m}$

$$\Pi_2 \left[x_2, \varepsilon, \bar{p}_1, p_2 \left(x_2, \sum_m y_{2,m} \right) \right] > \Pi_2 \left[x'_2, \varepsilon, \bar{p}_1, p_2 \left(x'_2, \sum_m y_{2,m} \right) \right]$$

(2)

The informed's optimal strategy depends on the aggregate uninformed demand curve $\sum_m y_{2,m}$ and the realization that p_2 depends on x_2. Plugging in the equilibrium demand curve x_2, $E[\Pi_2]$ can be rewritten in terms of p_1 only. Let $E\Pi[x_1, p_1]$ be the informed agent's total expected profits.

$$E\Pi[x_1, p_1] = \Pi_1[x_1, p_1] + \pi E\Pi_2[p_1]$$

x_1 is the informed agent's equilibrium demand curve in $t = 1$ if, for all alternative demand curves x'_1 and equilibrium demand curves $y_{1,m}$

$$E\Pi \left[x_1, p_1 \left(x_1, \sum_m y_{1,m} \right) \right] > E\Pi \left[x'_1, p_1 \left(x'_1, \sum_m y_{1,m} \right) \right]$$

(3)

which is similar to equation (2).

5.6 Solution to the model

I will focus on a linear solution of the model. The formal solution of the linear equilibrium is derived in appendix A. In this subsection I discuss the main results of the model and the various steps necessary to arrive at the solution.

Proposition 1 *If*

$$var\left[\varepsilon \mid p_1, \widehat{p}_{m,2}^u\right] > \frac{C}{A^2 (M-1) \sigma_u^2}$$

(4)

with C a constant in terms of the parameters of the model, a linear solution to the problem exists with the following equilibrium demand functions

$$x_1 = \beta_1^i (v_0 + \varepsilon - p_1) - \mu\varepsilon \tag{5}$$

$$x_2 = \beta_2^i (v_0 + \varepsilon - p_2) \tag{6}$$

$$y_{1,m} = \beta_1^u (v_0 - p_1) - \gamma_1 u_{1,m} \tag{7}$$

$$y_{2,m} = \beta_2^u (v_0 + E[\varepsilon \mid p_1] - p_2) - \gamma_2 u_{2,m} \tag{8}$$

and the following equilibrium prices

$$p_1 = v_0 + \lambda_1 \left[(\beta_1^i - \mu)\varepsilon - \gamma_1 \sum_M u_{1,m} \right] \tag{9}$$

$$p_2 = v_0 + E[\varepsilon \mid p_1] + \lambda_2 \left[\beta_2^i (\varepsilon - E[\varepsilon \mid p_1]) - \gamma_2 \sum_m u_{2,m} \right] \tag{10}$$

with slopes of the aggregate demand curve defined as

$$\lambda_1 = \frac{1}{\beta_1^i + M\beta_1^u} \tag{11}$$

$$\lambda_2 = \frac{1}{\beta_2^i + M\beta_2^u} \tag{12}$$

The proof can be subdivided in four parts.

1. First I guess that the equilibrium is of the linear form described by the proposition.

2. Secondly, given the hypothesized linear policy rules, I solve for the uninformed agents' expectation of the true value of ε. Each uninformed agent m observes all other agents' demand curves. This sums up to a residual demand curve, which includes the informed agent's demand and provides a noisy signal about the true value of ε. In $t = 1$ this residual demand curve is the only signal observed by the uniformed investors. In $t = 2$ the uninformed investors also observe p_1 which yields information about the asset's true value as well.

3. Given the uninformed investors' expectation of ε, I can solve for the informed and uninformed's optimization problems and derive the equilibrium demand functions. In the appendix I show that these functions equal the ones I hypothesized. Having established all agents' demand curves, I can calculate equilibrium prices. I equate all individual demand curves for each period and calculate the price at which markets clear.

$$x_t + \sum_m y_{m,t} = 0$$

4. The existence of the equilibrium depends on the second order conditions of the problem. The second period's first order condition is the most restrictive existence condition and can be summarized by equation (4). What this condition

shows is that the uncertainty about the asset's true value at the end of period $t = 2$ must not be too small. The intuition behind this result follows from the trade-off faced by the uninformed agents. On the one hand they benefit from trading because this enables them to engage in risk sharing. On the other hand they face adverse selection costs. When the uncertainty about ε after trade in $t = 2$ is not too large, these adverse selection costs will dominate and the uninformed will find it optimal not to trade and an equilibrium will not exist.[39] In the remainder of the paper I will assume that (4) holds.

The intuition behind proposition (1) follows largely from the definition of the equilibrium. The uninformed demand curves $y_{1,m}$ and $y_{2,m}$ are a function of endowments and prices. First of all, the uninformed agent wants to rebalance his portfolio. For example, if he is endowed with a large long position in the asset, he will want to sell some of this position. This argument for trade is captured by the $\gamma's$ in equations (7) and (8). Secondly, the uninformed's demand will depend on the expected value of the asset which is determined by past prices and the current period's residual demand curve. Since the uninformed agents know their own equilibrium demand curve, the information from the residual demand curve can be summarized in terms of the equilibrium price p_t. If this is high, this implies a higher expected value of the asset and a higher demand for it. In equations (7) and (8) this is captured by the β^u's. Note that the coefficient on p_t is still negative in these expressions. This reflects the fact that uninformed demand is in general downward sloping because of limited risk bearing capacity. However, in the presence of asymmetric information, this effect is dampened by the fact that a high equilibrium price also reflects a higher expected value for the asset.

The informed demand schedules in equations (5) to (6) are downward sloping as well. This is directly the results of the monopolistic optimization problem. Unlike the uninformed agents, the insider is allowed to trade in every period. Because his trades reveal some of his information, his optimization problem has an important timing decision. How much of the private signal is the informed agent willing to reveal in each period? Suppose that the informed agent trades very aggressively on his signal in $t = 1$. He will make a big profit in that period, but will also reveal a large fraction of his signal and this will cause expected profits in $t = 2$ to fall. In other words, the informed agent faces a trade-off between current and future profits which is determined by parameter π. If π is high, and the second period occurs with high probability, the informed agent has an incentive to 'save' more of the private signal for the future than if π is low. In equation (5) this intuition is captured by μ, which is proportional to π.

Equations (9) and (10) give the resulting equilibrium prices. These reflect the change in the fundamental value ε. However, prices never fully equal $v_0 + \varepsilon$ and the model generates volatility, even in the absence of new information. The intuition behind this follows from two factors. First of all, there is always noise

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[39] The conditions for existence becomes less binding when σ_u^2 or M increase. This follows from the fact that if σ_u^2 is relatively large compared to σ_ε^2, or if M is big, adverse selection costs will fall as more trade will take place for risk sharing reasons.

in the aggregate demand curve. As long as the informed agent does not submit a horizontal demand curve at $v_0 + \varepsilon$, prices will deviate from the fundamental value. The second factor has to do with liquidity. In the model, liquidity comes at a cost. As explained before, counterparties need to be compensated for absorbing a certain position in the asset. This implies that as long as $\sum_m u_{m,t} \neq 0$, there will be a wedge between the expected value of the asset and the actual price. Note that this wedge is transitory because in the next period different endowment shocks reach the market. By assumption, these shocks are independent over time and the price changes they induce will be reversed in the next trading period.

This final element generates return predictability in the return series. This is a natural and fully rational element of the model. The risk averse uninformed investors have to offer other investors a predictable return to compensate them for taking risks on their books. The risk neutral informed investor does not trade very agressively on this return predictability either because (1) trading on this mispricing would reveal some of his private information and (2) he benefits from this return predictability and since he acts monopolistically he has no incentive to arbitrage it away.

5.7 Predictions about price changes

The model has a number of specific predictions about the resulting price changes. These predictiona are summarized in the following corollaries. All proofs are in appendix A. First, prices in London and Amsterdam both move to reflect ε_k. Assume that the price change in London over episode k can be written as

$$\Delta p_k^L = \varepsilon_k + L_k$$

where L_k reflects temporary disturbances in the London price change similar to the impact of endowment shocks in Amsterdam.

The first regression of interest is

$$p_{k,1} - p_{k,0} = a_{news} + b_{news}\Delta p_k^L + \eta_k$$

which measures the extent to which the price change in Amsterdam that occurs right after the arrival of a boat is correlated with the price change in London over the same episode. Note that at the beginning of episode k, Amsterdam investors have not yet observed Δp_k^L (see figure 10). The regression coefficients are given by

$$a_{news} = 0 \text{ and } b_{news} = \frac{cov\left(\Delta p_k^L, p_{k,1} - p_{k,0}\right)}{var\left(\Delta p_k^L\right)} \tag{13}$$

Corollary 2 *The model predicts that $b_{news} > 0$*

The intuition behind this result is straightforward. The informed agent trades on the private signal he has just received and as a result the price change in Amsterdam will (partly) reflect that information.

The second regression of interest is

$$p_{k,2} - p_{k,1} = a_{nonews} + b_{nonews}\Delta p_k^L + \eta_k$$

which measures to what extent the change in the Amsterdam price between $t = 1$ and $t = 2$, the trading period that takes place in the absence of news, is correlated with the return over the same episode k in London. Regression coefficients are given by

$$a_{nonews} = 0 \text{ and } b_{nonews} = \frac{cov\left(\Delta p_k^L, p_{k,2} - p_{k,1}\right)}{var\left(\Delta p_k^L\right)} \tag{14}$$

Corollary 3 *The model predicts that* $b_{nonews} > 0$

The intuition behind this result is that in the beginning of $t = 2$ the private signal ε_k is not fully revealed after trade in $t = 1$. The informed agent will try to benefit from his informational advantage whilst trading in $t = 2$. As a result, the price change in $t = 2$ reflects some of the insider's private knowledge.

Corollary 4 *Finally, the model predicts that as long as* $\pi < 1$, $b_{news} > b_{nonews}$ *or*

$$cov\left(\Delta p_k^L, p_{k,1} - p_{k,0}\right) > cov\left(\Delta p_k^L, p_{k,2} - p_{k,1}\right) \tag{15}$$

If $\pi < 1$ the insider runs the risk that period $t = 2$ does not occur and he will lose all profits from that period. This implies that the insider will trade relatively aggressively in $t = 1$. As a result the co-movement between Amsterdam and London will be particularly strong in $t = 1$.

The second set of predictions relate to the reversal of price changes in the next trading period. The intuition for these reversals is simple. Start in a random period τ. In period τ the equilibrium price is affected by the aggregate endowment shock of that period. This component disappears, and the price change of τ is partly reversed in the next period $\tau + 1$, when a different endowment shock reaches the market.

Reversals can be measured empirically by performing the regression

$$p_{\tau+1} - p_\tau = c + d\left(p_\tau - p_{\tau-1}\right) + \eta_\tau$$

where

$$d = \frac{cov\left(p_{\tau+1} - p_\tau, p_\tau - p_{\tau-1}\right)}{var\left(p_\tau - p_{\tau-1}\right)}$$

In the model two different types of reversals can be identified.
  (1) The reversal of a return taking place in the **absence** of news
  (2) The reversal of a return taking place in the **presence** of news
  In appendix A the different reversal coefficients are formally derived. Here I only discuss the results and intuition.
  The reversal-coefficient of case (1) is given by

$$d_{nonews} = \frac{cov\,(v - p_2, p_2 - p_1)}{var\,(p_2 - p_1)} \tag{16}$$

After $t = 2$, the price in Amsterdam will be equal to v plus a disturbance unrelated to v or the endowment shocks in $t = 1$ or $t = 2$. As a result the relevant covariance term can be written as $cov\,(v - p_2, p_2 - p_1)$.

The coefficient of reversal for case (2), returns taking place right after the arrival of a boat, is slightly more complicated. There are two subcases:

(2a) the arrival of one boat is immediately followed by the next

(2b) the next boat is delayed and there is a trading period without news.

The coefficient of reversal for case (2a) is given by

$$d^a_{news} = \frac{cov\,(v - p_1, p_1 - v_0)}{var\,(p_1 - v_0) + var\,(v - p_2)} \tag{17}$$

The numerator is similar to the one in (16) and should be intuitive. The denominator is slightly different. To understand this note that after the arrival of a boat the Amsterdam price will move to reflect two factors. First of all, the change in the price will reflect informed and liquidity trading taking place in $t = 1$ of episode k, $p_1 - v_0$. Secondly, the price will adjust to reflect the public revelation of the private signal of the previous episode $k - 1$ and the reversals of the endowment shocks from that episode. The variance of this second component equals $var\,(v - p_2)$.[40]

The coefficient of reversal for case (2b) is given by

$$d^b_{news} = \frac{cov\,(p_2 - p_1, p_1 - v_0)}{var\,(p_1 - v_0) + var\,(v - p_2)} \tag{18}$$

which is very similar to expression (17). The main difference is in the numerator where v is replaced by p_2. It can be shown (see appendix A) that

$$d^a_{news} = d^b_{news} = d_{news}$$

The model's predictions about the reversals of returns are summarized by the following corollaries.

Corollary 5 *The model predicts that $d_{nonews} < 0$*

Corollary 6 *and $d_{news} < 0$*

This corollary simply formalizes the intuition that the price impact of endowment shocks is reversed in the next period.

The following corollary shows one of the key results from the model

Corollary 7 *if $\pi < 1$, $d_{nonews} < d_{news}$ or $|d_{nonews}| > |d_{news}|$*

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[40] The variance of this second factor depends on whether episode $k - 1$ consists of one or two trading periods. Throughout I will assume that episode $k - 1$ had two periods because this assumption turns out to be more restrictive for the propositions that follow (see the appendix for details).

The intuition for this result is similar to the one of corollary 5. If $\pi < 1$ the insider will discount future profits. He will trade relatively aggressively on his private signal. This has two implications. First of all, the price change in $t = 2$ reflects less fundamental information than the price change in $t = 1$ (see corollary 5). Secondly, adverse selection costs for the uniformed agents are lower in $t = 2$ than in $t = 1$. As a result uninformed agents will trade more intensively on their endowments. These two effects combined ensure that compared to the price change in $t = 1$, price movements in $t = 2$ predominantly reflect the clearing of liquidity trades and only to a lesser extent the revelation of the private signal. As a result, the return in $t = 2$ will exhibit a stronger reversal than the return in $t = 1$.

Corollary 8 *The model finally predicts that*

$$\frac{\delta\left(d_{nonews}\right)}{\delta\sigma_\varepsilon^2} < 0 \text{ or } \frac{\delta\left|d_{nonews}\right|}{\delta\sigma_\varepsilon^2} > 0$$

The corollary states that if the uncertainty about signal ε increases, the degree to which the return in $t = 2$ are reversed should increase. The intuition behind this result follows from the fact that more uncertainty leads to larger risk premia and to larger return reversals.

6 Empirical evidence

6.1 Introduction

In this section I present empirical evidence for the model's predictions. For the sake of brevity I will focus on the EIC only.[41] First of all, the model predicts that returns in Amsterdam should foreshadow developments in London, as the same underlying private signal gets incorporated into prices in both cities. This effect should be especially strong right after the arrival of a boat from London. Secondly, the model predicts that price changes should partly be reversed in the next trading period. Returns taking place in the absence of news should display a larger reversal, because trade for risk sharing motives is more important during these periods.

Before going into the empirical tests let me first present evidence on one of the main assumptions of the model: the uncertainty about the arrival of the next boat from London. This feature of the model plays an important role, but how realistic is it? I use weather data and other information at the disposal of an investor to check how much uncertainty there actually was about the arrival of the next boat.

Suppose the English letters have just arrived in Amsterdam and a market participant wants to predict the number of days it will take before the next

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[41] The empirical results hold for the BoE as well and are available upon request. Price notations in London for SSC stock were very irregular during the period (see page 20). This means that the model's predictions cannot be verified for the SSC.

Figure 11: Predicting the arrival of news
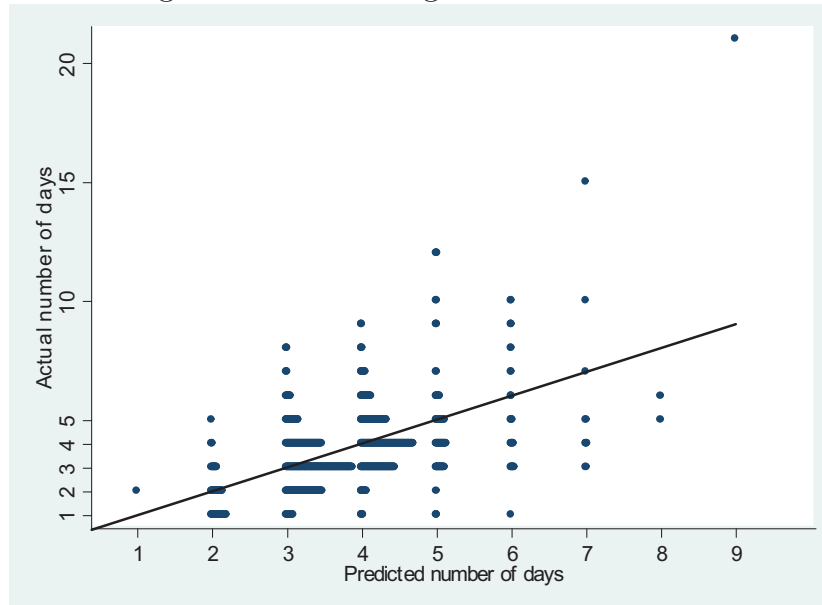
shipment of news arrives. Two things will matter: the departure date of the next boat that is expected and current weather conditions, such as the wind direction and speed and the possible presence of ice in the harbor (and at sea). As I mentioned in section 2, there is a unique dataset of weather observations available from the observatory of *Zwanenburg*, a town close to Amsterdam (KNMI). Since these observations come from a town close to Amsterdam, they can be used to approximate an investor's information set in this city.

I estimate a survival analysis model with Weibull distribution in which I include this information. Specifically I include the number of days since the departure of a specific boat, the direction of the wind, the wind speed, wind direction and speed interacted, the temperature, a dummy for temperatures below zero, two lags of all weather observations and finally the month in which an observation occurred.

Figure 11 presents a dot plot of the predicted values of the Weibull survival model and the actual number of days it took for the next shipment of English news to arrive in Amsterdam. It is clear that 18th century observers could, to some extent, have predicted the arrival of news. Predicted and actual values have a correlation coefficient of 0.52. Predictions did involve a large margin of error. For example, if the next boat is predicted to arrive in 3 days, it can actually take anything between 1 and 8 days for this to actually happen, with the 95% confidence lying between 2 and 5 days. The assumption that investors faced uncertainty about when the next boat arrived, is borne out by the data.

Figure 12: Setup Empirics
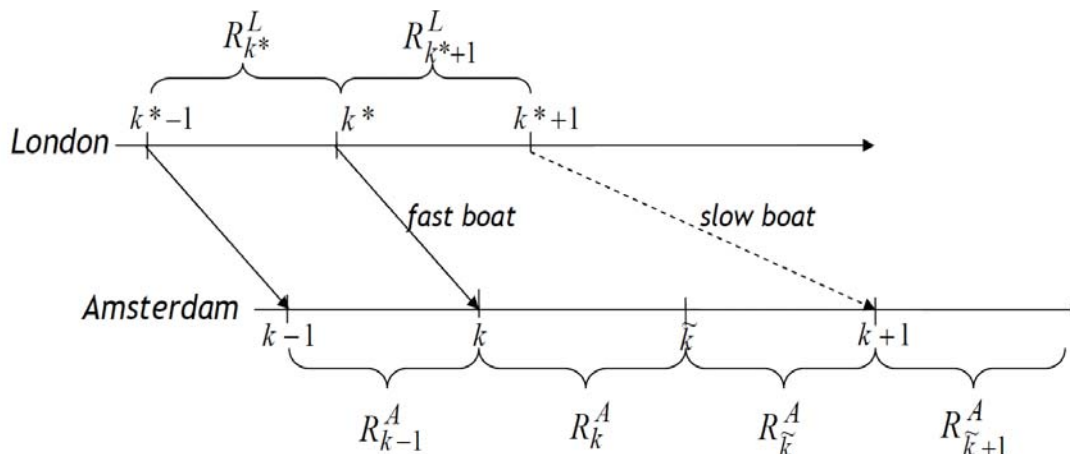
6.2 Benchmark results

To guide the empirical discussion, let me lay out a simple framework in figure
12. This figure applies the setup of the model from figure 10 to the empirical
setting. There are two time-axes in the diagram, one for London and one for
Amsterdam. Time is indexed by k^* for London and simply k for Amsterdam.
k^* and k indicate moments in time a boat departs for Amsterdam or arrives
from London. When I speak of boat k, I mean the boat that sails between k^*
and k.

As discussed, the time it took for boats to get across the North Sea depended
on the weather conditions. Suppose that boats $k - 1$ and k have arrived in
Amsterdam relatively quickly, while boat $k + 1$ is delayed. The delay of boat
$k + 1$ means that after k there is an additional period in Amsterdam denoted
$\widetilde{k}$ in which there is trade in the English stocks, but no new information from
London. These periods $\widetilde{k}$ are the no-news periods referred to in the previous
sections. At some point after this period $\widetilde{k}$ boat $k + 1$ arrives.

I define Amsterdam and London returns as follows. $R_{k^*+1}^L$ is the return in
London between boat k^* and boat $k^* + 1$. $R_{\widetilde{k}}^A$ is the return in Amsterdam that
takes place in the no-news period $\widetilde{k}$ after the arrival of boat k. This is loosely
referred to as a 'no-news return'. R_k^A is the return in Amsterdam that takes
place between the arrivals of boat $k - 1$ and k. $R_{\widetilde{k}+1}^A$ is the Amsterdam return
between no-news period $\widetilde{k}$ and the arrival of boat $k + 1$. R_k^A and $R_{\widetilde{k}+1}^A$ and
referred to as 'news returns'.

Note that it is also possible that boat $k + 1$ arrives without any delay. In
that case period $\widetilde{k}$ would not take place (imagine that the dotted line in figure
12 points directly at $\widetilde{k}$) and R_k^A would be directly followed by the next news
return R_{k+1}^A.

How well do the corollaries established by the model hold up? Let's first
look at impact of insider trading and the resulting co-movement of London and

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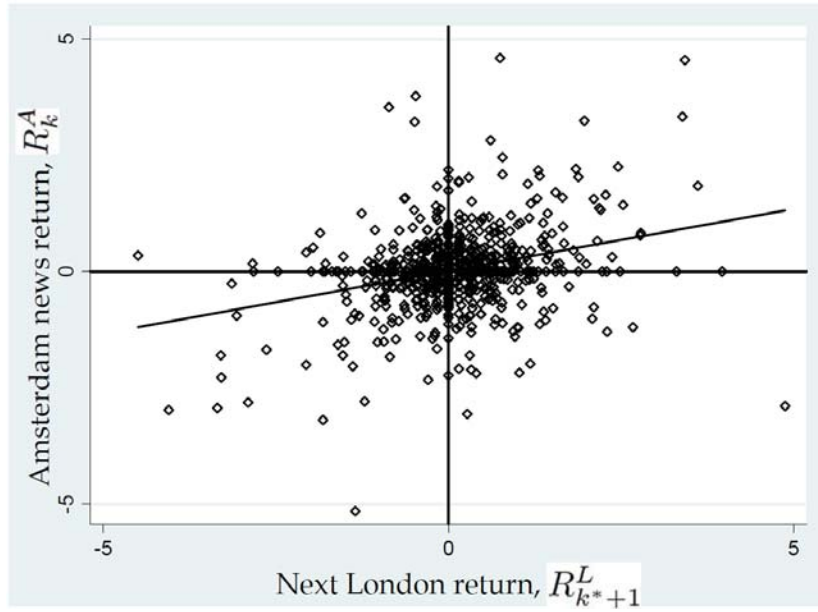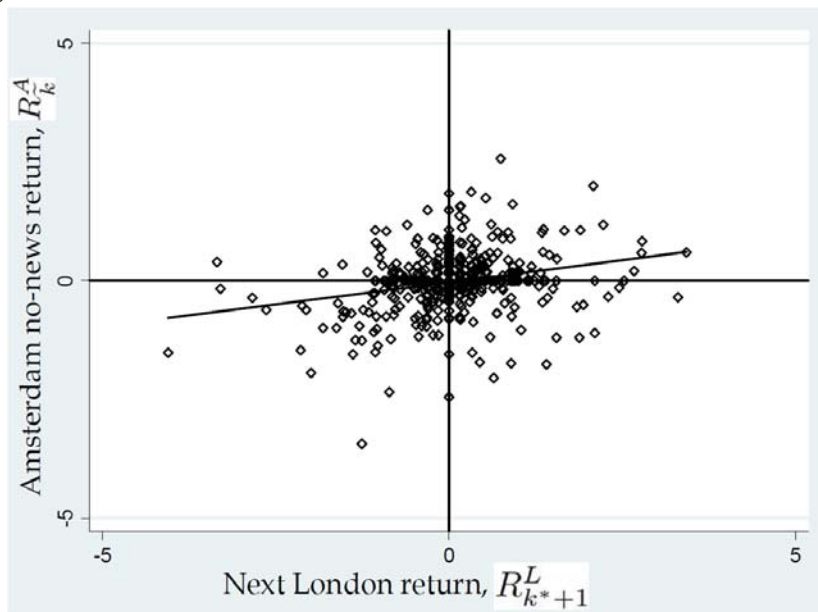Figure 13: Co-movement Amsterdam-London - news returns

Figure 14: Co-movement Amsterdam-London - no-news returns

Amsterdam returns. Remember that corollaries 2 and 3 state that returns in Amsterdam, both right after the arrival of news from London and during subsequent periods without any new information, should predict developments in London that will take place right after the departure of the news to Amsterdam. Or in terms of figure 12 (see page 44) both R_k^A (the Amsterdam news return) and $R_{\widetilde{k}}^A$ (the Amsterdam no-news return) should be correlated with the next London return $R_{k^*+1}^L$.

Figure 13 shows that R_k^A is positively correlated with London return $R_{k^*+1}^L$. Likewise, figure 14 shows that $R_{\widetilde{k}}^A$ is also correlated with $R_{k^*+1}^L$. These correlations are highly statistically significant with t-values of 4.93 and 3.76 respectively. This implies that price changes in Amsterdam predict the contemporaneous (but as of yet unreported) return in London – news of which will only arrive in the future. Note that this cannot be the result of the generation of relevant news in Amsterdam. The time lags involved in getting news from Amsterdam to London make it nearly impossible that London developments between k^* and $k^* + 1$ are influenced by Amsterdam developments between k and $\widetilde{k}$.[42]

In table 8 I estimate these correlations in a formal econometric framework. Columns 1 (news returns) and 3 (no-news returns) present the results from figures 13 and 14. It is possible that these positive relations are driven by momentum in the stock price series. In columns 2 and 4 I therefore condition on $R_{k^*}^L$, the last London return Amsterdam investors actually observed, to correct for possible momentum in the return series. Results remain virtually unchanged.

Comparing columns 1 and 3 (or columns 2 and 4) it also becomes clear that this co-movement with future London returns is especially strong for returns taking place right after the arrival of a boat from England. This is consistent with corollary 4, which states that the relation between Amsterdam and future London returns should be stronger right after news from London is received. However, the difference between the two coefficients is not significant at standard confidence levels.

How big is the effect of informed trading economically? The coefficient of $R_{k^*}^L$ in the second column of table 8 measures the extent to which Amsterdam returns co-move with current London news returns, i.e. the most recent price changes in London that are publicly observed (see figure 12). Compared to the impact of public information, the coefficients on $R_{k+1^*}^L$ are between 30% (R_k^A) and 55% ($R_{\widetilde{k}}^A$) smaller. This suggests that private information is less important than public news, but far from negligible.

What about the model's prediction for the reversal of returns (corollaries 5 to 8)? Figure 15 shows that Amsterdam no-news returns, $R_{\widetilde{k}}^A$, are negatively correlated with subsequent news returns $R_{\widetilde{k}+1}^A$. This means that no-news returns are (partly) reversed in the next period. If for example the EIC stock price goes up in period $\widetilde{k}$, the share price in period $k + 1$ tends to fall. This negative correlation is significant with a t-statistic of -3.28.

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[42] In addition, in section 3 I have shown results from Granger causality tests that Amsterdam returns have, in general, no predictive power for London returns.

Figure 15: Reversal of no-news returns
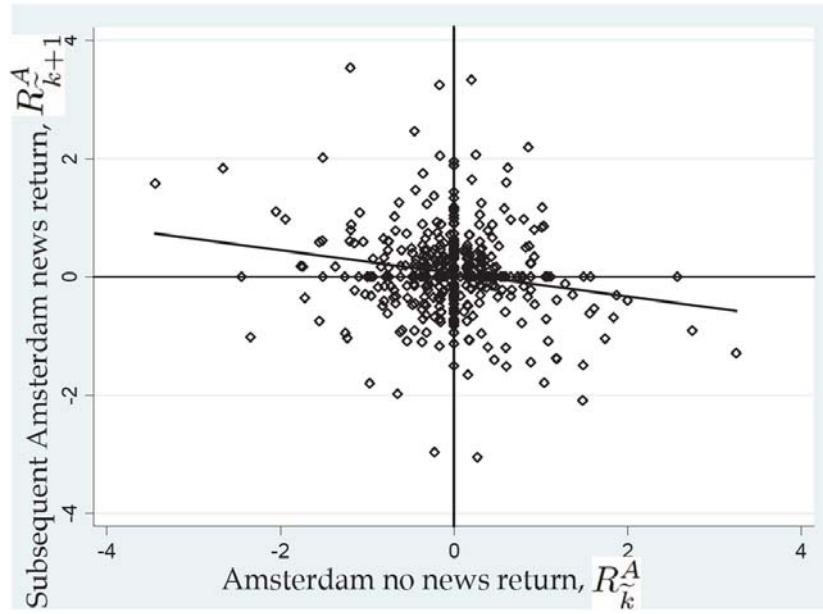
Figure 16: Reversal of news returns
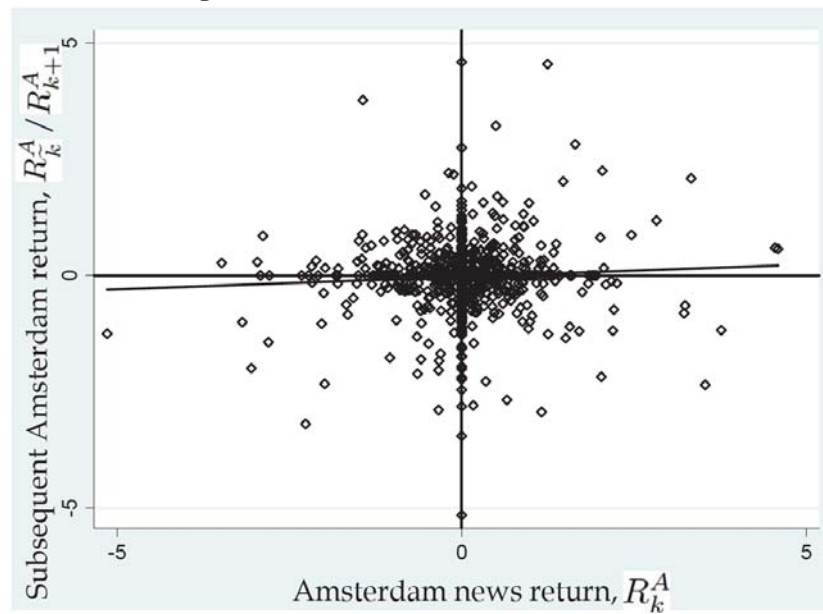
Table 8: Co-movement of returns

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	Amsterdam news return, R_k^A		Amsterdam no-news return, $R_{\widetilde{k}}^A$	
Next London news return, $R_{k^*+1}^L$	0.2639 (0.0523)***	0.2604 (0.0446)***	0.1580 (0.0459)***	0.1657 (0.0433)***
Current London news return, $R_{k^*}^L$		0.3660 (0.0403)***		0.1288 (0.0486)***
Constant	0.0161 (0.027)	-0.0025 (0.0256)	-0.0226 (0.0303)	-0.0366 (0.0285)
Obs	817	811	471	463
R2	0.09	0.27	0.04	0.08
Chi2 test (p-value)	2.43 0.1194	2.00 0.1571		

*** denotes statistical significance at the 1% level. Robust, bootstrapped standard errors(1000 replications) are reported in parentheses.
This table tests corollaries 2-4 on the co-movement between future London returns in EIC stock and Amsterdam returns in the presence (columns 1 and 2) and absence (columns 3 and 4) of news. In columns 3 and 4 I condition on current London returns, $R_{k^*}^L$, to adjust for possible momentum in stock returns. The Chi2 test-value is reported for the hypothesis that R_k^A and $R_{\widetilde{k}}^A$, Amsterdam news and no-news returns, co-move similarly with the next London news returns $R_{k^*+1}^L$.

This result fails to hold for news returns. Figure 16 shows that news returns R_k^A are uncorrelated with returns in the next trading period, $R_{\widetilde{k}}^A$ or R_{k+1}^A (t-statistic of 1.25). Put differently, return reversals seem to be a unique feature of the no-news returns. The slopes of figures 15 and 16 are statistically different from each other with a χ^2 statistic of 11.13.

Table 9 presents these results in a more formal econometric framework. Columns 1 and 3 replicate the results from figures 15 and 16. The regressions results confirm the finding that $R_{\widetilde{k}}^A$ is partly reversed during the next period. This pattern is seemingly absent for R_k^A. This is inconsistent with the model that predicts that both types of returns should partly be reversed. The difference in reversal between Amsterdam news and no-news returns is highly statistically significant. This means that corollary 7 of the model is confirmed: reversals are stronger for Amsterdam returns over periods without news.

It is likely that the coefficients measuring the reversal of returns are biased towards zero. The regression results from table 8 indicate that Amsterdam returns R_k^A and $R_{\widetilde{k}}^A$ are both positively correlated with the London return $R_{k^*+1}^L$.

Table 9: Reversal of Amsterdam returns

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	Subsequent Amsterdam (news) return, $R^A_{\tilde{k}+1}$		Subsequent Amsterdam return, $R^A_{\tilde{k}}$ / R^A_{k+1}	
Amsterdam no news return, $R^A_{\tilde{k}}$	-0.1874 (0.0596)***	-0.2885 (0.0605)***		
Amsterdam news return, R^A_k			0.0313 (0.0417)	-0.1112 (0.0451)***
Current London news return, $R^L_{k^*+1}$		0.3537 (0.0534)***		0.2982 (0.0378)***
Past London news return, $R^L_{k^*}$		-0.021 (0.0330)		0.0911 (0.0451)**
Constant	0.0448 (0.0332)	0.0308 (0.0288)	-0.0249 (0.0252)	-0.0433 (0.0240)*
Obs	474	463	852	846
R2	0.03	0.20	0.00	0.01
Chi2 test	11.13***	6.61**		
(p-value)	0.008	0.0102		

***, **, * denotes statistical significance at the 1, 5 and 10% level. Robust, bootstrapped standard errors (1000 replications) are reported in parentheses. This table tests corollaries 5 to 7 on the reversal of Amsterdam returns on EIC stock in the absence (columns 1 and 2) and presence (columns 3 and 4) of news. In order to estimate the return reversals more precisely, I condition on $R^L_{k^*+1}$ and $R^L_{k^*}$, past and future London news returns, in columns 2 and 4. The Chi2 test is reported for the hypothesis that R^A_k and $R^A_{\tilde{k}}$, Amsterdam news and no-news returns, exhibit the same reversal in the next period.

$R^L_{k^*+1}$ captures the arrival of news from London and plays an important role in the reversal of returns at $k+1$. This potentially biases the reversal coefficients upwards. Take for example the negative correlation between $R^A_{\tilde{k}}$ and $R^A_{\tilde{k}+1}$ presented in column 1. Both $R^A_{\tilde{k}}$ and $R^A_{\tilde{k}+1}$ are positively correlated with $R^L_{k^*+1}$ and as a result there will be a positive element in the correlation between $R^A_{\tilde{k}}$ and $R^A_{\tilde{k}+1}$ and this will bias the negative correlation between these returns towards zero. One can correct for this by including $R^L_{k^*+1}$ in the regressions. This is done in columns 2 and 4 of table 9. In the same columns I also correct for $R^L_{k^*}$, the past London news returns. This makes a big difference. The reversal of the Amsterdam no-news return $R^A_{\tilde{k}}$ roughly increases by half. In addition, once corrected for new information from London, the Amsterdam news return R^A_k now displays a statistically significant reversal. This is fully in line with

corollary 6 of the model. In other words, the prediction of the model that all returns, taking place over periods with or without news, are partly reversed, is confirmed by the data. The difference in the degree to which Amsterdam news and no-news returns are reversed, is still highly statistically significant.

Finally, corollary 8 of the model states that the reversals of no-news returns increase with the underlying volatility of the asset. This prediction is tested in table 10. Columns 1 and 3 give the benchmark results from table 9. The impact of high volatility observations is analyzed in columns 2 and 4 by ways of an interaction term between $R_{\tilde{k}}^A$ and a dummy indicating whether an observation occurs in a high volatility regime or not.[43] The results suggest that the degree of reversal is indeed higher in high volatility regimes. The interaction terms in both column 2 and 4 are both negative. This effect is statistically significant after correcting for London returns R_{k*}^L and R_{k*+1}^L.

In table 11 I summarize the predictions made by the model and the extent to which they are consistent with the empirical evidence. In general, empirical findings are in line with the model.

6.3   Robustness checks

Some of the empirical findings can be driven by other factors. In this sub-section I will discuss a number of these alternative explanations.

6.3.1   Slipping through of news

The first finding regards the positive correlation between Amsterdam and London returns in the absence of news that was presented in figure 14 and table 8. In the previous section I have already shown that this relation is unlikely to be driven by momentum in the return series. An alternative explanation could be the fact that some news may simply have arrived in Amsterdam outside of the official packet boat system.[44] As argued in sections 2 and 4, it is unlikely that alternative news channels played an important role, but it is not impossible. To test for this possibility I look at the degree of co-movement during periods where the weather was particularly bad so that the packet boats were seriously delayed or could not sail out at all. The idea is that under these circumstances other boats must have found it difficult as well to make their way across the North Sea. If the slipping through of news was the main driver behind the positive correlation between Amsterdam and London returns in the absence of news, this correlation should be close to zero during periods of bad weather.

Figure 17 plots $R_{\tilde{k}}^A$ against R_{k*+1}^L for the restricted bad weather sample.[45]

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[43] High volatility regimes are defined based on the London return R_{k*+1}^L observed in Amsterdam in $k+1$. If R_{k*+1}^L is bigger than the 75th percentile or smaller than the 25th percentile, the corresponding observation $R_{\tilde{k}}^A$ is said to be part of the high volatility regime.

[44] Note that this would not fully disqualify the presence of private information. The co-movement between R_k^A and R_{k*+1}^L would still point into the direction of insider trading.

[45] An observation is included in the bad weather category if a packet boat took longer than the median time period to cross the North Sea.

Table 10: Reversal of Amsterdam returns - high volatility

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	Subsequent Amsterdam news return, $R^A_{\widetilde{k}+1}$			
Amsterdam no news return, $R^A_{\widetilde{k}}$	-0.1874 (0.0596)***	-0.1054 (0.0746)	-0.2885 (0.0605)***	-0.1553 (0.0790)**
Amsterdam no news return, $R^A_{\widetilde{k}}$ x high volatility		-0.1162 (0.1072)		-0.1806 (0.1026)*
Current London news return, $R^L_{k^*+1}$			0.3537 (0.0534)***	0.3544 (0.0551)***
Past London news return, $R^L_{k^*}$			-0.021 (0.0330)	-0.0198 (0.0340)
High volatility		0.0001 (0.0679)		0.001 (0.0581)
Constant	0.0448 (0.0332)	0.0431 (0.0324)	0.0308 (0.0288)	0.0286 (0.0309)
Obs	474	474	463	463
R2	0.03	0.03	0.2	0.2

***, **, * denotes statistical significance at the 1, 5 and 10% level. Robust, bootstrapped standard errors (1000 replications) are reported in parentheses. This table tests corollary 8 which states that reversals of Amsterdam returns taking place in the absence of news exhibit a stronger reversal in high volatility regimes. This is done in columns 2 and 4 by adding an interaction term between $R^A_{\widetilde{k}}$ and a high volatility dummy to the benchmark estimates from columns 1 and 3 (see table 9). The total reversal coefficient of high volatility regimes is given by adding the coefficients in rows 1 and 3. In columns 3 and 4 I condition on past and current London news returns, $R^L_{k^*}$ and $R^L_{k^*+1}$.

The figure shows that during periods when its was difficult to get news across the North Sea, there was still a positive correlation between returns in London and Amsterdam. Table 12 presents the corresponding regression results. The impact of bad weather observations is analyzed in the second column by ways of an interaction term between $R^L_{k^*+1}$ and a bad weather dummy. The table shows that the degree of co-movement was even twice as strong under these conditions, although not in a tightly estimated fashion. To summarize, these results suggest that the co-movement between Amsterdam and London returns is not driven by news slipping through the official packet boat system.

Table 11: Summary empirical results

Corollary	Prediction	Confirmed by the data?
2	Co-movement London and Amsterdam news returns	+
3	Co-movement London and Amsterdam no-news returns	+
4	Co-movement stronger for news returns	+**
5	Reversal of Amsterdam news returns	+*
6	Reversal of Amsterdam no-news returns	+
7	Reversals stronger for news returns	+
8	Reversals stronger during periods of high uncertainty	+*

** not statistically significant
* only significant when controlling for London returns

6.3.2 Illiquidity

The second finding, the large scale reversal of no-news returns, could be the result of low liquidity in the market on days that no news arrived from England. It could be the case that investors want to trade more when there is new information available and that their participation in the Amsterdam market in the absence of news was limited (e.g. Kandel and Pearson 1995). In a thin market, price changes would often be extreme and return reversals would simply reflect low liquidity.

To test this alternative explanation, I collected evidence on stock transactions in Amsterdam. Because the Amsterdam market was so decentralized, volume data is unavailable. However some transactions were recorded in notarial records and these can be reconstructed from the original sources (see appendix B). I collected data on a total of 119 transactions in EIC stock between 1771 and 1774, with a combined nominal value of £194 thousand (the total nominal value of the Company's stock was £3.2 million).[46]

Of these 119 transactions, 21.4% (weighted by the nominal value of the transactions) took place on days that news from London arrived. On average, news from London reached Amsterdam two times a week. So, if market participants were indifferent between trading on days with or without news, one would expect that on average 28.6% of transactions would take place on days with news. So, in actual fact, there was **less** trading on days when the London news arrived. The difference between the two percentages is significant with a p-value of 3.8%.

This simple calculation ignores the fact that there were certain regularities in trading intensity and the arrival of information over the week. The clearest

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[46] At first sight, a total of 119 transactions seems rather limited. Note however that the average transaction size was £1,600, which in today's money would amount to £159,000. Officer (2009)

Figure 17: Co-movement under bad weather conditions
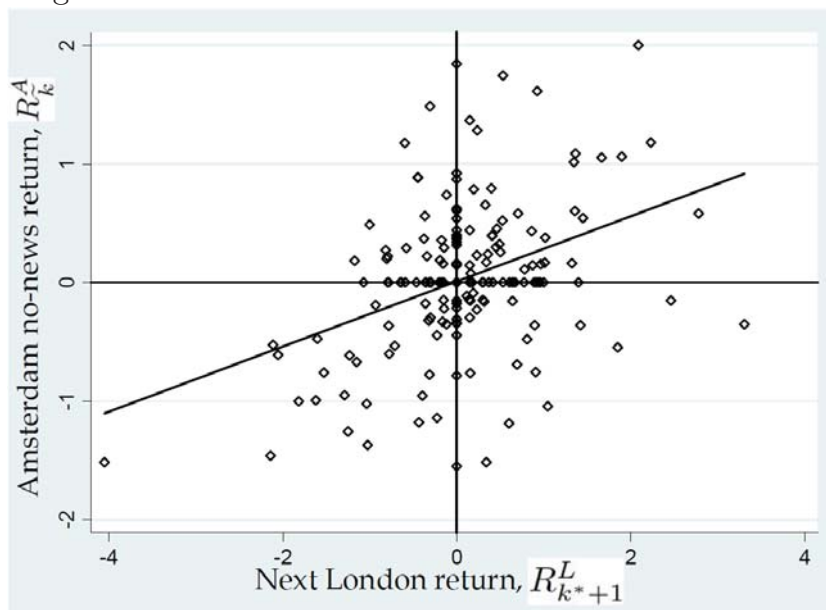
example is Sunday. Trade on this day was limited, while news arrived regularly. In the simple framework this is picked up as evidence that trading was limited on the days news came in.[47] One way to account for these day-of-the-week patterns is to replicate the simple analysis described above for individual days of the week. These are presented in table 13. The table shows that for Monday, Tuesday and Wednesday the amount of trade taking place on days without news was significantly less than one would expect if traders were indifferent between trading on days with or without news. For the remainder of the week, the amount of trading is not statistically different from this benchmark. On no single day did the arrival of news lead to a significant increase in trading. This evidence suggests that the Amsterdam market was not thinner in the absence of information from England. Amsterdam investors even seem to have had a preference for trading in the absence of news.

6.3.3 Initial underreaction to news

It is possible that investors displayed limited attention or sluggishness after the arrival of news and initially underreacted to the new information (Hong and Stein 2007). As a result, stock prices could have moved in the absence of news to reflect delayed reactions (Huberman and Regev 2001; Cohen and Frazzini 2008; Hirshleifer et al. 2009). It is not obvious that this played a role in 18$^{\text{th}}$ century

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[47]Thursday is another example. Boats left Harwich on Saturdays and Wednesdays and news tended to arrive in Amsterdam on Mondays and Fridays or one or two days later (a median sailing time of two days with an additional day for the coach to travel over land to Amsterdam). Hardly any news arrived in Amsterdam on Thursday. In the meanwhile the amount of trade on this day was around average. Again, the simple analysis would pick this up as evidence that trading was limited on the days news came in.

Table 12: Co-movement under different weather conditions
.

	Amsterdam no-news return, $R_{\tilde{k}}^A$	Amsterdam no-news return, $R_{\tilde{k}}^A$
Next London news return, $R_{k^*+1}^L$	0.1657 (0.0433)***	0.1254 (0.0574)**
Next London news return, $R_{k^*+1}^L$ x bad weather		0.1088 (0.0822)
Current London news return,	0.1288 (0.0486)***	0.1254 (0.0485)***
Bad weather		0.0332 (0.0564)
Constant	-0.0366 (0.0285)	-0.0482 (0.0370)
Obs	463	463
R2	0.09	0.09

***, ** denotes statistical significance at the 1 and 5% level. Robust, bootstrapped standard errors (1000 replications) are reported in parentheses. The second column of the regression table tests for the hypothesis that co-movement between $R_{\tilde{k}}^A$ and $R_{k^*+1}^L$ is smaller if weather conditions are worse than average. This is done by adding an interaction term between $R_{k^*+1}^L$ and a bad weather dummy to the benchmark regression presented in column 1 (see table 9). The total co-movement coefficient during bad weather episodes is given by the sum of the coefficients in rows 1 and 3.

Amsterdam. The first important thing to note is that the content of the English letters was relatively straightforward. There were only three British stocks and two English bonds traded. News on these assets was easily summarized. This contrasts with the huge amount of information flowing on today's financial markets. Secondly, Amsterdam investors also received information about the London price which further helped to interpret the news.

Nevertheless it is possible that underreaction played a role. Underreaction to news is often associated with a subsequent drift in the stock price series (Hong and Stein 2007; Hirshleifer et al. 2009). One would therefore expect that underreaction should lead to momentum in the return series. However, table 4 on page 27 shows that there is practically no momentum in the return series. Table 14 on page 46 furthermore shows that, although Amsterdam no-news returns are positively correlated with past London news returns, this effect is small compared to the impact of private information and liquidity shocks.

Table 13: Transactions and the arrival of information

	Transactions Value			$Pr[TrNews]$		$Pr[Boat]$	p-value
	Number	All	News				
Monday	7	15,500	2,000	0.129	<	0.418	0.021
Tuesday	23	36,500	7,000	0.192	<	0.336	0.067
Wednesday	15	28,500	0	0.000	<	0.221	0.024
Thursday	24	32,500	1,500	0.046	<	0.066	0.532
Friday	28	49,100	20,000	0.407	>	0.393	0.574
Saturday	17	25,000	10,500	0.420	>	0.314	0.865
Sunday	5	7,000	500	0.071	<	0.221	0.277
all	119	194,100	41,500	0.214	<	0.286	0.038

This table presents information about the distribution of transactions and the arrival of information over the week. $Pr[TrNews]$ gives the probability that a transaction takes place on a day a boat from London arrives. $Pr[Boat]$ is the probability that a boat arrives. The p-value in the final column corresponds to a one-sided test (bootstrap with $10,000$ replications) that $Pr[TrNews] < Pr[Boat]$.

6.3.4 Exchange rate fluctuations

Stock prices in Amsterdam were quoted in Pounds. Given that the fundamental value of the British stocks was determined in London, it is not clear that fluctuations in the exchange rate between London and Amsterdam could have played a role in explaining the volatility of returns in the absence of news. In addition, both England and the Netherlands were on a specie standard, so that exchange rates only displayed limited fluctuations.

Because of the delay in communication, arbitrage between London and Amsterdam was risky and it is possible that exchange rate fluctuations had an impact on the rate at which Amsterdam investors discounted short run claims in Pounds. This would have generated temporary pricing errors in the Amsterdam market. Unfortunately there is no exchange rate data available to test this interpretation directly. However, it seems logical that exchange rate fluctuations affected all British stocks in the same way. A check on the relevance of the model developed in this paper is therefore to redo all tests using idiosyncratic stock returns, i.e. returns on the English stocks that cannot be explained by common movements. Unreported results indicate that all findings go through. This does not reject the exchange rate explanation, but shows that empirical findings are robust to controlling for its effect.

7 Conclusion

In this paper, I use a unique natural experiment to examine the sources of stock price volatility. In modern data, a large fraction of asset price movements apparently takes place in the absence of relevant public news (e.g. Cutler, Poterba and Summer 1989; Mitchell and Mulherin 1994). However, it is difficult to test for the relevance of new information in modern datasets. News arrives constantly to the market; determining which news item is relevant and when it became available to investors is challenging. The unique natural experiment I use in this paper goes a long way in solving this problem. During the 18th century a number of English stocks were traded in both London and Amsterdam. All relevant information from England reached Amsterdam through mail boats. I reconstruct the arrival dates of these boats and this allows me to perfectly identify the flow of information. I then measure the effect of information on the volatility of the British stocks traded in Amsterdam. As is to be expected, the arrival of news has an important and statistically significant impact on stock price movements. However, asset price volatility is still considerable in the absence of new information and accounts for between 50 and 70% of total volatility. This confirms the finding that although news matters, it can only explain a minority of price changes in financial markets.

What moves asset prices in the absence of new information? DeLong et al. (1990) and others have argued for a behavioral explanation. Some market participants may not be fully rational and the resulting noise trading generates its own volatility.[48] While I cannot rule out behavioral explanations, I propose a rational expectations model of trading in a market with frictions that can explain why asset prices move in periods when no new information arrives. The model analyzes how an insider trades on his private information.[49] An informed agent unveils his information only slowly and information asymmetry, although decreasing, remains. Prices will be inherently volatile even if no new information reaches the market. Private information also has an effect on uninformed trading. As information asymmetries gradually decrease, it becomes less costly for uninformed agents to trade. As a result, the relative importance of uninformed trading increases over time. When the impact of private information on volatility becomes less dominant, a larger fraction of asset price movements is explained by uninformed trading.[50] Empirical results are consistent with the

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[48] The extensive literature on behavioral finance cannot be reviewed here. Cf. Shleifer (2000), Brunnermeier (2001), Hirshleifer (2001), Shiller (2001) and Hong and Stein (2007).

[49] Other papers that study the impact of private information include (amongst others) Kyle (1985, 1989), Glosten and Milgrom (1985), Holden and Subrahmanyam (1992, 1994), Foster and Viswanathan (1996), Chau and Vayanos (2008) and Caldentey and Stacchetti (2010).

[50] This finding is closely related to other papers that look at the impact of information asymmetries on uninformed trading like Admati and Pfleiderer (1988), Foster and Viswanathan (1990), Spiegel and Subrahmanyam (1992), George et al. (1994), Massoud and Bernhardt (1999), Baruch (2002), and Mendelson and Tunca (2004). The model developed in this paper differs on two points. First of all, it combines long lived private information with limited risk bearing capacity. Secondly, the model endogenizes uninformed trading and has the feature that uninformed trading becomes more important over time. This is the result of introducing uncertainty about when a private signal is publicly revealed (Back and Baruch 2004 and

model's predictions. Price movements in Amsterdam are correlated with the contemporaneous (but as of yet unreported) returns in London. This is consistent with the presence of a private signal that is incorporated into the price series of both markets. In addition, the reversal of price changes, a pattern that is often associated with uninformed trading, is predominantly observed for stock returns that take place in the absence of news.

It is interesting to observe that reversals were larger for returns taking place in the absence of news. This suggests that the reversal of returns, an important feature of today's financial markets as well (see inter alia Jegadeesh 1990), are not caused by overreaction to news (Cooper 1999; Subrahmanyam 2005). In addition, the transaction data presented in this paper show that the arrival of new information did not lead to abnormally high trading volumes. These two findings suggest that Amsterdam investors in the 18th century responded to new information in a rational and efficient way.

The episode studied in this paper played out more than two centuries ago. To what extent can the findings from this paper be generalized to today's financial markets? Equity markets were a lot smaller in the 18th century and trading mechanisms were obviously less developed than today. Nevertheless, the evidence presented in this paper does not suggest that markets in the 18th century were particularly inefficient (see also Neal 1990; Dempster et al. 2000). Any possible disadvantage from using historical date is more than compensated by the unique possibility of studying the impact of information in a well-identified way, something that is difficult to do in today's financial markets.

There is no obvious reason why insider trading would be less important today than it was in 18th century Amsterdam. In contrast to the past, insider trading today has become illegal. However the depth and anonymity of today's markets create many more opportunities to benefit from inside information than existed over two centuries ago. The model of insider trading developed in this paper is based on a number of assumptions that are similar to those often made in the market microstructure literature (e.g. Kyle 1985). Crucially, I assume that the insider is a monopolist over his signal, and that private information is long-lived, and arrives to the market in a non-continuous way. Although these assumptions fit well with the historical evidence, it is possible that private information in today's financial markets has different characteristics. Nevertheless, since private information or insider trading is by definition difficult to observe, any evidence on how it might influence the dynamics of trading is of interest.

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Caldentey and Stacchetti 2010). This feature is only shared with Baruch (2002).

London Chronicle, Burney Collection, British Library

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Journals Hope & Co, SAA 734
Letterbooks Hope & Co, SAA 734; 78,79,115 and 1510
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Appendix A

Proof. of proposition 2 ■

1. I hypothesize that the linear equilibrium can be described by equations (5) to (8) with corresponding prices (9) and (10).

2. I solve for the uninformeds' inference problem. Note that because of the linear equilibrium all relevant variables are normally distributed. This means that I can apply the projection theorem. Start in $t = 1$. The market clearing in

$t = 1$ can be rewritten from the perspective of uninformed agent m.

$$y_{1,m} + \beta_1^i (v_0 + \varepsilon - p_1) - \mu\varepsilon + (M - 1)\beta_2^u (v_0 - p_2) - \gamma_1 \sum_m u_{1,m} = 0$$

This can be rewritten as

$$p_1 = \widehat{p}_{1,m}^u + \lambda_1^u y_{1,m}$$

where $\widehat{p}_{1,m}^u$ is the residual demand curve observed by the uninformed agent

$$\widehat{p}_{1,m}^u = v_0 + \lambda_1^u \left[(\beta_1^i - \mu)\varepsilon - \gamma_1 \sum_{k \neq m} u_{1,k} \right] \tag{19}$$

and λ_1^u measures the individual impact of the uninformed's demand $y_{1,m}$

$$\lambda_1^u = \frac{1}{\beta_1^i + (M - 1)\beta_1^u} \tag{20}$$

$\widehat{p}_{1,m}^u$ holds important informational content. Note that all relevant information about ε can be summarized in

$$\theta_{1,m} = \frac{\widehat{p}_{1,m}^u - v_0}{\lambda_1^u (\beta_1^i - \mu)} \tag{21}$$

$$= \varepsilon - \frac{\gamma_1}{(\beta_1^i - \mu)} \sum_{k \neq m} u_{1,k} \tag{22}$$

Since everything is normally distributed the expected value of ε is given by

$$E[\varepsilon \mid \theta_{1,m}] = \rho_1 \theta_{1,m}$$

where

$$\rho_1 = \frac{cov(\varepsilon, \theta_{1,m})}{var(\theta_{1,m})} = \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \left(\frac{\gamma_1}{(\beta_1^i - \mu)}\right)^2 (M - 1)\sigma_u^2} \tag{23}$$

Using standard results from univariate statistics it can be shown that

$$var[\varepsilon \mid \theta_{1,m}] = (1 - \rho_1)\sigma_\varepsilon^2 \tag{24}$$

Then move to $t = 2$. In the second period, the uniformed agent observes two signals: the price from the first period, p_1, and the residual demand curve in $t = 2$, $\widehat{p}_{2,m}^u$. The informational content from p_1 can be summarized as follows

$$\theta_{12} = \frac{p_1 - v_0}{\lambda_1 (\beta_1^i - \mu)} \tag{25}$$

$$= \varepsilon - \frac{\gamma_1}{(\beta_1^i - \mu)} \sum_M u_{1,m} \tag{26}$$

Similar to equation (19) $\widehat{p}_{2,m}^u$ can be written as:

$$\widehat{p}_{2,m}^u = v_0 + E\left[\varepsilon \mid p_1\right] + \lambda_2^u \left[\beta_2^i \left(\varepsilon - E\left[\varepsilon \mid p_1\right]\right) - \gamma_2 \sum_{k \neq m} u_{2,m}\right] \qquad (27)$$

with

$$\lambda_2^u = \frac{1}{\beta_2^i + (M-1)\beta_2^u} \qquad (28)$$

Again the informational content of $\widehat{p}_{2,m}^u$ can be summarized in

$$\theta_{2,m} = \frac{\widehat{p}_{2,m}^u - v_0}{\lambda_2^u \beta_2^i} - \frac{\beta_2^u}{\beta_2^i} E\left[\varepsilon \mid p_1\right] \qquad (29)$$

$$= \varepsilon - \frac{\gamma_2}{\beta_2^i} \sum_{k \neq m} u_{2,m} \qquad (30)$$

The expected value of ε given these two signals is given by

$$E\left[\varepsilon \mid \theta_{12}, \theta_{2,m}\right] = \rho_{12}\theta_{12} + \rho_2 \theta_{2,m}$$

where

$$\rho_{12} = \rho_{12}^* - \rho_2 \frac{cov(\theta_{12}, \theta_{2,m})}{var(\theta_{12})}$$

$$= (1 - \rho_2)\rho_{12}^* \qquad (31)$$

and

$$\rho_2 = \rho_2^* - \rho_{12} \frac{cov(\theta_{12}, \theta_{2,m})}{var(\theta_{2,m})}$$

$$= (1 - \rho_{12})\rho_2^* \qquad (32)$$

with

$$\rho_{12}^* = \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \left(\frac{\gamma_1}{(\beta_1^I - \mu)}\right)^2 M\sigma_u^2} \qquad (33)$$

$$\rho_2^* = \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \left(\frac{\gamma_2}{\beta_2^I}\right)^2 (M-1)\sigma_u^2} \qquad (34)$$

and

$$var\left[\varepsilon \mid \theta_{12}, \theta_{2,m}\right] = (1 - \rho_{12} - \rho_2)\sigma_\varepsilon^2 \qquad (35)$$

3. Given the results from step (2) I solve the informed and uninformed agents' optimization problems and derive their demand curves. I start with the informed agent's problem in $t = 2$:

$$\max_{x_2}(v_0 + \varepsilon - p_2)x_2$$

Using (8), p_2 can be rewritten from the perspective of the informed as

$$p_2 = \widehat{p}_2^i + \lambda_2^i x_2$$

with

$$\lambda_2^i = \frac{1}{M\beta_2^u} \tag{36}$$

Plugging this into the maximization problem, this leads to the first order condition

$$x_2 = \beta_2^i (v_0 + \varepsilon - p_2)$$

with

$$\beta_2^i = \frac{1}{\lambda_2^i} \tag{37}$$

and second order condition $\beta_2^i > 0$. This expression confirms the guess in (6).

I then move to the informed's optimization problem in $t = 1$, which can be written as

$$\max_{x_1} E[\Pi] = x_1 (v_0 + \varepsilon - p_1) + \pi E[\Pi_2]$$

The first step is to find an expression for second period profits, Π_2, using equation (6):

$$\Pi_2 = x_2 (v_0 + \varepsilon - p_2) \tag{38}$$
$$= \beta_2^i (v_0 + \varepsilon - p_2)^2 \tag{39}$$

Using equations (36) and (37), p_2 can be rewritten as:

$$p_2 = v_0 + E[\varepsilon \mid p_1] + \frac{1}{2}(\varepsilon - E[\varepsilon \mid p_1]) - \frac{\gamma_2}{2\beta_2^i} \sum_m u_{2,m} \tag{40}$$

and expression (38) as

$$\Pi_2 = \frac{\beta_2^i}{4}\left(\varepsilon - E[\varepsilon \mid p_1] + \frac{\gamma_2}{\beta_2^i} \sum_m u_{2,m}\right)^2$$

In order to arrive at the correct first order condition note two things. First of all, x_1 has a direct impact on p_1. As before p_1 can be written as

$$p_1 = \widehat{p}_1^i + \lambda_1^i x_1$$

with λ_1^i given by

$$\lambda_1^i = \frac{1}{M\beta_1^u} \tag{41}$$

Secondly, x_1 has an indirect impact on Π_2 through $E[\varepsilon \mid p_1]$. Remember that $E[\varepsilon \mid p_1] = \rho_{12}^* \theta_{12}$, where θ_{12} is given by (25), which is a function of p_1. Plugging these two expressions into the informed's objective we arrive at the first order condition from expression (5):

$$x_1 = \beta_1^i (v_0 + \varepsilon - p_1) - \mu\varepsilon$$

where

$$\beta_1^i = \frac{1}{\lambda_1^i} - \frac{\pi \left(\rho_{12}^*\right)^2}{\lambda_2^i \left[\lambda_1 \left(\beta_1^i - \mu\right)\right]^2} \tag{42}$$

and

$$\mu = \left(1 - \frac{\rho_{12}^*}{\lambda_1 \left(\beta_1^i - \mu\right)}\right) \frac{\pi \rho_{12}^*}{2\lambda_2^i \lambda_1 \left(\beta_1^i - \mu\right)} \tag{43}$$

The expressions for β_1^i and μ are a function of $\beta_1^i - \mu$ which can be solved for[51] as

$$\beta_1^i - \mu = \frac{1}{2\lambda_1^i} \left(1 + \sqrt{1 - \frac{2\pi \rho_{12}^* \left(\lambda_1^i\right)^2}{\lambda_2^i \lambda_1}}\right) \tag{44}$$

which is function decreasing in λ_1^{i} [52].

The second order condition of the informed's optimization problem in $t = 1$ is given by

$$\lambda_1^i \left(1 - \frac{\pi \left(\rho_{12}^*\right)^2 \lambda_1^i}{2\lambda_2^i \left[\lambda_1 \left(\beta_1^i - \mu\right)\right]^2}\right) > 0$$

Since $\pi \geq 0$, it can be shown that this second order condition only holds if

$$0 < \lambda_1^i < \frac{2\lambda_2^i \left[\lambda_1 \left(\beta_1^i - \mu\right)\right]^2}{\pi \left(\rho_{12}^*\right)^2} \tag{45}$$

Let's move to the uninformed agents' problem. Again start in $t = 2$. Uninformed agents only trade in one period. Mean-variance optimization yields:

$$\max_{y_{2,m}} \left(v_0 + E\left[\varepsilon \mid \theta_{12}, \theta_{2,m}\right]\right) \left(u_{2,m} + y_{2,m}\right) - p_2 y_{2,m} - \frac{A}{2} \left(u_{2,m} + y_{2,m}\right)^2 var\left[\varepsilon \mid \theta_{12}, \theta_{2,m}\right]$$

p_2 can be rewritten from the perspective of the uniformed as

$$p_2 = \widehat{p}_{2,m}^u + \lambda_2^u y_{2,m}$$

In addition remember that $E\left[\varepsilon \mid \theta_{12}, \theta_{2,m}\right] = \rho_{12}\theta_{12} + \rho_2 \theta_{2,m}$ and $E\left[\varepsilon \mid p_1\right] = \rho_{12}^*\theta_{12}$, where θ_{12} and $\theta_{2,m}$ are given by (26) and (29). Using these facts and expressions (28), (31) and (35) the first order condition can be written as expression (8):

$$y_{2,m} = \beta_2^u \left(v_0 + E\left[\varepsilon \mid p_1\right] - p_2\right) - \gamma_2 u_{1,m}$$

---

[51] $\beta_1^i - \mu$ has a quadratic solution of which only one root is consistent with the second order condition.

[52] REMOVE

In other words, the net coefficient on ε in the informed's policy function is decreasing in the price impact he observes in $t = 1$. In addition, the function is increasing in λ_2^i. This means that if the informed's price impact in $t = 2$ decreases, the informed will trade less agressively on ε in $t = 2$. This shows one of the key results on the model. As there will be more relatively more uninformed liquidity trading in $t = 2$, the informed will trade less agressively in $t = 1$.

with

$$\beta_2^u = \frac{1}{\lambda_2^u} \frac{1 - \frac{\rho_2}{\beta_2^i \lambda_2^u}}{1 + \frac{\rho_2}{\beta_2^i \lambda_2^u} + \frac{A(1-\rho_{12}-\rho_2)\sigma_\varepsilon^2}{\lambda_2^u}} \tag{46}$$

and

$$\gamma_2 = \frac{A(1-\rho_{12}-\rho_2)\sigma_\varepsilon^2}{\lambda_2^u} \frac{1}{1 + \frac{\rho_2}{\beta_2^i \lambda_2^u} + \frac{A(1-\rho_{12}-\rho_2)\sigma_\varepsilon^2}{\lambda_2^u}} \tag{47}$$

Using (28), (37) and (36), these expressions can be simplified as

$$\beta_2^u = \frac{2\left[\frac{M-1}{2M-1} - \rho_2\right]}{A(1-\rho_{12}-\rho_2)\sigma_\varepsilon^2} \tag{48}$$

and

$$\gamma_2 = \frac{M-1}{2M-1} \frac{(M-1) - \rho_2(2M-1)}{M - \rho_2(2M-1)} \tag{49}$$

Note, that using the same logic the expression for p_2 in (40) can be further simplified to:

$$p_2 = v_0 + \frac{1}{2}(1 + \rho_{12}^*)\varepsilon - \frac{\rho_{12}^*\gamma_1}{2(\beta_1^i - \mu)} \sum_m u_{1,m} - \frac{\gamma_2}{2\beta_2^i} \sum_m u_{2,m} \tag{50}$$

with

$$\frac{\gamma_2}{2\beta_2^i} = \frac{A(1-\rho_{12}-\rho_2)\sigma_\varepsilon^2}{2[M - \rho_2(2M-1)]} \tag{51}$$

Finally, the second order condition of the uninformeds' problem in $t = 2$ is given by:

$$2\lambda_2^u + Avar[\varepsilon \mid \theta_{12}, \theta_{2,m}] > 0$$

Similar to before the uniformed's optimization problem in $t = 1$ is given by

$$\max_{y_{1,m}} (v_0 + E[\varepsilon \mid \theta_{1,m}])(u_{1,m} + y_{1,m}) - p_1 y_{1,m} - \frac{A}{2}(u_{1,m} + y_{1,m})^2 var[\varepsilon \mid \theta_{1,m}]$$

which yields the first order condition from expression (7):

$$y_{1,m} = \beta_1^u(v_0 - p_2) - \gamma_1 u_{1,m}$$

where

$$\beta_1^u = \frac{1}{\lambda_1^u} \frac{1 - \frac{\rho_1}{(\beta_1^i - \mu)\lambda_1^u}}{1 + \frac{\rho_1}{(\beta_1^i - \mu)\lambda_1^u} + \frac{A(1-\rho_1)\sigma_\varepsilon^2}{\lambda_1^u}} \tag{52}$$

and

$$\gamma_1 = \frac{A(1-\rho_1)\sigma_\varepsilon^2}{\lambda_1^u} \frac{1}{1 + \frac{\rho_1}{(\beta_1^i - \mu)\lambda_1^u} + \frac{A(1-\rho_1)\sigma_\varepsilon^2}{\lambda_1^u}} \tag{53}$$

which can be further simplified by using (44).

The second order condition of the problem is given by:

$$2\lambda_1^u + Avar\left[\varepsilon \mid \theta_{1,m}\right] > 0$$

4. Finally, the second order conditions I derived can be used to proof the existence of the equilibrium. I start in the second period. Using expressions (28), (37) and (36) it can be shown that both the uninformeds' and informed's second order conditions in $t = 2$ are fulfilled when

$$(M - 1) - (2M - 1)\rho_2 > 0$$

Using expressions (32), (49) and (36) this can be rewritten as (4) or

$$var\left[\varepsilon \mid \theta_{12}, \theta_{2,m}\right] > \frac{1}{\rho_2 A^2 (M - 1) \sigma_u^2} \tag{54}$$

Now move to the first period. By using (41) and (42) it can be shown that the second order conditions in period $t = 1$ can be summarized in the following condition:

$$\beta_1^u > \frac{1}{2M - 1} \frac{\pi \left(\rho_{12}^*\right)^2}{\lambda_2^i \left[\lambda_1 \left(\beta_1^i - \mu\right)\right]^2} \tag{55}$$

This expression demonstrates more or the less the same intuition as in the previous existence condition. Combined with (52) it shows that the market impact that is observed by uninformed agents must cannot exceed a certain level. Otherwise, uninformed agents will opt not to participate.

Proposition 9 *If (54) holds, so will (55). The reverse is not true. In other words, condition (54) is a sufficient condition for the existence of the equilibrium.*

Proof. by contradiction. Suppose that the uncertainty in $t = 2$ is sufficient for (54) to hold, but that uncertainty in $t = 1$ is too small for (55) to hold. If that were the case, then $var\left[\varepsilon \mid \theta_{12}, \theta_{2,m}\right] > var\left[\varepsilon \mid \theta_{1,m}\right]$ or $(1 - \rho_{12} - \rho_2)\sigma_\varepsilon^2 > (1 - \rho_1)\sigma_\varepsilon^2$. This is true iff $\rho_{12} + \rho_2 < \rho_1$. This is excluded by (23), (31) and (32). ∎

Proof. of corollary 2

Equation (9) gives that $Cov\left(\Delta p_k^L, p_{k,1} - p_{k-1,t}\right) = \lambda_1 \left(\beta_1^i - \mu\right)\sigma_\varepsilon^2$. It follows from the informed's and uninformed's second order conditions in $t = 1$ that both $\lambda_1^u > 0$ and $\lambda_1^i > 0$. Equations (41), (20) and (11) imply that $\lambda_1 > 0$. In addition, expression (44) gives that $\beta_1^i - \mu > 0$. ∎

Proof. of corollary 3

Equations (9) and (50) yield that $Cov\left(\Delta p_k^L, p_{k,2} - p_{k,1}\right) = \left[\frac{1}{2}\left(1 + \rho_{12}^*\right) - \lambda_1 \left(\beta_1^i - \mu\right)\right]\sigma_\varepsilon^2$. Following expression (33), $\rho_{12}^* > 0$. In order for $Cov\left(\Delta p_k^L, p_{k,2} - p_{k,1}\right) > 0$ we need that $\lambda_1 \left(\beta_1^i - \mu\right) \leq \frac{1}{2}$. Suppose $\pi = 0$, in that case $\lambda_1 \left(\beta_1^i - \mu\right) = \frac{1}{2}$. To see this note from expression (43) that if $\pi = 0$, $\mu = 0$. It can be shown that

in this case the informed's problem in $t = 1$ is very similar to the one in $t = 2$ and p_1 will be given by an expression similar to (40), where $E[\varepsilon \mid p_1]$ is replaced with zero. For any $\pi > 0$, $\mu > 0$ and $\lambda_1(\beta_1^i - \mu) < \frac{1}{2}$. ∎

Proof. of corollary 4

This follows directly from simulating the model and calculating $Cov(\Delta p_k^L, p_{k,1} - p_{k-1,t})$ and $Cov(\Delta p_k^L, p_{k,2} - p_{k,1})$. It can be shown that $Cov(\Delta p_k^L, p_{k,1} - p_{k-1,t}) > Cov(\Delta p_k^L, p_{k,2} - p_{k,1})$ ∎

Discussion of the derivation of the reversal coefficients

To analyze the reversal of returns I reintroduce subscript k in the notation, where k indicates a certain episode between the arrival of two boats. For simplicity, write prices in episode k and periods $t = 1$ and $t = 2$ as follows.

$$p_{k,1} = v_{k-1} + \alpha_1 \varepsilon_k - \delta_1 \sum_m u_{k,1,m}$$

and

$$p_{k,2} = v_{k-1} + \alpha_2 \varepsilon_k - \delta_2 \sum_m u_{k,2,m} - \zeta \sum_m u_{k,1,m}$$

where α_t, δ_t and ζ are given by (9) and (50).[53]

The price change in Amsterdam that takes place in the absence of news can be written as

$$p_{k,2} - p_{k,1} = (\alpha_2 - \alpha_1)\varepsilon_k - \delta_2 \sum_m u_{k,2,m} - \zeta \sum_m u_{k,1,m}$$

The price change in Amsterdam that takes place right after the arrival of a boat is slightly more complicated and consists of two elements.

$$p_{k,1} - p_{k-1,t} = (p_{k,1} - v_{k-1}) + (v_{k-1} - p_{k-1,t})$$

The first element, $(p_{k,1} - v_{k-1})$, reflects the price change that takes place as a consequence of the new private signal ε_k and liquidity shock $\sum_m u_{k,1,m}$.

$$p_{k,1} - v_{k-1} = \alpha_1 \varepsilon_k - \delta_1 \sum_m u_{k,1,m}$$

The second element, $(v_{k-1} - p_{k-1,t})$, reflects two things. First of all it captures the revelation of the previous private signal ε_{k-1}. In addition, it reflects the reversal of past episode's liquidity shocks. Here it matters whether episode $k - 1$ actually counted one or two periods ($t = 1$ or $t = 2$). I assume that episode $k - 1$ has two periods, because this is more restrictive for the results

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[53]Remember that every boat performs two functions. Let boat k be the boat that arrives at the beginning of episode k. First of all, boat k brings in the new private signal ε_k. Secondly it publicly reveals the previous private signal ε_{k-1}.

that I derive. Note that all results go through if episode $k-1$ only has one episode.

$$v_{k-1} - p_{k-1,2} = (1 - \alpha_2)\, \varepsilon_{k-1} + \delta_2 \sum_m u_{k-1,2,m} + \zeta \sum_m u_{k-1,1,m}$$

Of interest is whether returns in Amsterdam are reversed in the next trading period. To link the theoretical results to the empirical testing, I formulate this in terms of regressions coefficients.

Start in $t = 1$. The Amsterdam return in $t = 1$ is either followed by the arrival of a boat or an additional period of trade without news. Suppose that the first period is followed by a boat. Of interest is the following regression

$$(p_{k+1,1} - p_{k,1}) = c_{news}^a + d_{news}^a\, (p_{k,1} - p_{k-1,2}) + \eta_1^a$$

where

$$d_{news}^a = \frac{cov\,(p_{k+1,1} - p_{k,1}, p_{k,1} - p_{k-1,2})}{var\,(p_{k,1} - p_{k-1,2})}$$

$$= \frac{cov\,(p_{k+1,1} - p_{k,1}, p_{k,1} - p_{k-1,2})}{var\,(p_{k,1} - v_{k-1}) + var\,(v_{k-1} - p_{k-1,2})}$$

By the ergodicity of the problem and the independence of all shocks, this expression equals

$$d_{news}^a = \frac{cov\,(v_k - p_{k,1}, p_{k,1} - v_{k-1})}{var\,(p_{k,1} - v_{k-1}) + var\,(v_k - p_{k,2})}$$

Suppressing episode-subscripts k equation (17) is obtained.

Now suppose that the first period in Amsterdam is followed by an additional trading period without any new information. In that case the regression of interest is

$$(p_{k,2} - p_{k,1}) = c_{news}^b + d_{news}^b\, (p_{k,1} - p_{k-1,2}) + \eta_1^b$$

with

$$d_{news}^b = \frac{cov\,(p_{k,2} - p_{k,1}, p_{k,1} - p_{k-1,2})}{var\,(p_{k,1} - p_{k-1,2})}$$

which can be rewritten as (18) following the same logic as above. Note that the denominators in expressions (17) and (18) are the same. It can be shown that the covariance terms in (17) and (18) also equal, so that $d_{news}^a = d_{news}^b = d_{news}$.

Finally, let's look at the price change in Amsterdam in $t = 2$, periods without news, if they occur. Note that with certainty news will arrive in the next period. In this case the relevant regression is

$$(p_{k+1,1} - p_{k,2}) = c_{nonews} + d_{nonews}\, (p_{k,2} - p_{k,1}) + \eta_2$$

with

$$d_{nonews} = \frac{cov\,(p_{k+1,1} - p_{k,2}, p_{k,2} - p_{k,1})}{var\,(p_{k,2} - p_{k,1})}$$

which can be rewritten as (16) applying the same logic as before.

The covariances and variances are given by

$$
\begin{align}
cov\left(v - p_1, p_1 - v_0\right) &= \left(1 - \alpha_1\right)\alpha_1\sigma_\varepsilon^2 - \delta_1^2 M\sigma_u^2 \tag{56} \\
cov\left(p_2 - p_1, p_1 - v_0\right) &= \left(\alpha_2 - \alpha_1\right)\alpha_1\sigma_\varepsilon^2 + \left(\zeta - \delta_1\right)\delta_1 M\sigma_u^2 \tag{57} \\
cov\left(v - p_2, p_2 - p_1\right) &= \left(1 - \alpha_2\right)\left(\alpha_2 - \alpha_1\right)\sigma_\varepsilon^2 - \zeta\left(\zeta - \delta_1\right) M\sigma_u^2 \tag{58} \\
var\left(p_1 - v_0\right) &= \alpha_1^2\sigma_\varepsilon^2 + \delta_1^2 M\sigma_u^2 \tag{59} \\
var\left(v - p_2\right) &= \left(1 - \alpha_2\right)^2\sigma_\varepsilon^2 + \left(\delta_2^2 + \zeta^2\right) M\sigma_u^2 \tag{60} \\
var\left(p_2 - p_1\right) &= \left(\alpha_2 - \alpha_1\right)^2\sigma_\varepsilon^2 + \left[\delta_2^2 + \left(\zeta - \delta_1\right)^2\right] M\sigma_u^2 \tag{61}
\end{align}
$$

Proof. of Lemma 5 and 6

These results follow directly from simulating the model and calculating the covariances from expressions (56), (57) and (58). It can be shown that all three covariances are negative. ■

Proof. of Lemma 7

This results follows directly from simulating the model. Use covariances (56), (57) and (58) and variances (59), (60) and (61) to calculate expressions d_{news} and d_{nonews}. ■

Proof. of Lemma 8.

This expression also follows directly from simulation results. ■

Appendix B

Information on volume is not available for the Amsterdam stock market in the 18$^{\text{th}}$ century. Fortunately, some transactions were recorded and can be retraced in the archival sources. At times stocks traders bought English stocks on credit. They would buy a stock and they would immediately use it as collateral to finance a large part of the purchase (usually up to 90%). These loan agreements had to be signed before a notary and some of these notarial deeds survive in the archival sources.

From these notarial deeds it can be inferred on what date a stock was transacted. The deeds mention the starting date of the loan and this corresponds quite precisely to the date the stock was actually purchased. Evidence for this is provided by the following. A large fraction of the stock purchases were executions of expiring future contracts that were signed at an earlier (unknown) point in time. The expiry dates of the future contracts were fully standardized (see footnote on p. 15) and are therefore always known. I checked whether the expiry date of the future contract corresponded with the starting date of the loan. Only in 7.5% of transactions did the two dates deviate.

I obtained a sample of these contracts by collecting all notarial deeds involving EIC stock from the archives of notary Van den Brink between November 1771 and February 1774. Notary Van den Brink specialized in transactions related to the English funds and his archives are therefore relatively abundant

with the relevant contracts (this source was first used by Wilson 1941). The choice for the sample period is determined by data limitations.

I collected a total of 207 transactions in EIC stock, with a combined nominal value of £350 thousand (the total nominal value of the Company's stock was £3.2 million). Almost half of these transactions had to be discarded, either because they dealt with continuations or because they involved the execution of future contracts of which the starting date is not known. In the end 119 transactions were left, with a combined nominal value of £194 thousand. 21.4% of these transactions (weighted by their value) took place on days news arrived from England, which is statistically different ($p - value$ of 3.8) from the 28.6% one would expect if the number of transactions were the same on days with or without news.

As said, I estimate that 7.5% of all transactions are dated incorrectly. This measurement error causes an upward bias in the estimated percentage of transactions that took place in presence of news. Calculations indicate that if 7.5% of all transactions are dated imprecisely, only 19% of all transactions would have taken place in the absence of news.