Trading and Financial Market Efficiency in Eighteenth-Century Holland

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To Floor Koudijs

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SUMMARY

The three chapters of this thesis revolve around the trade in English stocks on the Amsterdam exchange during the 18$^{\text{th}}$ century. In the first chapter I use the primitive communication technology of that time to identify the impact of news on stock price volatility. I find that the arrival of news through sailing boats can explain between 30 and 50% of the price movements of the English stocks in Amsterdam. In the second chapter I provide evidence for the use and revelation of private information in the Amsterdam market. I show that price movements in Amsterdam and London are correlated, even when no information could be transmitted between the two markets. In the final chapter (joint with Hans-Joachim Voth) we study the impact of distressed trade in Amsterdam on stock prices. We show that prices responded immediately to news about distress, but that the actual distressed transactions were delayed.

Este tesis estudia el negocio en acciones ingleses en el mercado de valores de Amsterdam durante el siglo XVIII. En capítulo uno aplico la comunicación primitiva de esa época para identificar el impacto de noticias sobre la volatilidad de cotizaciones de acciones. Observo que la llegada de noticias mediante barco a vela explica entre 30 y 50% de los movimientos en las cotizaciones de acciones ingleses en el mercado de Amsterdam. En capítulo dos enseño que en Amsterdam se utilizó información privada sobre las acciones ingleses. Muestro una correlación entre los movimientos en las cotizaciones de Amsterdam y Londres, incluso cuando no hay intercambio de información entre los dos mercados. En el último capítulo (junto con Hans-Joachim Voth) estudiamos el impacto de transacciones forzados en Amsterdam sobre las cotizaciones. Mostramos que las cotizaciones responden notablemente a noticias sobre la necesidad de negociar, pero que las transacciones forzados fueron aplazadas.

PREFACE

Leafing through the financial section of a newspaper it is impossible to overlook the columns filled with information about the price movements of stocks, bonds and exchange rates and the approximate reasons for the observed fluctuations. Unfortunately the newspaper can tell us very little about what precisely drives markets. On the trading floors of exchanges (or in the computer systems of electronic markets) a multitude of small processes take place that eventually result in the final movements that make the financial sections of newspapers. In recent decades a burgeoning literature has arisen on this microstructure aspect of financial markets (see O'Hara 1997, Vives 2008, Hasbrouck 2008 and references therein).

One of the most important questions this literature tries to explain is how price fluctuations in financial markets are driven by information. Prices can incorporate information through the arrival of news or through the revelation of private information in the trading process. It is a challenge to identify how these two factors have an impact on price dynamics in modern financial markets. Although modern datasets contain a lot of information, a number of important variables are often imperfectly observed.

First of all, it is difficult to adequately measure the arrival of news to a market. There is so much information floating around in this age of advanced communication technology that it is hard to determine when a certain piece of news reaches the market. In addition, with the multitude of news items available it is often unclear to the outside observer what is relevant and what is not.

Secondly, private information is by definition unobserved and it is generally impossible to study the behavior of investors with access to inside information. Our empirical knowledge about the impact of private information is therefore based on indirect evidence that can be inferred from anonymous transaction data. It is still an open question how privately informed trading influences the dynamics of prices and how they affect the market as a whole (see Hasbrouck 2008 for an overview).

Going back to history can go a long way in solving these problems. I turn to a unique natural experiment from the 18th century to shed more light on the impact of information on asset prices. The first chapter of my thesis deals with the impact of the arrival of news on stock prices. During the 18th century the shares of a number of British companies were actively traded in Amsterdam.[1] The economic capital of the Dutch Republic was the most important financial market of the period and featured an active trade in the "English funds". For a number of specific periods within the 18th century[2] all relevant information about these British stocks originated in London.

The English news arrived in Amsterdam through so-called mail packet boats that normally sailed twice a week between Holland and England (Hemmeon 1912). Since these boats were sailing ships, the time it took them to cross the North Sea could differ greatly, as their speed depended crucially on the direction of the wind. The arrival dates of these ships were recorded in the newspapers of the time and this makes it possible to perfectly identify the arrival of news in Amsterdam. Together with data on stock prices in Amsterdam, this information provides a unique opportunity to study the impact of news.

The second chapter of my thesis deals with private information or insider trading. London insiders frequently used the Amsterdam market to trade on their private information (Sutherland 1952). Using the same packet boat service they would send private letters to their agents in Amsterdam who would then execute their orders. The historical setting provides a unique opportunity to study how private information is incorporated into prices. I compare price developments in Amsterdam and London. I show that prices in Amsterdam and London tended to move in the same direction, even if no boat was actually sailing between the two markets. This points to the presence of private information that is slowly revealed in both places.

Apart from the impact of information, the market microstructure literature is also concerned with the question how prices are affected by shifts in the demand for an asset,

[1] Larry Neal was the first to thoroughly analyze this situation. His published papers on the topic are collected in Neal (1990). See Smith (1919), Van Dillen (1931) and Wilson (1941[1966]) for early contributions. Later work using Neal's data includes Harrison (1998) and Dempster et al. (2000).

[2] Amongst which 1771-1777 and 1783-1787; the specific periods studied in this thesis.

often coined liquidity shocks. One of the most important roles of financial markets is to provide liquidity. In a perfect world an investor would be able to trade right away and at the right price (Scholes 1972). However, recent evidence suggests that markets do not always function this way, especially in times of distress. Markets can have serious problems in accommodating large liquidity shocks of distressed traders and prices may adjust dramatically so that the market equilibrium is restored (see Duffy 2010 and references therein).

It is difficult to study the exact mechanisms through which these liquidity shocks have an impact on prices. For privacy reasons, modern datasets seldom feature detailed transaction data that would allow for a reconstruction of the transactions of distressed traders. In the third chapter of my thesis (joint with Hans-Joachim Voth) we again use unique data from the Amsterdam market during the 18^{th} century. Through extensive archival research we reconstruct the trading activity of distressed agents after two episodes of significant financial distress in Amsterdam in 1772 and 1773. We are able to track the actions of the *dramatis personae* involved in these two events and we provide unique insight on how liquidity shocks affect markets and prices.

Throughout these three chapters, my thesis paints a detailed picture of the way in which financial markets operated in the 18^{th} century. What stands out are the similarities with markets today. My thesis demonstrates that historical data can be successfully used to answer important questions from the modern finance literature. Historical idiosyncrasies, such as the way news was transmitted, and the non-anonymity of the sources provide unique opportunities to significantly contribute to the finance literature.[3]

[3] Other recent examples include Temin and Voth (2004), Schnabel and Shin (2004), Silber (2005), Jones (2008), Brown, Mulherin and Weidenmier (2008), Brünner, Fohlin and Gehrig (2009), White (2009), Braggion and Moore (2009), Frehen, Goetzmann and Rouwenhorst (2010), Benmelech and Moskowitz (2010), Carlson, Mitchener and Richardson (2010); Friedman and Saks (2010), and Drelichman and Voth (2011).

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CHAPTER I

THE BOATS THAT DID NOT SAIL: NEWS AND ASSET PRICE VOLATILITY IN A NATURAL EXPERIMENT.

1.1 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. Roll 1988 and 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. Roll 1988, Mitchell and Mulherin 1994 and Berry and Howe 1994). 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). In addition, the information content of news

[1] The seminal contribution is Roll (1984). 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).

items may differ dramatically (Antweiler and Frank 2006; Tetlock, Saar-Tsechansky and Macskassy 2008). Others compare asset price volatility for periods with and without trade (e.g. French and Roll 1986). These contributions 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 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; Wilson 1941[1966]; Neal 1990; Dempster et al. 2000). 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

[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.

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 18th 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.

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 (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; Wilson 1941[1966], p. 88; 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. In the second chapter of this thesis I will delve further into the question why the trading process is responsible for such a large fraction of stock price volatility.

This paper is related to two 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 (Roll 1984, 1988, 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; Antweiler and Frank 2006; Boudoukh et al. 2007; Tetlock, Saar-Tsechansky and Macskassy 2008). 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 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.

The rest of the paper is organized as follows. Section 2 discusses the historical

[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).

A different strand in the literature has looked at price drift and reversals around news events. See for example Chan (2003), Vega (2006) and Antweiler and Frank (2006).

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

[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.

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. 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. Section 5 concludes.

1.2 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).[7] 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.[8] Neal makes a strong argument for the efficiency of the two markets in the 18th 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. Harrison (1998) studies the time series properties of returns in London and Amsterdam and argues that these were very similar to those of 20th century markets.

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[1966]). 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

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

[8] 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.

investors (Bowen 1989; Wright 1999). These studies show that during the 1770's more or less one third of the shares in the British companies were in the hands of Dutch investors. During the 1780's this fell to around a fifth.[9] 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.

1.2.1 Stocks and sample period

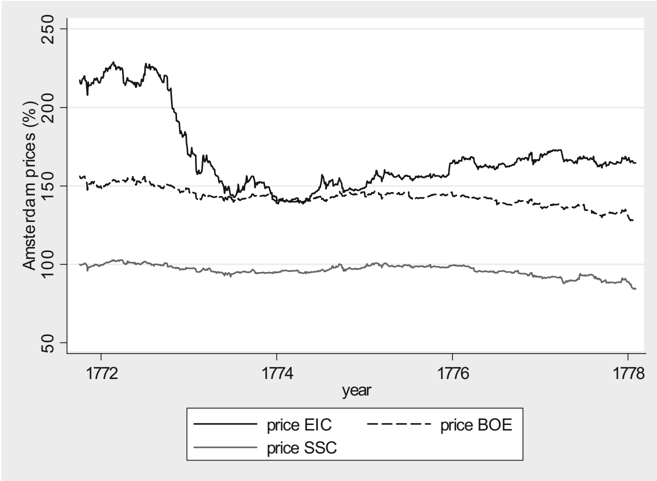
The three British companies analyzed in this study were concerned with a number of activities. The EIC was a trading company that held large possessions in what is today's India. The company's prospects were to a large extent determined by conditions in India. However, during the second half of the 18th 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

[9] For the SSC these fractions are slightly higher

Figure 1: Stock prices Amsterdam, 1771-1777



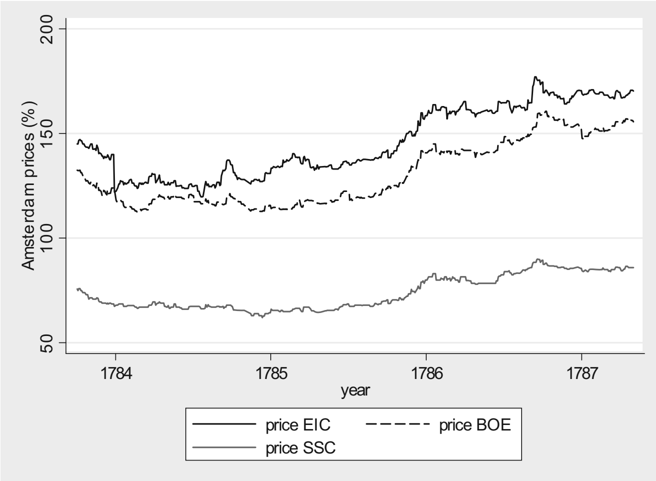
wars or the threat of a war breaking out, and England was involved in nearly all of them (Neal 1990). In addition, during the 18$^{\text{th}}$ century Amsterdam was still the financial capital of the world. Financial crises like the one in 1763 were centered on the city. It is obvious that such developments 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, September 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

Figure 2: Stock prices Amsterdam, 1783-1787



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.

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).

Figure 3: Map of the North Sea

1.2.2 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.[10]

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

[10] Wilson (1941[1966], pp. 74-75) gives a number of examples where people with an interest in 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).

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).

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 26). 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.[11]

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.[12]

During the sample periods that I study, there was peace on the European continent. The packetboat service was therefore not disturbed by military or political developments. There is one exception. On April 30 1777 a privateer sailing under the American Revolutionary flag (in 1777 the United States were still fighting the War of Independence against England) attacked a packet boat and captured the ship and the English letters. The privateers seem to especially have valued the latter as, according to an eye witness, they planned to send these letters to the US Congress.[13] This incident seems to have been a very rare event. The *Amsterdamsche Courant* reports that, as far as anybody can remember, this is 'only the third time a ship has been captured by enemies'.[14] At least for the sample periods I study I did not find any evidence that this type of threats influenced the sailing times of packet boats at any time except for this incident.

[11] 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 boat

Hope & Co, SAA 735; 78,79, 115 and 1510, see also the correspondence in Van Nierop 1931, passim and that in Staal - van Piershil, NA 3.20.54; 379, 380, 381.

[12] 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.

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

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

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

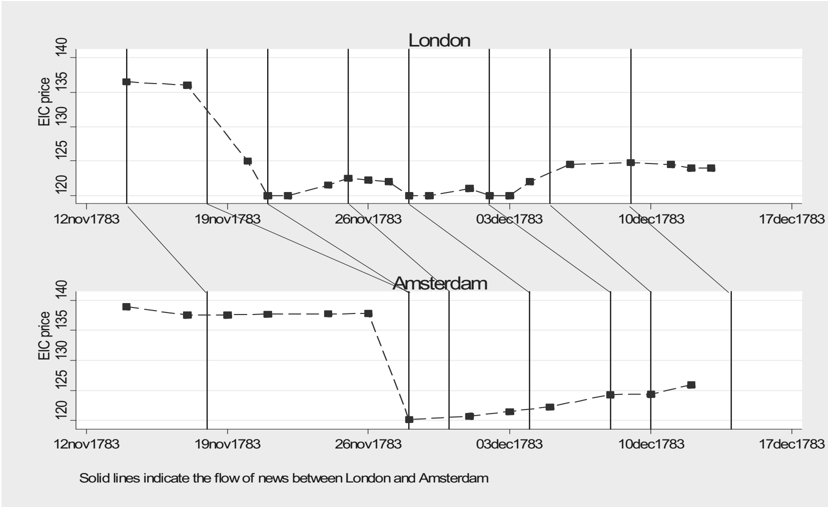
Although the packet boat service seems to have been the most important source of information for Dutch investors, the flow of news through alternative channels can never be completely ruled out. It is possible that investors set up private initiatives to get information from London. For example, there 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.[15] 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).[16] 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.

[15] Something of the sort did seem to happen during the years of the Continental System (1806-1814). During this period some Amsterdam merchants chartered private fisher boats to get information from England. The reason for this was that sailing between Holland and England was officially forbidden and the packet boat service suspended. In this case, boats would dock at Katwijk aan de Zee, a fishing town closer to Amsterdam. (Jonker and Sluyterman 2000, p. 136)

[16] 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.

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



The *Rotterdamsche Couran*t 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.[17]

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. 1.2.1). 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 to reach Hellevoetsluys and on November 28 Amsterdam investors heard about the recent news

[17] 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.

from London. The Amsterdam price adjusted immediately to 120.

1.2.3 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)[18]. Price data from London are available on a daily frequency and are taken from Neal (1990).

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). The correspondence in Van Nierop (1931) suggests that prices were interpreted as the midpoint of prices observed on a certain day.

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[19]. 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

[18] 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. 15.

[19] 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.

only had limited running periods (up to three months, see footnote on page 24), so the impact of interest rate fluctuations is likely to be small.

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.[20] 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.

1.3 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.

1.3.1 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

[20] 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*

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 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.

1.3.2 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.

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).[21] 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).

[21] 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 5: VAR analysis: EIC

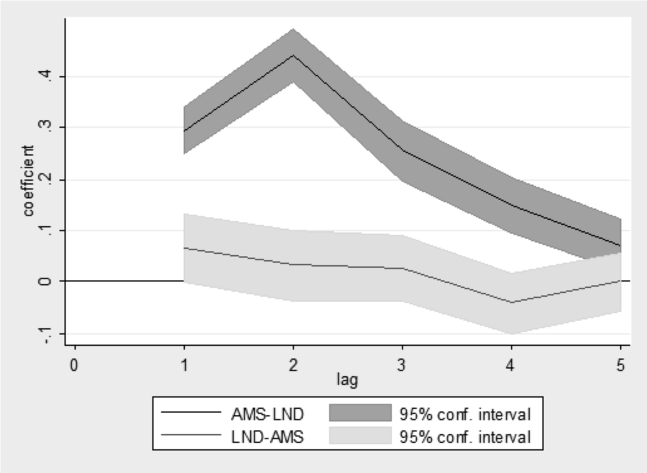


Figure 6: Var analysis: BoE returns

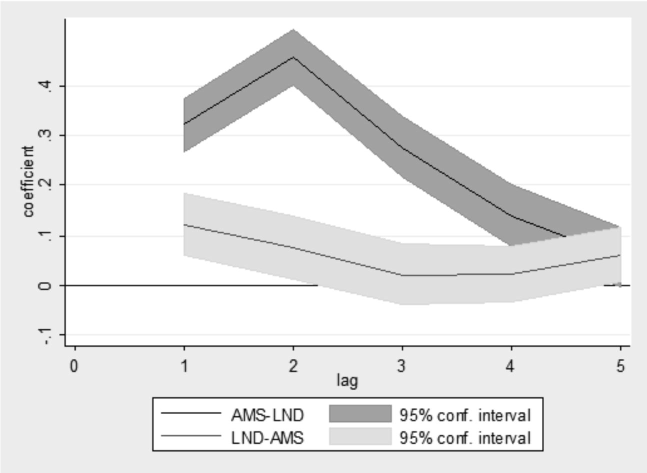


Table 2: Granger causality and information shares

		F-stat	p-value	Information shares
EIC	LND → AMS	96.23	0.0000	0.977
	AMS → LND	1.50	0.1869	0.023
BOE	LND → AMS	81.64	0.0000	0.990
	AMS → 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 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.[22]

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.

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

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 the English stocks. I focus on two periods in which developments in France were relatively unimportant (see the discussion on page 17). 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.

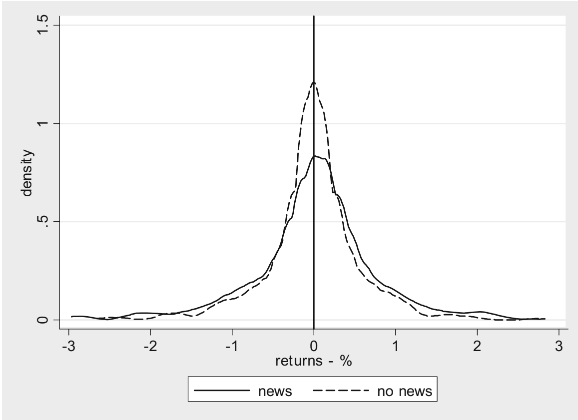
There is an additional complication for EIC stock. A significant fraction of relevant news for this company came from Asia. The Dutch had an important presence in Asia as well through their own East India Company (VOC). It is therefore possible that news from Asia may have reached Amsterdam through Dutch 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.

1.4 Volatility and the arrival of information

1.4.1 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

Figure 7: Return distributions EIC, news vs no-news



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).[23] 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)

$$R = f(N) + g(T) \tag{1}$$

Further suppose that the covariance between return innovations due to the arrival of

[23] See footnote on page 27.

Figure 8: Return distributions SSC, news vs no-news

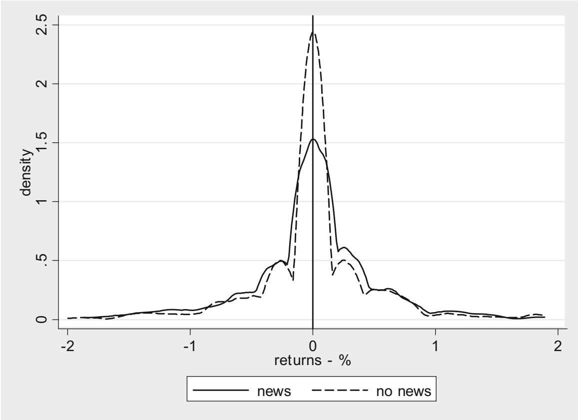


Figure 9: Return distributions BoE, news vs no-news

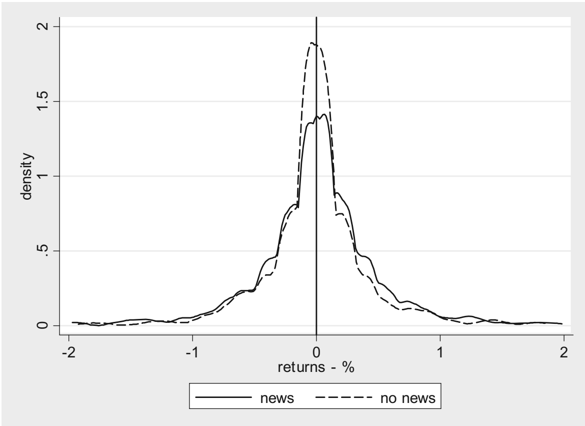


Table 3: Benchmark results

		Returns					Variance
		mean	var	skew	kurt	N	no-news/news (BF stat)
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.

new information and innovations due to trade related factors is zero.[24] 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, $R_{\widetilde{k}} = g\left(T_{\widetilde{k}}\right)$. The fraction of the variance that can be attributed to trade related factors N can therefore be estimated as

$$\frac{var\left[g\left(T\right)\right]}{var\left[R\right]} = \frac{var\left[R_{\widetilde{k}}\right]}{var\left[R_k\right]} \tag{2}$$

and $1 - \frac{var\left[R_{\widetilde{k}}\right]}{var\left[R_k\right]}$ 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 $\frac{var\left[R_{\widetilde{k}}\right]}{var\left[R_k\right]}$ lies between 0.48 and 0.73, depending on the stock. This suggest that the fraction of return

[24]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).

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

Table 4: Results from ARCH model

	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.

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 by endogeneity bias.

1.4.2 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 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 brought in

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	0.8921
						(14.82)***	0.13
SSC	0.01	0.2019	-0.24	8.47	261	0.5615	0.7774
						(10.16)***	(3.02)*
BoE	0.03	0.1565	0.94	8.55	261	0.573	0.7785
						(14.21)***	(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.

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

Table 6: No news from Asia

		Returns					Variance no-news/news (BF stat)
		mean	var	skew	kurt	N	
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.

consists of all the English and Dutch stocks traded on the exchange.[25] 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.

1.5 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. Roll 1984, 1988; 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

[25] 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

		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.

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.

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 18$^{\text{th}}$ century and trading mechanisms were obviously less developed than today. Nevertheless, the evidence presented in this paper does not suggest that markets in the 18$^{\text{th}}$ century were particularly inefficient (see also Neal 1990; Harrsion 1998; 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.

1.6 Appendix A: Identifying the arrival of news

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

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

All transport within Holland took place by coach. This way of transport was relatively independent of the weather[26] and the time a coach took to go from one city to another was more or less constant (Knippenberg en de Pater 1988, p. 55).[27] The information available indicates that it took less than a day for the letters from Hellevoetsluys to reach Amsterdam. A map from 1810 with the main mail connections in Holland indicates that it took around 10 hours for the mail to travel between Hellevoetsluys and Amsterdam (Knippenberg en de Pater 1988, p. 55).[28]

From the *Rotterdamsche Courant* there is information available on what day a specific packet boat arrived. Unfortunately the paper does not give an exact time of arrival in Hellevoetsluys. However, from 1774 onwards the newspaper does indicate whether a

[26] The only exception is heavy snowfall. Going through the *Amsterdamsche* and *Rotterdamsche Courant*, I found that only very seldom coach services were seriously delayed by the weather.

[27] See also table of transport times of mail to European destinations in Ten Berg (1969, p. 21). While the time for a letter to reach London 'depended on the weather', the time to destinations reached by coach (like Antwerp and Brussels) was constant.

[28] Stitt Dibden (1965) mentions a transport time of 14 hours.

boat arrived in the morning or afternoon. Together with the average time it took for a coach to reach Amsterdam it is possible to get an approximate indication when the English letters arrived in Amsterdam.

Sometimes, this dating procedure leads to ambiguous results. Take the example of a boat that arrived on Monday. If the boat had arrived early in the morning the news would reach Amsterdam on the same day. If the boat arrived during the end of the morning, news would reach Amsterdam only on Tuesday, a day later. In order to determine more precisely when the English news arrived in Amsterdam, I use the dates of publication of the English news in the *Rotterdamsche Courant*. This newspaper appeared three times a week (on Tuesday, Thursday and Saturday) and was a morning paper that reported all news that had come in up to the previous day. Based on the editorials from *Rotterdamsche Courant* it seems that the newspaper was sent to the printers early in the evening the day before it came out. The English news reports in the *Rotterdamsche Courant* can be used to determine the arrival of the news in Rotterdam. Take the example of a boat that arrived in Hellevoetsluys on Monday. If the news it brought in was published in Tuesday's paper, this indicates that the news arrived in Rotterdam on Monday in time to be published in next day's paper. If on the other hand the news was published in Thursday's paper, this is an indication that the news must have arrived in Rotterdam Monday evening or on Tuesday.

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

1.7 *Appendix B: interpretation of prices*

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

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

In 18$^{\text{th}}$ century Amsterdam a future contract involved the following: party S would sell its shares to party B, but the actual transfer of the shares would only take place during fixed periods of settlement called 'rescontre'. There were only four of such rescontre periods a year (for the 1770's and 1780's these were in February, May, August and November). These settlement periods usually lasted two weeks during which specialized 'rescontreurs' would settle all transactions. Just as today the payment for the delivery of an asset was also deferred to the future (Smith 1919). So far this closely resembles modern day future contracts. The 18$^{\text{th}}$ century contracts differed only in one detail: all dividend payments made before the day of settlement accrued to the buyer B and not to the seller S, which is usual in today's contracts. Any dividend or interest payments made in this period would be deducted from the price B would have to pay S on the day of settlement.

The relation between a spot price and a 18$^{\text{th}}$ century future price can be expressed as:

$$FP_{it} = SP_{it}e^{r_t(\tau - t)/T} \tag{3}$$

where FP_{it} is the future price of asset i at time t, SP_{it} is the spot price and τ is the settlement date, which is in February, May, August or November. This expression includes the interest rate r_t defined over T periods .

This expression closely resembles that of modern day futures. The only difference lies in the treatment of dividends. After the payment of dividend, the price of an 18th century future contract would go ex-dividend. This is not the case for modern day future contracts where dividends accrue to the seller (Hull 2005).

What prices were exactly reported in the *Amsterdamsche Courant*? The newspaper did not only report the price of the future contract, it also mentioned the rescontre period in which the contract would be settled. Without exception this was always the next rescontre period. For example, prices reported from March to May would correspond to futures expiring in May. In June this would change to the prices for future contracts expiring in August, the next rescontre month.[29]

This has an important implication for the future prices that are reported. Immediately after settlement has been finished, the future contract for which prices are reported changes from one rescontre period to another (in the example above from May to June or from June to August). The future prices before and after this change are not directly comparable. For example, the last future price observed for the May contract would have a very short time to maturity (τ close to t in equation (3)), whereas the first price of the August contract would have a time to maturity of close to three months (three months between τ and t in (3)). As a result, the difference between these two prices should, on average, reflect the 3 month interest rate.

To sum up, the preceding discussion implies that there are two testable implications that should hold if this view on 18th century future prices is correct:

1. Reported prices should go ex-dividend.

2. Right after settlement, when the future contract for which prices are reported changes from one rescontre period to another, prices should, on average, change by the equivalent of the 3 month interest rate.

Unreported empirical tests confirm both predictions for the English stocks traded in Amsterdam. All price changes around ex-dividend dates or directly after settlement are statistically significant and have the expected sign and size. Consequently, the returns

[29] Qualitative evidence from Hope & Co, (SAA 735; 1155, 1156) suggests that these were the only type of future contracts traded on a given moment in time.

that are used in this paper are corrected for both issues.

CHAPTER II

'THOSE WHO KNOW MOST': INSIDER TRADING IN 18^{TH} C. AMSTERDAM.

2.1 Introduction

The results in the first chapter of this thesis indicate that the arrival of news mattered importantly for stock price movements in 18^{th} Amsterdam. Nevertheless there is still a large fraction of stock price volatility that is left unexplained. Between half and two thirds of fluctuations seem to be unrelated to the arrival of information. What can explain this finding? What does this tell us about the way in which stock markets function?

In the present chapter I provide a possible explanation that not only generates stock price movements in the absence of news, but which can also match the specific price patterns that we observe in Amsterdam between the arrival of boats. This explanation is based on two important frictions in the trading process: namely asymmetric information (or insider trading) and limited risk bearing capacity. It seems natural to take these two frictions as a staring point of the analysis. Anecdotal evidence from the 18^{th}century indicates that both factors played an important role in the Amsterdam market (see page 50 and further). Specifically, insider trading seems to have been an important feature of the market. London insiders frequently used the Amsterdam market to trade on their private information. Using the same packet boat service that was discussed in the previous chapter, they would send private letters to their agents in Amsterdam who would then execute their orders. I will develop a simple model that features both private information and limited risk bearing capacity and I will show that the empirical evidence from the 18^{th} century is consistent with the model's predictions.

The results from this chapter are not just relevant in explaining stock market dynamics in the 18^{th} century. Asymmetric (or private) information and limited risk bearing capacity are widely seen as the most important frictions present in today's financial markets.[1] However, identifying their impact empirically has proven to be challenging (see Hasbrouck 2008 for an introduction). I will argue that the historical episode studied in this chapter provides a unique setting to study the impact of these factors in a well identified way. First of all, the flow of information is almost perfectly identified. I know exactly when private information reached the market and when no new information was available. Also, I can perfectly control for the impact of public information. Secondly, by comparing stock prices in Amsterdam with those in London, it is actually possible to identify the impact of private information and insider trading.

After providing more historical detail about the stock market in 18$^{\text{th}}$ century Amsterdam, I will develop a theoretical model which embeds the two aforementioned frictions. I argue that asymmetric information, or insider trading, can explain why prices move when no new information reaches the market. 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; Llorente et al. 2002).

The presence of asymmetric information changes the dynamics of the risk sharing

[1] For seminal studies see Grossman and Stiglitz (1980), Glosten and Milgrom (1985), Kyle (1985), and Grossman and Miller (1988).

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 chapter is related to two strands in the existing literature. First of all, this chapter 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) and some papers have started using different approaches to study the impact of private information (Kelly and Ljungqvist 2009; Colla and Marin 2010). 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.

Secondly, this chapter 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).[2]

Relative to this literature I make the following contributions. First of all I show that private information is slowly absorbed into prices, confirming the predictions from Kyle (1985), Glosten and Milgrom (1985) and related contributions.[3] Secondly, the results in this chapter indicate that the overreaction to news hypothesis is probably invalid, or at least does not apply to the 18^{th} 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 chapter suggest that there is a relation 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. As such, the evidence seems to be consistent with the prediction that the trading activity of uninformed agents actively responds to the degree of asymmetric information in the market (Admati and Pfleiderer 1988; Foster and Viswanathan 1990; George et al. 1994).

This chapter is organized as follows. Section 2 discusses the historical background

[2] 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).

[3] For similar evidence from recent IPOs see Van Bommel, Dahya and Shi (2010).

and context in more detail. I provide further details about the microstructure of the Amsterdam market and I provide anecdotal evidence about the relevance of private information and market participants' limited risk bearing capacity. The theoretical framework is discussed in section 3. Section 4 provides empirical evidence supporting the model's predictions and section 5 concludes.

2.2 Historical background

The empirical analysis of this chapter is based on the same general setting, data and time period that were used in the previous chapter. For detailed information I refer to section 1.2. In this section I provide further historical background about the Amsterdam market. I will focus on the particular institutional environment in which trade took place. In addition, I will provide anecdotal evidence about the importance of private information and limited risk bearing capacity in this market.

2.2.1 Market microstructure

During the 18th century stock trade in Amsterdam 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).

This has an interesting implication for the prices we observe. The prices that were reported 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.

As discussed on page 24, 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. This has the important implications that it was relatively easy for market participants to take considerable short positions[4].

2.2.2 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'.[5]

There is also evidence that EIC directors James Cockburn and George Colebrooke 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,

[4] For example, in the beginning of 1772 Alexander Fordyce, a London investor, had built up a considerable short position in EIC and BoE stock in the Amsterdam futures market. When prices continued to rise, this created a spectacular bankruptcy. Wilson (1941 [1966]) and chapter 3 of this thesis.

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

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.[6] 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'.[7]

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

[6] http://www.fas.org/irp/ops/ci/docs/ci1/ch1c.htm
[7] Private letter from Wentworth to Hope, Hope & Co., SAA 735; 115.

price of EIC stock in Amsterdam fell from 169.5 to 161 on December 30, reaching its lowest point on January 4, 1773 at 157.50[8]. 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, 1155; 1156).

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 selling came to an end, the stocks suddenly started to rise again'.[9]

Two other examples are dicussed in the next chapter.

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[8] In London the EIC stcok price did fall to 154 on January 16^{th}.

[9] 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

2.3 Model

2.3.1 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.[10] 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 51). 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)[11] the insider will spread out his trades over time 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 (Chowdry and Nanda 1991). 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

[10] I fully abstract from public information. The underlying assumption is that public information is immediately incorporated into prices after this information is received and that it is independent of private information.
See Kim and Verecchia (1997) for an application where public and private information can be complementary.
[11] See also Glosten and Milgrom (1985) and Holden and Subrahmanyam (1992).

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; Wang 1994; Llorente et al. 2002)[12]. This feature also closely resembles the situations such as described by Robert Hennebo (see page 52).[13] 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 2.4.

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).[14][15]

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 (Back and Baruch 2004 and Caldentey and Stacchetti 2010).

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[12] Examples of other papers who combine informed trading with limited risk bearing capacity include Kim and Verecchia (1991), Subrahmanyam (1991, 1994), Holden and Subrahmanyam (2002), Chordia and Subrahmanyam (2004) and Gabaix et al. (2006). In these papers private information is short lived.

[13] See also the third chapter of this thesis.

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

Existing empirical evidence comes from the study of volume and liquidity around (anticipated) announcements, see Chae (2005), Graham, Kokski and Loewenstein (2006), and Tetlock (2010).

[15] Grundy and McNichols (1989), Wang (1994) and Llorente et al. (2002) also provide models where agents can trade either for informational or liquidity reasons. However in these models agents act competitively and do not take their own price impact into consideration.

This risk of revelation will lead the insider to trade relatively aggressively 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.[16][17]

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 non-competitive limit order framework developed by Kyle (1989).[18] 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, endogenous liquidity trade and limited risk bearing capacity in an non-competitive setting. Secondly, the model has the feature that uninformed liquidity trade becomes more important over time as asymmetric information is reduced. In most models this does not arise because informed agents have an incentive to follow uniformed traders (Admati and Pfleiderer 1988). The model breaks this 'run but cannot hide' element because the moment when the private signal is revealed is uncertain. This 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.

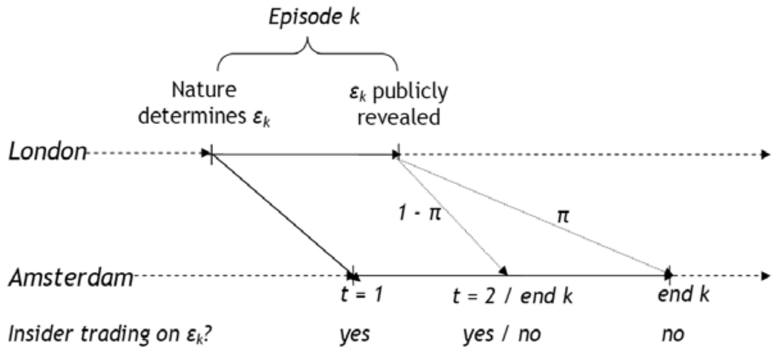
[16] I am not the first to introduce the risk of the revelation of private information in a model of insider trading (Back and Baruch 2004 and Caldentey and Stacchetti 2010). However, the model developed in this paper is the first to trace its effects on liquidity trading.

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.

[17] See Vives (1995) for a general treatment of the impact of short horizons on information dissemination.

[18] See also Vayanos (1999) who uses this framework. Most theoretical contributions mentioned use the Kyle (1985) framework which involves a centralized market maker.

Figure 10: Setup model



2.3.2 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 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.[19] 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.[20]

[19]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.

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

2.3.3 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.

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.[21] 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 $v = v_0 + \varepsilon$.

2.3.4 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

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

18^{th} 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.[22] 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.

2.3.5 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 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.

[22] 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 18^{th} 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.

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 $U_{t,m}\left[y_{t,m}, p_t\right]$ 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

$$\begin{aligned} & U_{t,m}\left\{y_{t,m},u_{t,m},p\left(y_{t,m},x_t,\sum_{k\neq m}y_{t,k}\right),E\left[\varepsilon\mid p_t\right]\right\} \\ > \quad & U_{t,m}\left\{y'_{t,m},u_{t,m},p\left(y'_{t,m},x_t,\sum_{k\neq m}y_{t,k}\right),E\left[\varepsilon\mid p_t\right]\right\} \end{aligned} \tag{4}$$

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 ($p_t = p\left(y_{t,m},\cdot,\cdot\right)$).

Let $\Pi_2 = \Pi_2\left[x_2,\varepsilon,\overline{p}_1,p_2\right]$ 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 $\overline{p}_1$, all alternative demand curves x'_2 and equilibrium demand curves $y_{2,m}$

$$\Pi_2\left[x_2,\varepsilon,\overline{p}_1,p_2\left(x_2,\sum_m y_{2,m}\right)\right] > \Pi_2\left[x'_2,\varepsilon,\overline{p}_1,p_2\left(x'_2,\sum_m y_{2,m}\right)\right] \tag{5}$$

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, $E\left[\Pi_2\right]$ can be rewritten in terms of p_1 only. Let $E\Pi\left[x_1,p_1\right]$ be the informed agent's total expected profits.

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

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 $y_{1,m}$

$$E\Pi\left[x_1,p_1\left(x_1,\sum_m y_{1,m}\right)\right] > E\Pi\left[x'_1,p_1\left(x'_1,\sum_m y_{1,m}\right)\right] \tag{6}$$

which is similar to equation (5).

2.3.6 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*

$$var\left[\varepsilon\mid p_1,\widehat{p}^u_{m,2}\right] > \frac{C}{A^2\left(M-1\right)\sigma_u^2} \tag{7}$$

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

$$x_1 = \beta_1^i (v_0 + \varepsilon - p_1) - \mu\varepsilon \tag{8}$$

$$x_2 = \beta_2^i (v_0 + \varepsilon - p_2) \tag{9}$$

$$y_{1,m} = \beta_1^u (v_0 - p_1) - \gamma_1 u_{1,m} \tag{10}$$

$$y_{2,m} = \beta_2^u (v_0 + E[\varepsilon \mid p_1] - p_2) - \gamma_2 u_{2,m} \tag{11}$$

and the following equilibrium prices

$$p_1 = v_0 + \lambda_1 \left[\left(\beta_1^i - \mu\right) \varepsilon - \gamma_1 \sum_M u_{1,m} \right] \tag{12}$$

$$p_2 = v_0 + E[\varepsilon \mid p_1] + \lambda_2 \left[\beta_2^i (\varepsilon - E[\varepsilon \mid p_1]) - \gamma_2 \sum_m u_{2,m} \right] \tag{13}$$

with slopes of the aggregate demand curve defined as

$$\lambda_1 = \frac{1}{\beta_1^i + M\beta_1^u} \tag{14}$$

$$\lambda_2 = \frac{1}{\beta_2^i + M\beta_2^u} \tag{15}$$

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 (7). 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.[23] In the remainder of the paper I will assume that (7) 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 (10) and (11). 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 (10) and (11) 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 (8) to (9) 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

[23]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.

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 (8) this intuition is captured by μ, which is proportional to π.

Equations (12) and (13) 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 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.

2.3.7 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

$$a_{news} = 0 \text{ and } b_{news} = \frac{cov\left(\Delta p_k^L, p_{k,1} - p_{k,0}\right)}{var\left(\Delta p_k^L\right)} \tag{16}$$

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

$$a_{nonews} = 0 \text{ and } b_{nonews} = \frac{cov\left(\Delta p_k^L, p_{k,2} - p_{k,1}\right)}{var\left(\Delta p_k^L\right)} \tag{17}$$

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*

$$cov\left(\Delta p_k^L, p_{k,1} - p_{k,0}\right) > cov\left(\Delta p_k^L, p_{k,2} - p_{k,1}\right) \tag{18}$$

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

$$d_{nonews} = \frac{cov(v - p_2, p_2 - p_1)}{var(p_2 - p_1)} \tag{19}$$

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

$$d^a_{news} = \frac{cov(v - p_1, p_1 - v_0)}{var(p_1 - v_0) + var(v - p_2)} \tag{20}$$

The numerator is similar to the one in (19) 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 $var(v - p_2)$.[24]

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

$$d^b_{news} = \frac{cov(p_2 - p_1, p_1 - v_0)}{var(p_1 - v_0) + var(v - p_2)} \tag{21}$$

which is very similar to expression (20). 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.

[24] 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).

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* $|d_{nonews}| > |d_{news}|$

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*

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

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.

2.4 Empirical evidence

2.4.1 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.[25] First of all, the model predicts that returns in

[25] 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 28). This means that the model's predictions cannot be verified for the SSC.

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 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 18^{th} 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

Figure 11: Predicting the arrival of news

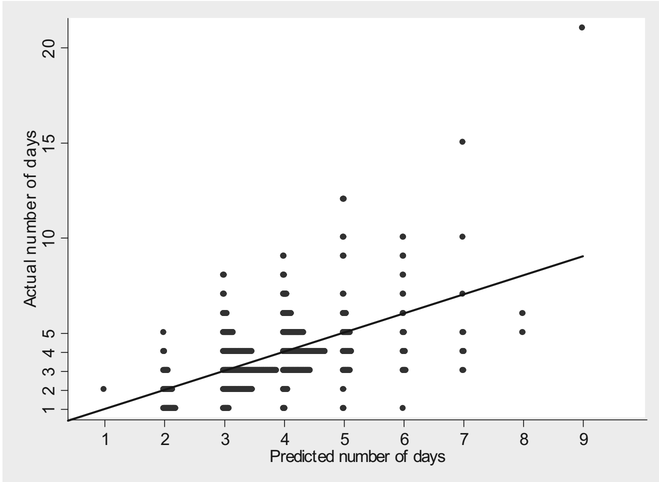
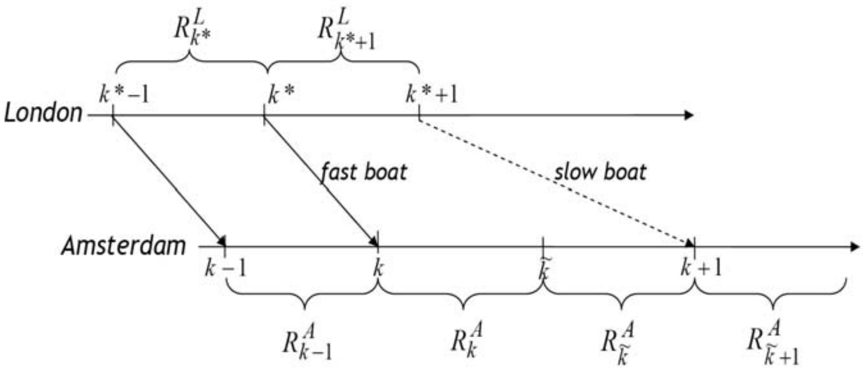


Figure 12: Setup Empirics



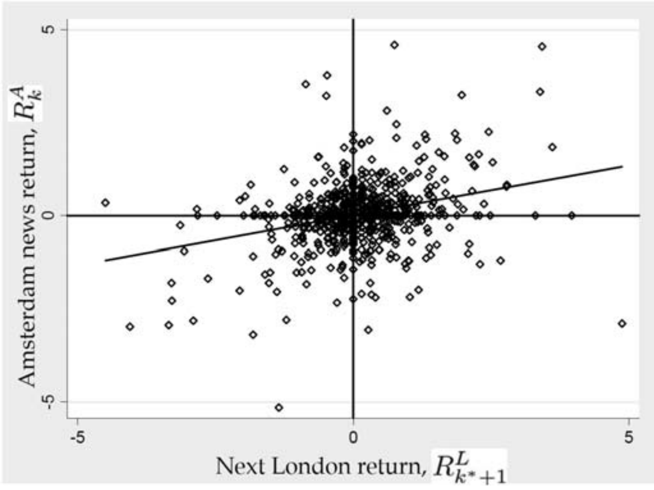
assumption that investors faced uncertainty about when the next boat arrived, is borne out by the data.

2.4.2 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

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



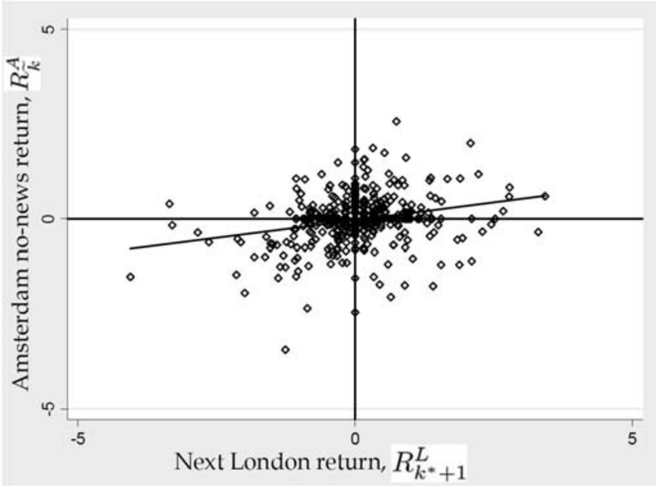
relatively quickly, while boat $k+1$ is delayed. The delay of boat $k+1$ means that after k there is an additional period in Amsterdam denoted $\widetilde{k}$ in which there is trade in the English stocks, but no new information from London. These periods $\widetilde{k}$ are the no-news periods referred 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 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 69) both R_k^A (the Amsterdam news return) and $R_{\widetilde{k}}^A$ (the Amsterdam no-news return) should be

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



correlated with the next London return $R^L_{k^*+1}$.

Figure 13 shows that R^A_k is positively correlated with London return $R^L_{k^*+1}$. Likewise, figure 14 shows that $R^A_{\widetilde{k}}$ is also correlated with $R^L_{k^*+1}$. 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 $\widetilde{k}$.[26]

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 $R^L_{k^*}$, 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

[26] 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.

Table 8: Co-movement of returns

	Amsterdam news return, R^A_k		Amsterdam no-news return, $R^A_{\widetilde{k}}$	
Next London news return, $R^L_{k^*+1}$	0.2639 (0.0523)***	0.2604 (0.0446)***	0.1580 (0.0459)***	0.1657 (0.0433)***
Current London news return, $R^L_{k^*}$		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, $R^L_{k^*}$, to adjust for possible momentum in stock returns. The Chi2 test-value is reported for the hypothesis that R^A_k and $R^A_{\widetilde{k}}$, Amsterdam news and no-news returns, co-move similarly with the next London news returns $R^L_{k^*+1}$.

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 $R^L_{k^*}$ 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 $R^L_{k+1^*}$ are between 30% (R^A_k) and 55% ($R^A_{\widetilde{k}}$) 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, $R^A_{\widetilde{k}}$, are negatively correlated with subsequent news returns $R^A_{\widetilde{k}+1}$. 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.

Figure 15: Reversal of no-news returns

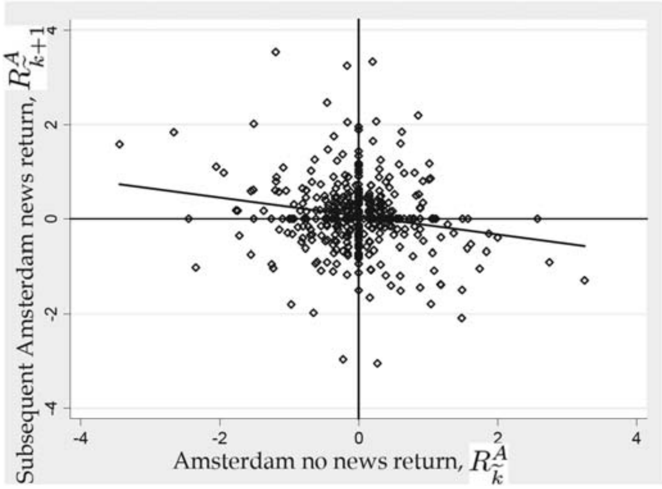


Figure 16: Reversal of news returns

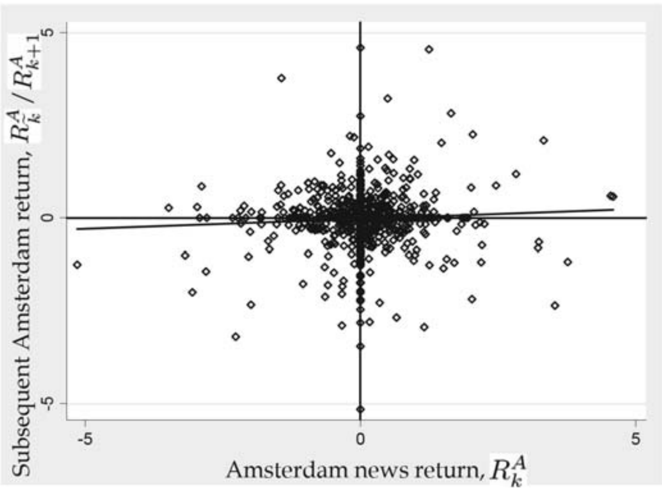


Table 9: Reversal of Amsterdam returns

	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.

This result fails to hold for news returns. Figure 16 shows that news returns R^A_k are uncorrelated with returns in the next trading period, $R^A_{\tilde{k}}$ or R^A_{k+1}(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 $R^A_{\tilde{k}}$ is partly reversed during the next period. This pattern is seemingly absent for R^A_k. 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 $R_{\tilde{k}}^A$ are both positively correlated with the London return $R_{k^*+1}^L$. $R_{k^*+1}^L$ 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 $R_{\tilde{k}}^A$ and $R_{\tilde{k}+1}^A$ presented in column 1. Both $R_{\tilde{k}}^A$ and $R_{\tilde{k}+1}^A$ are positively correlated with $R_{k^*+1}^L$ and as a result there will be a positive element in the correlation between $R_{\tilde{k}}^A$ and $R_{\tilde{k}+1}^A$ and this will bias the negative correlation between these returns towards zero. One can correct for this by including $R_{k^*+1}^L$ in the regressions. This is done in columns 2 and 4 of table 9. In the same columns I also correct for $R_{k^*}^L$, the past London news returns. This makes a big difference. The reversal of the Amsterdam no-news return $R_{\tilde{k}}^A$ roughly increases by half. In addition, once corrected for new information from London, the Amsterdam news return R_k^A 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.[27] 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

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

Table 10: Reversal of Amsterdam returns - high volatility

	Subsequent Amsterdam news return, $R^A_{\tilde{k}+1}$			
Amsterdam no news return, $R^A_{\tilde{k}}$	-0.1874 (0.0596)***	-0.1054 (0.0746)	-0.2885 (0.0605)***	-0.1553 (0.0790)**
Amsterdam no news return, $R^A_{\tilde{k}}$ 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 $R^A_{\tilde{k}}$ 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 $R^L_{k^*+1}$.

they are consistent with the empirical evidence. In general, empirical findings are in line with the model.

2.4.3 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.

2.4.3.1 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

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

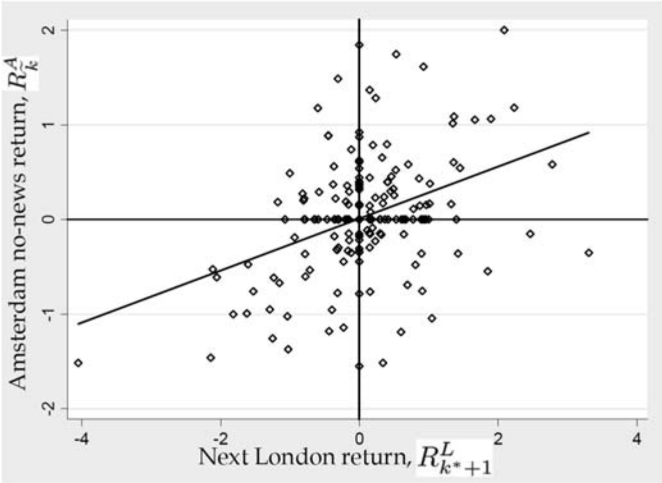
the return series. An alternative explanation could be the fact that some news may simply have arrived in Amsterdam outside of the official packet boat system.[28] As argued in sections 2 and 4, it is unlikely that alternative news channels played an important role, but it is not impossible. To test 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 $R^A_{\tilde{k}}$ against $R^L_{k^*+1}$ for the restricted bad weather sample.[29] 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.

[28] Note that this would not fully disqualify the presence of private information. The co-movement between $R^A_{\tilde{k}}$ and R^L_{k*+1} would still point into the direction of insider trading.

[29] 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.

Figure 17: Co-movement under bad weather conditions



2.4.3.2 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. Harris and Raviv 1993 and 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).[30]

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

[30] 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)

Table 12: Co-movement under different weather conditions

	Amsterdam no-news return, $R^A_{\tilde{k}}$	Amsterdam no-news return, $R^A_{\tilde{k}}$
Next London news return, $R^L_{k^*+1}$	0.1657 (0.0433)***	0.1254 (0.0574)**
Next London news return, $R^L_{k^*+1}$ 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 $R^A_{\tilde{k}}$ and $R^L_{k^*+1}$ is smaller if weather conditions are worse than average. This is done by adding an interaction term between $R^L_{k^*+1}$ 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.

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 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.[31] 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

[31]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 13: Transactions and the arrival of information

	Transactions Number	Value All	News	$Pr[TrNews]$		$Pr[Boat]$	p-value
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 $Pr[TrNews] < Pr[Boat]$.

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.

2.4.3.3 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 18th century 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 34 shows that there is practically no momentum in the return series. Table 14 on page 71 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.

2.4.3.4 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.

2.5 Conclusion

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.[32] 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.[33] 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.[34]

Empirical results are consistent with the 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), were 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

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

[33] 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).

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

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.

To what extent can these historical findings from this paper be generalized to 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.

2.6 Appendix A: mathematical proofs

Proof. of proposition 2 ■

1. I hypothesize that the linear equilibrium can be described by equations (8) to (11) with corresponding prices (12) and (13).

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

$$\widehat{p}_{1,m}^u = v_0 + \lambda_1^u \left[\left(\beta_1^i - \mu\right)\varepsilon - \gamma_1 \sum_{k \neq m} u_{1,k} \right] \tag{22}$$

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

$$\lambda_1^u = \frac{1}{\beta_1^i + (M-1)\beta_1^u} \tag{23}$$

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

$$\begin{aligned}\theta_{1,m} &= \frac{\widehat{p}_{1,m}^u - v_0}{\lambda_1^u\left(\beta_1^i - \mu\right)} && (24)\\ &= \varepsilon - \frac{\gamma_1}{\left(\beta_1^i - \mu\right)} \sum_{k \neq m} u_{1,k} && (25)\end{aligned}$$

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

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

where

$$\rho_1 = \frac{cov\left(\varepsilon, \theta_{1,m}\right)}{var\left(\theta_{1,m}\right)} = \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \left(\frac{\gamma_1}{\left(\beta_1^i - \mu\right)}\right)^2 (M-1)\,\sigma_u^2} \tag{26}$$

Using standard results from univariate statistics it can be shown that

$$var\left[\varepsilon \mid \theta_{1,m}\right] = \left(1 - \rho_1\right)\sigma_\varepsilon^2 \tag{27}$$

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

$$\begin{aligned}\theta_{12} &= \frac{p_1 - v_0}{\lambda_1\left(\beta_1^i - \mu\right)} && (28)\\ &= \varepsilon - \frac{\gamma_1}{\left(\beta_1^i - \mu\right)} \sum_{M} u_{1,m} && (29)\end{aligned}$$

Similar to equation (22) $\widehat{p}_{2,m}^u$ can be written as:

$$\widehat{p}_{2,m}^u = v_0 + E\left[\varepsilon \mid p_1\right] + \lambda_2^u \left[\beta_2^i\left(\varepsilon - E\left[\varepsilon \mid p_1\right]\right) - \gamma_2 \sum_{k \neq m} u_{2,m}\right] \tag{30}$$

with

$$\lambda_2^u = \frac{1}{\beta_2^i + (M-1)\beta_2^u} \tag{31}$$

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

$$\begin{aligned}\theta_{2,m} &= \frac{\widehat{p}_{2,m}^u - v_0}{\lambda_2^u \beta_2^i} - \frac{\beta_2^u}{\beta_2^i} E\left[\varepsilon \mid p_1\right] && (32)\\ &= \varepsilon - \frac{\gamma_2}{\beta_2^i} \sum_{k \neq m} u_{2,m} && (33)\end{aligned}$$

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

$$\begin{aligned} \rho_{12} &= \rho_{12}^{*} - \rho_2 \frac{cov(\theta_{12}, \theta_{2,m})}{var(\theta_{12})} \\ &= \left(1 - \rho_2\right)\rho_{12}^{*} \end{aligned} \tag{34}$$

and

$$\begin{aligned} \rho_{2} &= \rho_{2}^{*} - \rho_{12} \frac{cov(\theta_{12}, \theta_{2,m})}{var(\theta_{2,m})} \\ &= \left(1 - \rho_{12}\right)\rho_{2}^{*} \end{aligned} \tag{35}$$

with

$$\rho_{12}^{*} = \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \left(\frac{\gamma_1}{\left(\beta_1^I - \mu\right)}\right)^2 M\sigma_u^2} \tag{36}$$

$$\rho_{2}^{*} = \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \left(\frac{\gamma_2}{\beta_2^I}\right)^2 \left(M - 1\right)\sigma_u^2} \tag{37}$$

and

$$var\left[\varepsilon \mid \theta_{12}, \theta_{2,m}\right] = \left(1 - \rho_{12} - \rho_2\right)\sigma_\varepsilon^2 \tag{38}$$

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

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

with

$$\lambda_2^i = \frac{1}{M\beta_2^u} \tag{39}$$

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

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

with

$$\beta_2^i = \frac{1}{\lambda_2^i} \tag{40}$$

and second order condition $\beta_2^i > 0$. This expression confirms the guess in (9).

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 (9):

$$\Pi_2 = x_2 (v_0 + \varepsilon - p_2) \tag{41}$$

$$= \beta_2^i (v_0 + \varepsilon - p_2)^2 \tag{42}$$

Using equations (39) and (40), p_2 can be rewritten as:

$$p_2 = v_0 + E[\varepsilon \mid p_1] + \frac{1}{2}(\varepsilon - E[\varepsilon \mid p_1]) - \frac{\gamma_2}{2\beta_2^i} \sum_m u_{2,m} \tag{43}$$

and expression (41) 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

$$\lambda_1^i = \frac{1}{M\beta_1^u} \tag{44}$$

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 (28), 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 (8):

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

where

$$\beta_1^i = \frac{1}{\lambda_1^i} - \frac{\pi (\rho_{12}^*)^2}{\lambda_2^i \left[\lambda_1 (\beta_1^i - \mu)\right]^2} \tag{45}$$

and

$$\mu = \left(1 - \frac{\rho_{12}^*}{\lambda_1 \left(\beta_1^i - \mu\right)}\right) \frac{\pi \rho_{12}^*}{2\lambda_2^i \lambda_1 \left(\beta_1^i - \mu\right)} \tag{46}$$

The expressions for β_1^i and μ are a function of $\beta_1^i - \mu$ which can be solved for[35] as

$$\beta_1^i - \mu = \frac{1}{2\lambda_1^i} \left(1 + \sqrt{1 - \frac{2\pi \rho_{12}^* \left(\lambda_1^i\right)^2}{\lambda_2^i \lambda_1}}\right) \tag{47}$$

which is function decreasing in λ_1^i[36].

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

$$0 < \lambda_1^i < \frac{2\lambda_2^i \left[\lambda_1 \left(\beta_1^i - \mu\right)\right]^2}{\pi \left(\rho_{12}^*\right)^2} \tag{48}$$

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 (29) and (32). Using these facts and expressions (31), (34) and (38) the first order condition can be written as expression (11):

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

with

$$\beta_2^u = \frac{1}{\lambda_2^u} \frac{1 - \frac{\rho_2}{\beta_2^i \lambda_2^u}}{1 + \frac{\rho_2}{\beta_2^i \lambda_2^u} + \frac{A(1 - \rho_{12} - \rho_2)\sigma_\varepsilon^2}{\lambda_2^u}} \tag{49}$$

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

[36] 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 agresively 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 agresively in $t = 1$.

and

$$\gamma_2 = \frac{A\left(1-\rho_{12}-\rho_2\right)\sigma_\varepsilon^2}{\lambda_2^u}\frac{1}{1+\frac{\rho_2}{\beta_2^i\lambda_2^u}+\frac{A(1-\rho_{12}-\rho_2)\sigma_\varepsilon^2}{\lambda_2^u}} \tag{50}$$

Using (31), (40) and (39), these expressions can be simplified as

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

and

$$\gamma_2 = \frac{M-1}{2M-1}\frac{(M-1)-\rho_2\left(2M-1\right)}{M-\rho_2\left(2M-1\right)} \tag{52}$$

Note, that using the same logic the expression for p_2 in (43) can be further simplified to:

$$p_2 = v_0 + \frac{1}{2}\left(1+\rho_{12}^*\right)\varepsilon - \frac{\rho_{12}^*\gamma_1}{2\left(\beta_1^i-\mu\right)}\sum_m u_{1,m} - \frac{\gamma_2}{2\beta_2^i}\sum_m u_{2,m} \tag{53}$$

with

$$\frac{\gamma_2}{2\beta_2^i} = \frac{A\left(1-\rho_{12}-\rho_2\right)\sigma_\varepsilon^2}{2\left[M-\rho_2\left(2M-1\right)\right]} \tag{54}$$

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

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

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

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

which yields the first order condition from expression (10):

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

where

$$\beta_1^u = \frac{1}{\lambda_1^u}\frac{1-\frac{\rho_1}{(\beta_1^i-\mu)\lambda_1^u}}{1+\frac{\rho_1}{(\beta_1^i-\mu)\lambda_1^u}+\frac{A(1-\rho_1)\sigma_\varepsilon^2}{\lambda_1^u}} \tag{55}$$

and

$$\gamma_1 = \frac{A\left(1-\rho_1\right)\sigma_\varepsilon^2}{\lambda_1^u}\frac{1}{1+\frac{\rho_1}{(\beta_1^i-\mu)\lambda_1^u}+\frac{A(1-\rho_1)\sigma_\varepsilon^2}{\lambda_1^u}} \tag{56}$$

which can be further simplified by using (47).

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 (31), (40) and (39) 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 (35), (52) and (39) this can be rewritten as (7) or

$$var\left[\varepsilon \mid \theta_{12}, \theta_{2,m}\right] > \frac{1}{\rho_2 A^2 (M-1)\sigma_u^2} \tag{57}$$

Now move to the first period. By using (44) and (45) it can be shown that the second order conditions in period $t = 1$ can be summarized in the following condition:

$$\beta_1^u > \frac{1}{2M-1} \frac{\pi\left(\rho_{12}^*\right)^2}{\lambda_2^i \left[\lambda_1\left(\beta_1^i - \mu\right)\right]^2} \tag{58}$$

This expression demonstrates more or the less the same intuition as in the previous existence condition. Combined with (55) 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 (57) holds, so will (58). The reverse is not true. In other words, condition (57) is a sufficient condition for the existence of the equilibrium.*

Proof. by contradiction. Suppose that the uncertainty in $t = 2$ is sufficient for (57) to hold, but that uncertainty in $t = 1$ is too small for (58) 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 (26), (34) and (35). ■

Proof. of corollary 2

Equation (12) 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 (44), (23) and (14) imply that $\lambda_1 > 0$. In addition, expression (47) gives that $\beta_1^i - \mu > 0$. ■

Proof. of corollary 3

Equations (12) and (53) 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 (36), $\rho_{12}^* > 0$. In order for $Cov\left(\Delta p_k^L, p_{k,2} - p_{k,1}\right) > 0$ we need that $\lambda_1\left(\beta_1^i - \mu\right) \leqq \frac{1}{2}$. Suppose $\pi = 0$, in that case $\lambda_1\left(\beta_1^i - \mu\right) = \frac{1}{2}$. To see this note from expression (46) 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 (43), where $E\left[\varepsilon \mid p_1\right]$ is replaced with zero. For any $\pi > 0$, $\mu > 0$ and $\lambda_1\left(\beta_1^i - \mu\right) < \frac{1}{2}$. ■

Proof. of corollary 4

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

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 (12) and (53).[37]

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

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

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

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

[37]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}.

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 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

$$(p_{k+1,1} - p_{k,1}) = c^a_{news} + d^a_{news} (p_{k,1} - p_{k-1,2}) + \eta^a_1$$

where

$$\begin{aligned} d^a_{news} &= \frac{cov(p_{k+1,1} - p_{k,1}, p_{k,1} - p_{k-1,2})}{var(p_{k,1} - p_{k-1,2})} \\ &= \frac{cov(p_{k+1,1} - p_{k,1}, p_{k,1} - p_{k-1,2})}{var(p_{k,1} - v_{k-1}) + var(v_{k-1} - p_{k-1,2})} \end{aligned}$$

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

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

Suppressing episode-subscripts k equation (20) 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

$$(p_{k,2} - p_{k,1}) = c^b_{news} + d^b_{news} (p_{k,1} - p_{k-1,2}) + \eta^b_1$$

with

$$d^b_{news} = \frac{cov\left(p_{k,2} - p_{k,1}, p_{k,1} - p_{k-1,2}\right)}{var\left(p_{k,1} - p_{k-1,2}\right)}$$

which can be rewritten as (21) following the same logic as above. Note that the denominators in expressions (20) and (21) are the same. It can be shown that the covariance terms in (20) and (21) also equal, so that $d^a_{news} = d^b_{news} = d_{news}$.

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

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

with

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

which can be rewritten as (19) applying the same logic as before.

The covariances and variances are given by

$$cov\left(v - p_1, p_1 - v_0\right) = \left(1 - \alpha_1\right)\alpha_1\sigma^2_\varepsilon - \delta^2_1 M\sigma^2_u \tag{59}$$

$$cov\left(p_2 - p_1, p_1 - v_0\right) = \left(\alpha_2 - \alpha_1\right)\alpha_1\sigma^2_\varepsilon + \left(\zeta - \delta_1\right)\delta_1 M\sigma^2_u \tag{60}$$

$$cov\left(v - p_2, p_2 - p_1\right) = \left(1 - \alpha_2\right)\left(\alpha_2 - \alpha_1\right)\sigma^2_\varepsilon - \zeta\left(\zeta - \delta_1\right)M\sigma^2_u \tag{61}$$

$$var\left(p_1 - v_0\right) = \alpha^2_1\sigma^2_\varepsilon + \delta^2_1 M\sigma^2_u \tag{62}$$

$$var\left(v - p_2\right) = \left(1 - \alpha_2\right)^2\sigma^2_\varepsilon + \left(\delta^2_2 + \zeta^2\right)M\sigma^2_u \tag{63}$$

$$var\left(p_2 - p_1\right) = \left(\alpha_2 - \alpha_1\right)^2\sigma^2_\varepsilon + \left[\delta^2_2 + \left(\zeta - \delta_1\right)^2\right]M\sigma^2_u \tag{64}$$

Proof. of Lemma 5 and 6

These results follow directly from simulating the model and calculating the covariances from expressions (59), (60) and (61). It can be shown that all three covariances are negative. ■

Proof. of Lemma 7

This results follows directly from simulating the model. Use covariances (59), (60) and (61) and variances (62), (63) and (64) to calculate expressions d_{news} and d_{nonews}.

■

Proof. of Lemma 8.

This expression also follows directly from simulation results. ■

2.7 Appendix B: transaction data

Information on volume is not available for the Amsterdam stock market in the 18th 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. These loan agreements, which are very similar to today's repo contracts, 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. 24) 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 (SAA 5075; 10593-10613). 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.

CHAPTER III

OPTIMAL DELAY: DISTRESSED TRADING IN 18TH C. AMSTERDAM (WITH HANS-JOACHIM VOTH)

3.1 Introduction

A V-shaped pattern in asset prices – and in particular, sharp price changes followed by gradual reversals – are common across a range of assets (Duffie 2010; Shleifer and Vishny 2010). A growing literature emphasizes limits to arbitrage as an explanation. For example, liquidity providers may need to be compensated for holding larger-than-average positions (Grossman and Miller 1988; Nagel 2011). As they slowly off-load their positions, the initial price change will be reversed. Additional approaches in the same vein emphasize under-provision of risk capital due to frictions in financial intermediation (Shleifer and Vishny 1997; Gromb and Vayanos 2002; Brunnermeier and Pedersen 2008, He and Krishnamurthy 2010), inattention (Reis 2006), search frictions (Duffie, Garleanu and Pedersen 2005; Weill 2007), and the market power of participants (Brunnermeier and Pedersen 2005). An alternative interpretation emphasizes changes in asymmetric information, especially in periods of market dislocation (Gorton and Metrick 2010a, 2010b). Because detailed transaction data are often lacking, there is no consensus on which interpretation has more explanatory power in practice.

In this chapter, we analyze two periods of price overshooting on the Amsterdam stock market in 1772 and 1773. In both cases, news reached the market that a big market participant had to close his position as a result of major losses. We examine the price path of stocks and document significant overshooting in the short term, similar to the pattern observed in modern-day data, and an eventual reversal. Because we have access to the actual trading positions of the stricken investors, we can show that this overshooting occurred with very little distressed sales actually taking place. Most of these sales were delayed until mispricing had disappeared. This suggests that a V-shaped price path can be observed without additional risk capital actually being used up.

We use a theoretical model related to Vayanos (1999; 2001) to explain these facts. The size of the distressed agent's shock is unknown to the rest of the market. We assume that this shock is big enough to move prices at a horizon that liquidity providers care about.[1] Liquidity providers are risk averse and will demand an additional premium to be compensated for this risk, which comes on top of the usual fundamental risk. The distressed party does not face this source of uncertainty and this implies a friction in the degree of risk sharing that he and the liquidity providers are willing to engage in. Effectively, the distressed trader faces an additional premium to gain access to risk sharing. As a result, he may choose to transact very little. In the mean time, the equilibrium price will adjust to reflect the arrival of the shock to the market. As time progresses and more information about the size of the shock is revealed, this source of uncertainty disappears and prices rebound.

In both episodes we discuss, the centre stage is taken by the British stocks that were traded in both London and Amsterdam and which are discussed in the first two chapters of this thesis. The first episode we study takes place in June 1772. On June 9, London financier Alexander Fordyce defaults on his debtors. At "the time of his misfortunes" he has a large short position outstanding in the Amsterdam futures market in British East India Company (EIC) and Bank of England (BoE) stock. These short positions are managed by the Dutch bank Hope & Co. Because of the bankruptcy laws of the time, Hope has a clear incentive to cancel the short positions as quickly as possible. Any losses will be on account of Hope; any profits will have to be shared with the other creditors of Fordyce' estate. Effectively this leaves Hope with the downside risks. What is the impact of this event on prices?

It is challenging to identify overshooting (undershooting) after individual events. Many other developments take place that could influence stock prices. To solve this problem we look at the difference between stock prices in Amsterdam and London. We identify overshooting (undershooting) by an increase (decrease) of the Amsterdam price *compared to London*. After June 12, when the news of Fordyce' default reaches

[1] In the long run it is usually assumed that the demand curve for stocks is horizontal (Scholes 1972). In the medium run, however, the demand curve for stocks could be downward sloping. See the seminal contributions of Shleifer (1986), Harris and Gurel (1986) and related literature.

Amsterdam, we document a significant overshooting of the Amsterdam price of EIC and BoE stock with respect to London. Mispricing lasts up to four weeks. Surprisingly, Hope hardly transacts during this period of mispricing. Instead the bank waits for Amsterdam prices to be restored to equilibrium before it off-loads its position.

The second episode we study takes place immediately after Christmas 1772. A consortium of Dutch bankers, led by the brothers Van Seppenwolde, has been bulling EIC and BoE stock in Amsterdam for months. Their long position is largely financed through repo transactions, i.e. they borrow large sums of money to invest in EIC stock, which they then use to collateralize the loans. When the price of EIC and BoE stock falls dramatically during the last months of 1772, the consortium is unable to meet lenders' margin calls and is forced to default. The collateralized EIC and BoE stock now becomes the property of the lenders, who again have a clear incentive to get rid of this position as quickly as possible. Any profits on the stock will go to the defaulters' estate; any losses are for their own account. Again we report serious mispricing. For several weeks Dutch EIC and BoE prices fall significantly below prices in London. At the same time repo haircuts on new contracts increase from about 20 to 30%. However, very little actual transactions take place. Most sales are delayed by weeks, sometimes even months.

This chapter is related to a growing literature on V-shaped patterns in asset prices (see Duffie 2010 for a recent overview), which was initiated by Scholes (1972). Most relevant for this chapter are papers discussing fire sales (see Shleifer and Vishny 2010 for a recent overview). Coval and Stafford (2007) look at fire sales of mutual funds and they study the impact on the prices of those assets that are held commonly by distressed mutual funds. Mitchell, Pedersen and Pulvino (2007) study three cases, merger arbitrage in 1987, the LTCM crisis in 1998 and the convertible bond market in 2005. In all three cases they identify distress selling and find a significant impact on stock prices. Other relevant studies dealing with non-financial assets include Pulvino (1998; airplanes) and Campbell, Giglio, and Pathak (2010; real estate).

More generally this chapter is related to papers studying the price impact of index rebalancing (e.g. Shleifer 1986; Harris and Gurel 1986; Kaul, Mehrotha and Morck 2000; Madhavan 2001; Wurgler and Zhuravskaya 2002; Blume and Edelen 2003; Chen, Noranha and Singal 2004, Greenwood 2005; Hrazdil 2009), block trades (Scholes 1972; Holthausen, Leftwich and Mayers 1990), change in ratings (Chen, Lookman, Schürhoff and Seppi 2010; Feldhütter 2010), merger announcements (Mitchell, Pulvino and Stafford 2004), debt issuance (Newman and Rierson 2004), and the predictable rolling over of future positions (Mou 2011). There is also a burgeoning literature on the impact of market maker inventories on V-shaped stock returns (Hendershott and Seaholes 2008; Andrade, Chang and Seasholes 2008; Hendershott and Menkveld; Rinne and Suominen 2010; Nagel 2011).

Finally this chapter has a number of parallels with the recent financial crisis. Mitchell and Pulvino (2011) look at the default of prime brokers on Wall Street and document significant subsequent mispricing. The impact of financial turmoil on repo haircuts has been documented by Gordon and Metrick (2010a, 2010b) and Krishnamurty (2010). Garleanu and Pedersen (2011) provide evidence on the impact of haircuts on mispricing.

Relative to this literature our contribution is twofold. First of all, we provide uniquely detailed information about two important episodes of financial distress. Most importantly, we present detailed information about the trading behavior of the distressed parties and we can almost perfectly reconstruct how they settled their positions. Secondly, we provide evidence for a novel empirical finding, namely that mispricing and distressed selling (buying) do not have to coincide in time.

The rest of this chapter is organized as follows. Section 2 provides more details about the two historical cases. In section 3 we provide evidence for significant mispricing right after the two events took place. In section 4, we document when exactly the distressed trading took place and we show that there is a disconnect between mispricing and actual transactions. In section 5 we first use historical sources to document the existing uncertainty about the size of the distressed agents' positions. We then present a simple model that uses this feature to explain the apparent inconsistency between the timing of mispricing and actual transactions. Section 6 concludes.

3.2 *Two historical cases*

3.2.1 Alexander Fordyce and Hope & Co.

The first historical case we discuss takes place in June 1772 and involves British investor Alexander Fordyce and Dutch banker Hope & Co. Fordyce was a notorious speculator. Of humble Scottish origin he had made a fortune speculating in EIC stock in 1766 (Stock Account Fordyce, SAA 735, 1510). Hungry for more, he kept speculating and in 1772 he decided to bet heavily against the EIC share price. This went awfully awry and Fordyce failed in June 1772 (Wilson 1939, p. 120-1). On June 9 he fled London to escape his creditors, the news of which must have arrived in Amsterdam on June 12, where investors responded with anguish at the news (Leydse Courant, June 17, 1772).

At the time of his bankruptcy, Fordyce had a short position in EIC stock in the Amsterdam market with a size of £ 57,000 nominal.[2] In addition, Fordyce held a short position in BoE stock of £ 22,000 nominal.[3] These positions had been taken in the futures market and had been intermediated by the Anglo-Dutch banking house of Hope & Co. The short positions were to expire on August 15, 1772 (SAA, 735, 1510).

When Fordyce defaulted, Hope was stuck with considerable positions in EIC and BoE stock. At the time of default it was not clear to what extent any claims against Fordyce's estate could be recovered. Fordyce's flight probably suggested that his estate was in a very poor condition. This implied that Hope alone would be fully responsible for the losses that could be incurred on the position in the EIC stock. If, on the other hand, this position would turn out to be profitable, Hope would have to share the proceeds with all other claimants. This gave Hope a clear incentive to get rid of the short position as quickly as possible.[4]

According to Hope, the market was aware of the fact that Fordyce had maintained

[2] The total outstanding EIC stock amounted to £ 3,200,000 nominal. The average amount of stock that was transferred in the Company's transfer books in the month of June during the five preceding years amounted to £ 206,048, Bowen (2007).

[3] The total outstanding capital stock of the Bank of England amounted to £ 10,780,000, Andreades (1909 [1966]), p. 151.

[4] The London correspondent of Hope & Co argued that "it was not prudent to continue the risque of the stock rising by which a considerable loss might have happened which Mess Hopes standing the middle men between buyer and seller must have paid out of their pocket and could only have received back a dividend from Fordyces Estate". In later court proceedings dealing with Fordyce' default, it was acknowledged that "it cannot be reasonably contended that Mess Hopes were bound [...] to continue the engagement at their own risque to the rescontre [settlement date] in August" (Court Proceedings Fordyce's Default, SAA 735, 1510).

a significant short position through Hope & Co. The market also realized that Hope would try to get rid of the position as quickly as possible. As a result the EIC stock price would rise, making the liquidation of the position very costly. In a letter to Fordyce dated October, 16, 1772 Hope wrote that:

> "At the time of your misfortunes India was at 228 and upwards. The general knowledge of our having been sellers to [for] you [...] raised the expectation of a very important rise, on the supposition that we should immediately buy it in again" (SAA, 735, 1510).

It seems that the general public indeed knew that Fordyce had a significant short position in EIC stock. Right after Fordyce's default, on June 13, 1772 the English newspaper the *Middlesex Journal* mentioned that

> "It is said that the banker, who absented [Alexander Fordyce], had a difference of 10% to pay on a million and a half of India stocks, of which he had been a bear for many months past."

In addition, the market, especially in Amsterdam, seems to have been fully aware of the implications of Fordyce's default on the stock price. When Fordyce's short position was closed, prices would probably have to rise. The London newspaper the *Public Advertiser*, published the following letter from Amsterdam on June 24th, 1772

> "There is a vulgar proverb which says that it is a bad wind which blows nobody good. The misfortune or misconduct of Mr. Fordyce, call it which you will, must be attended with this advantage to the real proprietors of East-India stock. The value of their property will now be ascertained, for it is known here, that by weight of metal this gentleman caused that stock to rise and fall at pleasure. Our opinion here is that you must shortly see it at 250."
>
> "H-S", Amsterdam June 19, 1772.[5]

[5] It is possible that this letter was sent to influence stock prices in London. It was signed by "H-S", which probably stands for Hermanus van Seppenwolde, an Amsterdam financier who was part of a consortium of bankers that were trying to "pump and dump" the EIC stock in Amsterdam (see later in this section).

A few days later on June 27, 1772, the *Middlesex Journal* published an extract from another letter from Amsterdam dated June 23, which mentioned that stock prices in Amsterdam were higher than those in London. According to the author this showed that

> "we are not sorry that some rotten sheep in your pastures have been forced to fly away, and no longer infect the sound stock."

In the next section we provide further evidence about price patterns.

3.2.2 Clifford and Sons and brothers Van Seppenwolde.

The second historical case we discuss takes place in January 1773. During 1772 a consortium of Dutch bankers speculated heavily on a rise in the EIC stock price. According to a contemporary Hermanus and Johannes van Seppenwolde, George Clifford and Sons and Abraham ter Borch and Sons formed a "cabale" or conspiracy to "take the entire EIC stock on their horns" or in other words to bull the market for EIC stock.[6] Apart from EIC stock, the consortium also invested heavily in BoE stock (SAA, 5075, 10,593 – 10,613). The attempt to pump and dump the English stocks failed miserably. EIC stock prices, and to a smaller extent BoE stock prices, kept falling during the second half of 1772 and the Dutch consortium suffered considerable losses. In the end this led to the default of all three houses. Even Clifford and Sons, one of the most famous, largest and oldest bankers in Amsterdam, had to permanently shut its doors on January 1, 1773 (SAA, Stukken betreffende de Boedel van Clifford en Zonen, f. 1).

The long positions of the three houses were predominantly in the form of so-called "beleeningen"; securitized loans or more specifically repos.[7] Especially the brothers Van Seppenwolde and Clifford & Chevalier, a subsidiary of Clifford and Sons, bought large amounts of EIC and BoE shares on credit. The purchased shares were then used to collateralize the loans. Shares were transferred to the account of the lender for the duration of the contract, usually 6 or 12 months (SAA, 5075, 10,593 – 10,613).

[6] "eenere Cabale, die de geheel Engelsche Oost op haare hoornen zou genomen hebben", *De Koopman* 1772, pp 294-295. The Dutch saying "op de hoornen nemen" is derived from bulls who take dogs or people on their horns to throw them in the air, Ter Laan 2003, p. 148.

[7] There is evidence that the consortium initially took their positions in the futures market. However, during the second half of 1772 they did not manage to continue their positions in the futures market (maybe due to an increase in counterparty risk) an they opted to continue through repo agreements (SAA, 5075, 10,593 – 10,613).

The loan amounted to less than the full value of the shares. A "surplus", a margin or haircut, was maintained to protect the lender from a possible default. It was agreed that if the price fell below a critical threshold, the borrower had to transfer cash to pay back some of the loan or had to provide additional stock to increase the collateral. Note that the loan did not go under water when the stock price fell below this critical value. There was still a significant margin left at this critical price. With each price fall of 10% (of the nominal value of the underlying stock) additional margins were required (SAA, 5075, 10,593 – 10,613). When these margin calls could not be fulfilled, the contract gave the lender the unambiguous right to sell the collateral.

Clifford and Ter Borch actively supported the Van Seppenwoldes by lending money on security of these haircuts or margins. It is clear that these loans were effectively unsecured in case of a price fall and later court proceedings indicate that these agreements were quite irregular (NA, Staal van Piershil, 386, 396; OSA 3710; GAR, 90, 56). Effectively, Clifford, Ter Borch and the Van Seppenwoldes were in it together.

Table 14 shows the total nominal value of the stocks used in these repo transactions outstanding around December 30th, 1772 that were registered by one notary (Van den Brink). The table shows that the brothers Van Seppenwolde were heavily bulling the market for EIC and BoE stock.[8] Clifford and Chevalier also held a considerable long position in EIC stock. These figures are from one notary only. Actual positions were likely to have been bigger, although a casual investigation of other notaries' archives suggest that the large majority of repos were registered through Van den Brink.

Most repo contracts stipulated that if the price fell below 200% additional collateral had to be posted. With every additional price fall of 10% margins were to be replenished. When, in the second half of 1772, the price of EIC fell below 200%, 190% and 180%, the consortium managed to fulfil these additional margin requirements by posting additional stock as collateral (SAA, 5075, 10,593 – 10,613; NA, Staal van Piershil, 381; GAR, 90, 52).

New margins would be required if the EIC stock price fell below 170%. This happened during the end of November 1772. The consortium seems to have managed to

[8] The total outstanding EIC stock amounted to £ 3,200,000 nominal, Bowen (2007). The total outstanding capital stock of the Bank of England amounted to £ 10,780,000, Andreades (1909 [1966], p. 151).

Table 14: Stock positions brothers Van Seppenwolde and Clifford and Chevalier on December 30, 1772 and subsequent margin calls

	Stock position (PSt. nominal)	**Margin calls (PSt. nominal)**
East India Company		
Hermanus van Seppenwolde	£ 87,000	£ 55,500
Johannes van Seppenwolde	£ 79,000	£ 79,000
Clifford and Chevalier	£ 44,500	£ 33,000
Total	£ 210,500	£ 168,000
Bank of England		
Hermanus van Seppenwolde	£ 37,000	£ 13,000
Johannes van Seppenwolde	£ 17,000	£ 0
Clifford and Chevalier	–	–
Total	£ 54,000	£ 13,000

Source: Notary Van den Brink, SAA 5075, 10,593 – 10,613

postpone paying the margin calls. They were most likely helped by the fact that the EIC stock price did not fall any further and temporarily rose above 170% in the middle of December.

Between December 21 and December 27 there was a dominantly eastern wind on the North Sea and investors in Amsterdam did not receive any new information from London. In the mean time EIC prices in London had again fallen further to 168%. In addition, negative information about the state of the EIC was revealed (*Amsterdamsche Courant* December 29, 1772 and Harman to Hope, December 18, 1772, SAA 735, 115). When this news reached Amsterdam on December 28, the lenders of the securitized loans were not willing to wait any longer for the margin payments. From December 28 onwards a multitude of "insinuaties" or official reminders were registered at the notary Van den Brink's office urging the borrowers to pay up (Van Den Brink, 10,602, see also Wilson 1939). Table 14 gives an overview of all these official margin calls registered by notary Van den Brink.

The stock that was provided as collateral had been transferred to the account of the lender when the repo contract had been signed. By the rules of these contracts, when the margin calls could not be fulfilled, the economic property of the stock would also be transferred to the lenders. This meant that after December 28 the lenders were stuck with large amounts of stock that they did not have the intention of holding in the first place. The contracts gave them permission to sell the stock to avoid any future losses on their positions.

The contracts stipulated that the borrower would be responsible for any losses that the lender would incur. This implied that any benefits would also be for the account of the borrower (NA, Van Staal Piershil, 386; OSA 3710, 4583). In other words, lenders were only exposed to the downside. This gave the lenders an incentive to trade as quickly as possibly to get rid of this risk. This must have led to serious selling pressure on the Amsterdam exchange.[9]

These events were publicly known to the public in Amsterdam. Contributions in the Amsterdam periodical *De Koopman* indicate that the market was well aware that there was a large long position hanging above the market. This news was for example brought by *De Koopman* on December 29, 1772, only one day after the consortium finally failed to meet its obligations. Less than a week later, on January 3, 1773, *De Koopman* again had extensive coverage of the event.

3.3 Price patterns

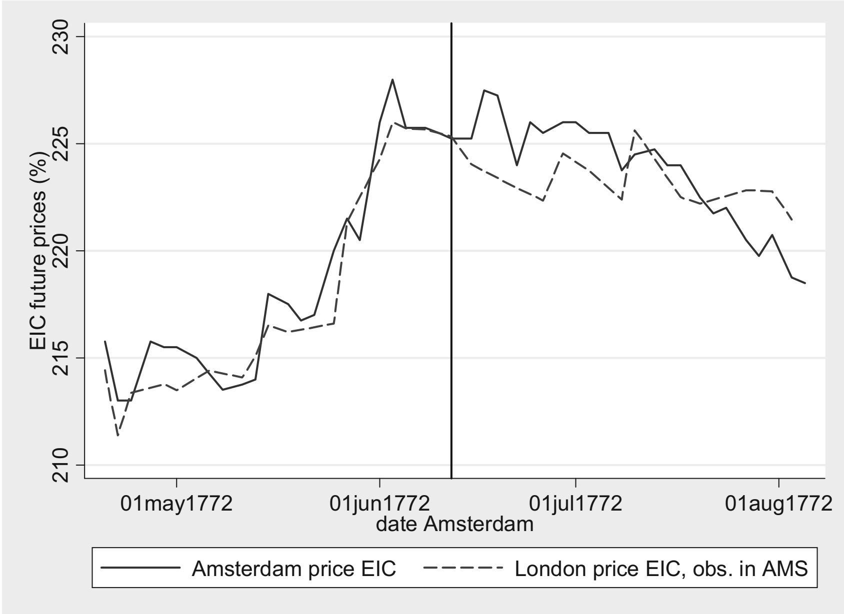
What measurable impact did the two shocks have on the Amsterdam market? In this section we determine the impact on the EIC and BoE stock prices in Amsterdam. We use of a unique feature of the data. EIC and BoE shares were both traded in London and in Amsterdam (Van Dillen 1931; Neal 1990) and prices are available for both markets. In the first two chapters of this dissertation it is shown that, due to communication delays, the London and Amsterdam market were imperfectly integrated. This means that if we want to study the impact of certain events on stock prices in Amsterdam, we can use the London price as a counterfactual.[10] Effectively we look at the difference between the stock price in Amsterdam and the stock price in London, as it was observed in Amsterdam. We will determine to what extent the two events in Amsterdam that we study led to a divergence of the Amsterdam and London stock price.

In the next section we study the trading behavior of the distressed agents in both events. Based on the archives of Hope & Co. we can largely reconstruct the way in which Hope settled the short position it inherited from Fordyce. In a similar way, we

[9] The average amount of stock that was transferred in the East India Company's transfer books in the month of January during the five preceding years amounted to £ 174,815, Bowen (2007).

[10] For an earlier example of this approach see Klerman and Mahoney (2005).

Figure 18: EIC prices in Amsterdam and London around Fordyce' default



use notary records to determine how and when the stock position of Clifford and Sons and the brothers Van Seppenwolde was liquidated.

3.3.1 Main results

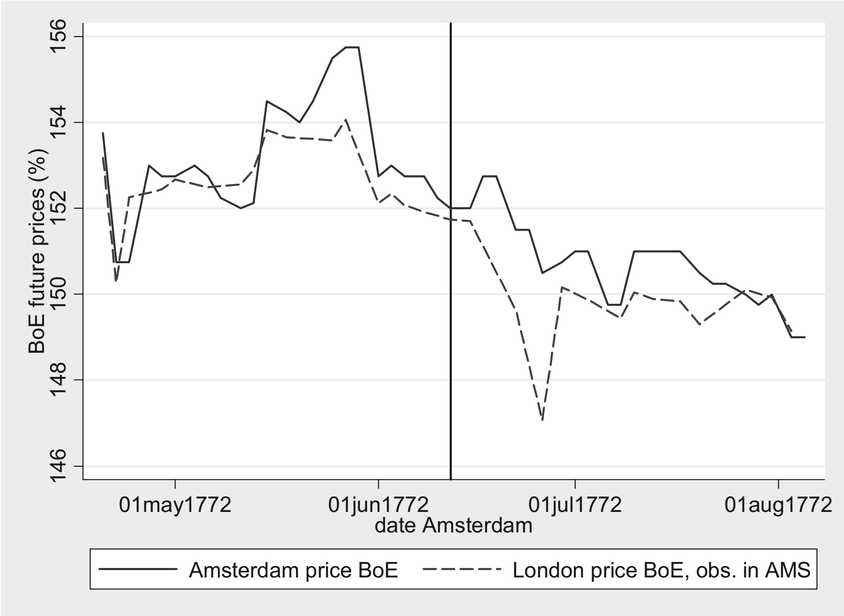
What was the impact of Fordyce' default on stock prices in Amsterdam? Figures 18 and 19 present the price series of EIC and BoE stock in Amsterdam and London around June 12, 1772. The Amsterdam price series are in real time, the London prices reported are those that were observed by the Amsterdam market on days the London news arrived.[11] Because Hope had to settle Fordyce's position in the futures market, we report futures prices.[12]

Figure 18 demonstrates that the EIC stock price rose significantly in both London and Amsterdam during the second half of May 1772. Fordyce's default can possibly be attributed to this price increase, which reduced the value of his short position. After Fordyce absconded on June 9 and this news reached Amsterdam on June 12, the EIC stock price was considerably higher in Amsterdam than in London for the duration of

[11] To determine the London prices as they are observed in Amsterdam we use information on the sailing of packet boats that was used in chapters 1 and 2.

[12] For Amsterdam these come from the original sources (see chapter 1). For London we took the spot prices as they are reported by Neal (1990) and transformed them into futures prices using a cost-to-carry annual interest rates of 2.75% (Smith 1919). London prices are also adjusted for differences in ex-dividend dates.

Figure 19: BoE prices in Amsterdam and London around Fordyce' default



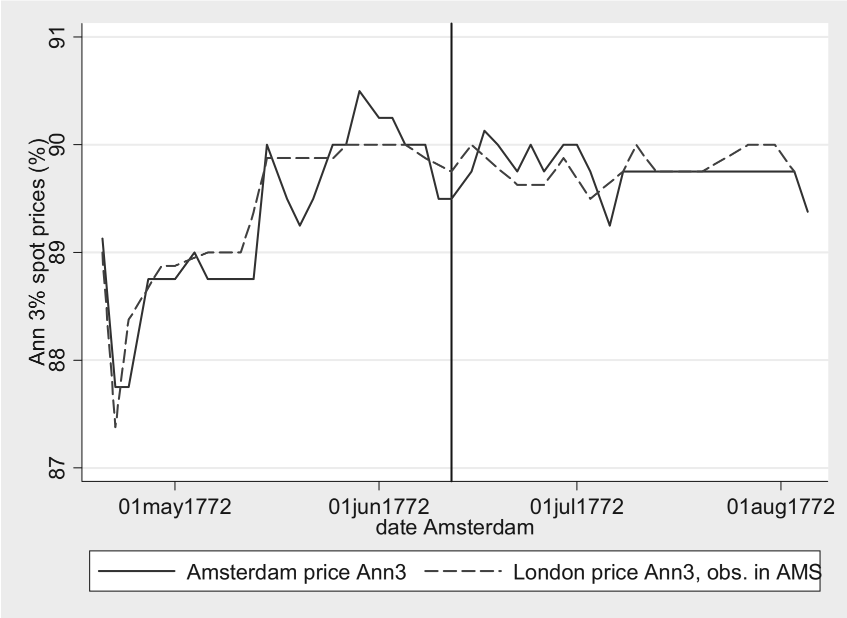
three weeks. This is consistent with Hope's complaints that the EIC stock price in Amsterdam overshot after Fordyce's default. Only in the beginning of July did the two price series converge.

The pattern for the BoE stock price in figure 19 looks largely similar. After the news of Fordyce' default reached Amsterdam, the Amsterdam price for BoE stock was consistently above the London price for the duration of six weeks.

It is not unthinkable that these results are driven by broader underlying developments in Amsterdam or London. To check this alternative explanation we do the same analysis for the 3% Annuities, a widely traded British bond for which prices are widely available in both London and Amsterdam. The results in figure 20 indicate that Fordyce' default had no impact on price differences for the Annuities.

To what extent is the divergence of the EIC and BoE price series after Fordyce's default economically and statistically significant? To answer this question we accumulate the differences between the Amsterdam and London price series after Fordyce's default for a number of different periods (2, 4, 6 and 8 weeks). We then compare these Event Cumulative Differences (ECD) with the Sample Cumulative Differences (SCD). This is the average cumulative difference between EIC stock prices in Amsterdam and London

Figure 20: Ann 3% prices in Amsterdam and London around Fordyce' default



calculated over periods of similar length between September 1771 and December 1777.[13] We do this analysis for the EIC and BoE price series and the 3% Annuity price series. Results are presented in table 15.

The table shows that the cumulative differences between EIC and BoE stock prices in Amsterdam and London for periods of 2, 4 or 6 weeks were far above the average. Statistical significance is tested in two ways. First of all a standard t-test is performed, of which the p-values are reported. Secondly, following Barber, Lyon, Tsai (1999), we calculate the empirical probability that the ECD is equal to the SCD. To do this we draw (with replacement) 1000 random periods from the period September 1771 and December 1777. Based on these 1000 draws we construct a distribution of cumulative differences and check at what percentile the value of the ECD is located. This gives us the empirical p-value.

The table shows that the ECD for EIC stock over 2 and 4 weeks is statistically significant at the 5% level. The EIC ECD is significant at the 10% level for a period of 6 weeks. Results for BoE stock differ according to which distribution is used. Using the t-distribution, the ECD is significant at the 5% level up to a horizon of 6 weeks. Using the empirical distribution, the ECD is only significant at the 5% level for a period of 2

[13] The sample period is driven by data constraints.

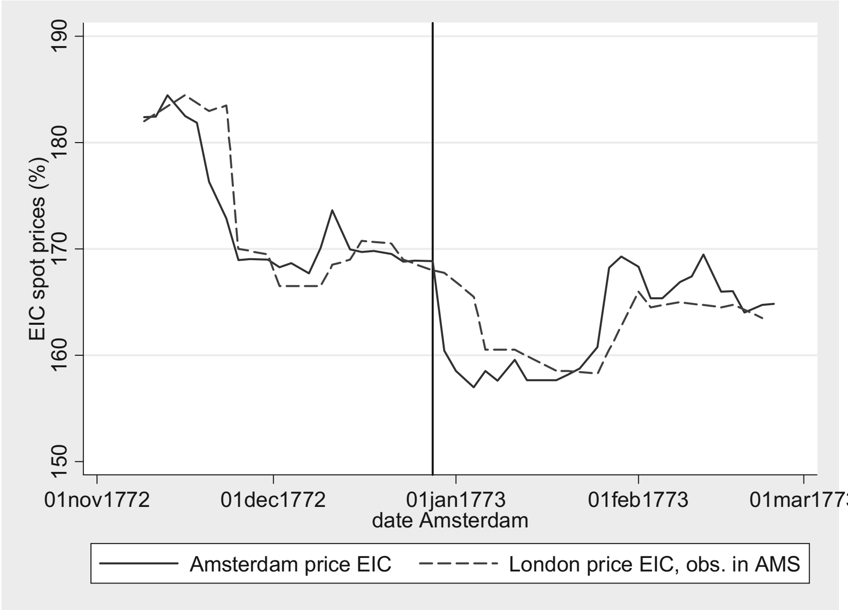
Table 15: Cumulative differences in stock price Amsterdam - London. Fordyce (ECD) vs Full sample (SCD)

Weeks after event	2	4	6	8
		EIC		
ECD	15.51	22.32	23.82	7.45
average SCD	-0.76	-1.56	-2.28	-3.12
P-value (t-test)	0.016	0.022	0.056	0.260
P-value (empirical)	0.018	0.019	0.063	0.230
		BoE		
ECD	9.79	13.62	20.25	19.31
average SCD	-0.23	-0.57	-0.68	-1.14
P-value (t-test)	0.016	0.041	0.031	0.089
P-value (empirical)	0.034	0.069	0.084	0.082
		Ann 3%		
ECD	0.52	0.53	0.53	-0.60
average SCD	-0.85	-1.72	-2.55	-3.45
P-value (t-test)	0.217	0.240	0.224	0.257
P-value (empirical)	0.212	0.269	0.238	0.246

ECD stands for Event Cumulative Differences. These are the accumulated differences between the stock price series in Amsterdam and London (as observed in Amsterdam) for periods of 2, 4, 6 or 8 weeks. The SCD are the Sample Cumulative Differences which are calculated for similar of 2, 4, 6 or 8 weeks over the entire sample between September 1771 - December 1777.

P-values for the null hypothesis that the ECD equals the SCD are calculated in two different ways. First of all, a standard t-test is performed. Secondly, a empirical p-value is calculated following Barber, Lyon and Tsai (1999). We draw (with replacement) 1000 random periods of the length of 2, 4, 6 or 8 weeks between September 1771 and December 1777. Based on these 1000 random periods we construct a distribution of Cumulative Differences and check at what percentile the ECD is. This gives us the empirical p-value.

Figure 21: EIC prices in Amsterdam around Clifford et al.'s default



weeks. For periods of 4 and 6 weeks we detect statistical significance at the 10% level. For the 3% Annuities cumulative differences are not significant at any horizon.

Figures 21 and 22 present the developments of EIC and BoE stock prices in Amsterdam and London around December 28, 1772. The figure shows that after the defaults Amsterdam prices of both EIC and BoE stock fell considerably under those in London. This situation continued for three weeks for both stocks. As in the Fordyce case, prices in Amsterdam deviated considerably from those in London. Looking at price differences for the 3% Annuities in figure 23 we also observe some divergence between Amsterdam and London. However the resulting price difference is quite small.

Table 16 tests whether the cumulative differences between Amsterdam and London prices are statistically significant. The procedure is the same as in table 15. The table shows that the cumulative price differences between Amsterdam and London for EIC stock are consistently large and negative and for periods of 2 and 4 weeks they are highly statistically significant at the 1% level. The ECD for BoE stock over a period of 2 weeks is also statistically significant at the 1% level. The ECD for BoE stock over a period of 4 weeks is significant at the 5% (t-distribution) or 10% (empirical distribution) level. The price difference of the 3% Annuities is slightly significant at the 10% level for the initial period of 2 weeks, but insignificant over longer horizons. This suggests that the

Figure 22: BoE prices in Amsterdam around Clifford et al.'s default

Figure 23: Ann 3% prices in Amsterdam around Clifford et al.'s default

shock of the consortium's default mainly had an impact on the Amsterdam prices of EIC and BoE stock, and to a lesser degree affected the price of the 3% Annuities.

Table 16: Cumulative differences in stock price Amsterdam - London. Clifford et al. default (ECD) vs Full sample (SCD)

Weeks after event	2	4	6	8
EIC				
ECD	-29.14	-36.72	-13.67	-2.86
SCD	-0.76	-1.56	-2.28	-3.12
P-value (t-test)	0.000	0.000	0.234	0.486
P-value (empirical)	0.003	0.003	0.208	0.487
BoE				
ECD	-10.78	-12.64	-8.69	-8.34
SCD	-0.23	-0.57	-0.68	-1.14
P-value (t-test)	0.007	0.059	0.238	0.292
P-value (empirical)	0.019	0.051	0.225	0.294
Ann 3%				
ECD	-3.89	-4.26	-1.76	-0.76
SCD	-0.85	-1.72	-2.55	-3.45
P-value (t-test)	0.054	0.193	0.596	0.702
P-value (empirical)	0.068	0.163	0.570	0.705

See explanation in table 15

To sum up, the two events had an economically and statistically significant impact on stock prices in Amsterdam. Price differences with London increased and remained high for a number of weeks after the events. In the next section we will discuss to what extent these price patterns are related to the actual actions of the distressed agents.

3.3.2 Direction of news

In this analysis we make the assumption that events in Amsterdam have no impact on prices in London. Under this assumption we can identify the impact of the two shocks on Amsterdam prices. If this assumption does not hold, and events in Amsterdam do have an impact on London, our identification strategy would break down. In that case, our London benchmark would just reflect a non-updated price and would therefore be less relevant.

The first thing to note is that over the entire sample of 1771 – 1777 there is compelling evidence that relevant information originated in London and not in Amsterdam (see the results in chapter 1). However, it is possible that, during the two of periods of financial distress that we analyze, events in Amsterdam did have an impact on London. The number of price observations available during the two episodes is too small to test this statistically. We therefore move to eye-ball econometrics. In figures 28, 29, 30, and 31 (Appendix B) we present EIC and BoE stock prices in London around the two events, and the Amsterdam stock prices as they were observed in London.[14] If events in Amsterdam have an impact on London, we should observe this through a reaction of London prices to observed Amsterdam prices. This does not seem to be the case. London prices do not respond to Amsterdam.

3.3.3 Arbitrage and interpretation

How should we interpret these results? If the cumulative difference between Amsterdam and London stock prices is significant over a period of x weeks, what does this mean exactly? Suppose that no arbitrage whatsoever could take place between Amsterdam and London. In that case we could interpret the two events we study as two local shocks, specific to the Amsterdam market. As these shocks dissipate over time their effect on prices disappears. Prices in Amsterdam move back to the equilibrium levels observed in London. The time it takes for this to happen would tell us how long it takes the Amsterdam market to fully absorb the shock.

However, from qualitative evidence (see for example in the next section) we know that arbitrage between Amsterdam and London was very well possible. If market participants used these arbitrage opportunities, Amsterdam prices would move back to London prices much quicker than the time it took for the shock to dissipate. This means that the time it takes for the price in Amsterdam to move back to the London price is actually a lower bound estimate of the time it takes for the Amsterdam market to absorb the shock. Rather what we measure is the time it takes before arbitrage opportunities between Amsterdam and London disappear.

[14] To determine the Amsterdam price as it was observed in London we use information on the departure of mail packet boats from Hellevoetsluys to Harwich from the *Rotterdamsche Courant*. We use the average sailing time to determine on what day what news must have arrived in London.

3.4 Trading patterns

3.4.1 Alexander Fordyce and Hope & Co

In what way did Hope & Co. settle the short position in EIC and BoE stock that they effectively inherited from Alexander Fordyce' bankrupt estate? The easiest way to settle was by buying off-setting long positions in the future market with the same expiration date of August 15, 1772. As we explained before, Hope had a clear incentive to do this as quickly as possible as they alone were responsible for the downside, while the upside had to be shared with all the other creditors of Fordyce' estate. Did they indeed settle immediately after June 12? The available evidence shows that, even though stock prices in Amsterdam responded immediately, Hope actually waited a few weeks before it finally settled the positions.

In Hope's letter to Alexander Fordyce of October 16, 1772 they had mentioned that "the general knowledge of our having been sellers to [for] you, raised the expectation of a very important rise, on the supposition that we should immediately buy it in again." In addition they indicated that

> "[this] left us the prospect and apprehension of a very great deficiency. But by delaying a few weeks and waiting the occasion of sellers, we gradually realized the whole of the India Stock and Bank without loss, and soon to a small profit".

To which they added that "you may easily conceive with a pernicious effect would have attended a timid and hasty realization of such a large amount" (SAA 735, 1510). In other words, when Hope tried to buy English stocks to settle the existing short positions, they faced serious buying pressure in Amsterdam. As a consequence they delayed the purchases by a few weeks and these were exectuted in a gradual way.

The specifics can be reconstructed from a number of archival sources.[15] £ 47,000 of the total short position of £ 57,000 EIC stock was indeed settled in the Amsterdam future market by buying offsetting futures expiring on August 15, 1772. It is unknown at what dates this was done exactly. However, we do know that the average price at

[15] Hope's *Grootboeken* and *Journalen* (general and day to day accounting books) (SAA 735, 894 and 1155), Alexander Fordyce' stock account with Hope (Stock Account Fordyce, SAA 735, 1510) and the court proceedings after Fordyce' default (Court Proceedings Fordyce's Default, SAA 735, 1510).

which the future purchases were made was 225.36% of nominal value. The price of EIC stock only fell below 226% after July 3 (see figure 18). So this must imply that Hope indeed waited a number of weeks before it actually made any purchases.

Hope also settled £ 10,000 of Fordyce's position in London. We know the exact dates of these transactions: they took place between July 17 and July 30, with most purchases transacted on July 17 and July 28. This is between a month and a month-and-a-half after Fordyce' default.

The reason for transacting in the English market was that "the price in London was under ours"(SAA 735, 1510). In other words, Hope tried to actively arbitrage between Amsterdam and London. A closer look at the details of these transactions reveal why this type of arbitrage between Amsterdam could be troublesome, even for a sophisticated investor with good connections in London like Hope & Co.[16] Figure 24 presents the Amsterdam and London future prices of EIC stock and the London purchases that were made (in this figure both price series are in real time). The figure shows that the first £ 4,500 purchased in London was indeed bought at a time at which the London price was still below that in Amsterdam. However all the remaining transactions took place over a period when London prices were above prices in Amsterdam. A reason for this might have been that Hope's agents in London had limit orders to buy EIC stock.[17] When the stock price in London fell, they immediately bought the stocks, not yet having received the news that prices in Amsterdam had fallen even further.

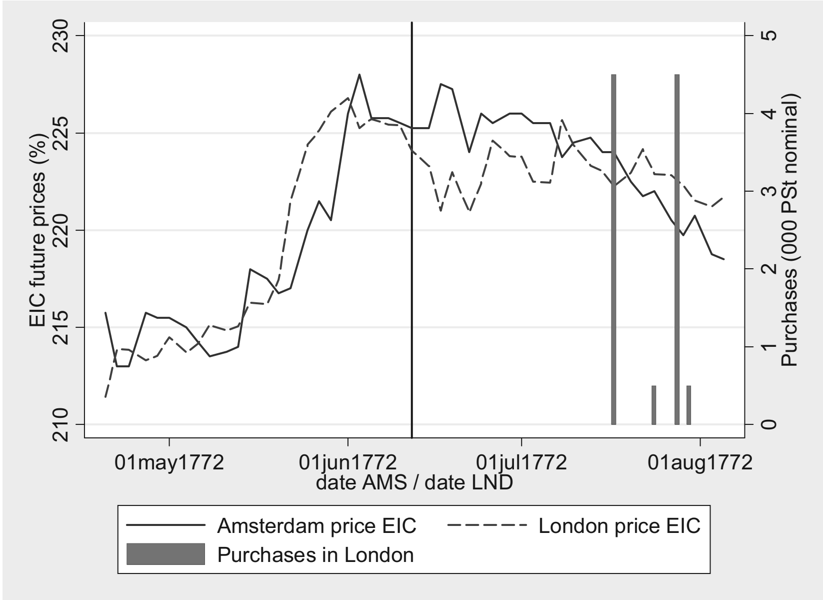
Problems of this sort might explain why Hope did not settle the entire position in London. Another reason may have been that a developed futures market in London was missing. Hope was therefore forced to buy in the spot market. This implied that they had to sell this position again around August 15, to avoid any additional risks.[18] Using spot transactions instead of forward transactions meant a significant capital outlay,

[16] Hope's agent in London was the banking house Gurnell, Hoare and Harman, SAA 735, 115 and 1510.

[17] In the rule, Dutch investors wishing to trade in the London marker used "limitte" orders, see for example NA, Staal van Piershil, 356 and GAR, 199, 5.

[18] After the introduction of Barnard's act in 1734 derivative trading in London was officially banned. There is an ongoing debate about whether these official regulations indeed stopped the derivative trade from taking place (Neal 1990, Harrison 2003). In the Dutch archives there are some indications that people in London could engage in future transactions (NA, Staal van Piershil, 379). However, this market seems to have been quite thin and market participants frequently used the futures market in Amsterdam to get future positions (SAA, 735, 894, 895, 1155, and 1166 ; NA, Staal van Piershil, 379; OSA, 3710).

Figure 24: Hope's purchases of EIC stock in London, July 1772



which had to be borrowed or, if financed with own capital, implied a opportunity cost. Secondly, settling through spot transactions implies that a stock has to be transacted twice. At both instances there is a risk that the market moves against the seller or buyer. Finally, there were additional transaction costs involved with transacting twice in London which in total amounted to 1.7% of nominal value (instead of 0.625% of transacting once in Amsterdam).[19]

Finally, the short position in £. 22,000 BoE stock that was outstanding was not settled before the future contract expired. It was only settled around the expiration date of August 15 at a price of 148%. So this risky position was left on Hope's books for over 2 months.

To sum up, both short positions (£. 57,000 EIC and £. 22,000 BoE stock) were only settled after a delay of between 3 weeks and 2 months, even though Hope faced considerable downside risk and no upside. Only £. 10,000 EIC stock was settled in London. Due to various problems this was not a success either and Hope hardly benefited from higher prices in London.

[19]In the bankruptcy proceedings after Fordyce' default we find complaints about this. It was even argued that Hope should pay "the extraordinary expenses of making purchases and delivering the £. 10,000 India stock in London" out of their own pocket, since "the stock could have been purchased with less expense, as for instance in Holland" (SAA, 735, 1510).

3.4.2 Clifford and Sons and brothers Van Seppenwolde

In a similar way we reconstruct the trading activity after the default of Clifford and Sons and the brothers Van Seppenwolde. As we explained, the lenders of the repo contracts had every reason and right to sell the English stocks that were surrendered as collateral as quickly as they could. Just as with Hope & Co., they only faced downside risk and no upside at all.

From the records of notary Van den Brink we can reconstruct the dates at which "insinuaties" or official reminders of margin calls were made against the consortium. In addition, there is data available on the dates at which the collateral was actually sold (SAA, 5075, 10,593 – 10,613). This information is presented in figures 25 (EIC stock) and 26 (BoE stock). The first thing to note is that there is a strong correlation between the divergence of stock prices in London and Amsterdam and the timing of margin calls. Prices in the Amsterdam market responded instantaneously to the degree of distress in the market. This is the case for both EIC and BoE stock. The second thing to note is that there is a disconnect between mispricing and margin calls on the one hand and actual transactions on the other. Most sales were postponed to a later period in time. Very little transactions in EIC stock actually took place during the period for which we can identify a significant divergence between the Amsterdam and London price.[20] Within the time frame of figure 26 literally no transaction in BoE stock took place. The first sale that we find was on May 17, 1773 (for £. 15,000).

In addition to this quantitative evidence, we found a number of accounts detailing how certain lenders liquidated the collateral that was surrendered to them after the default of the consortium. The first example comes from the archives of the Rotterdam Society for Insurance, Discounting and Securitized Lending (Maatschappij van Assurantie, Discontering en Beleening der Stad Rotterdam). The Society had lent f. 57,000 and f. 38,000 guilders to Hermanus and Johannes van Seppenwolde on the security of EIC stock, which amounted to £ 3,400 and £ 2,400 respectively. Both contracts had stipulated that if the EIC stock price would fall below 170%, additional collateral had

[20] Some of these transactions actually took place in the Amsterdam futures market, possibly to avoid serious price pressure in the spot market. The estate of the deceased Dionis Muilman for example settled a position of £. 1,000 this way on January 28, SAA, 5075, 10,605.

Figure 25: EIC prices, margin calls and sales around Clifford et al.'s default

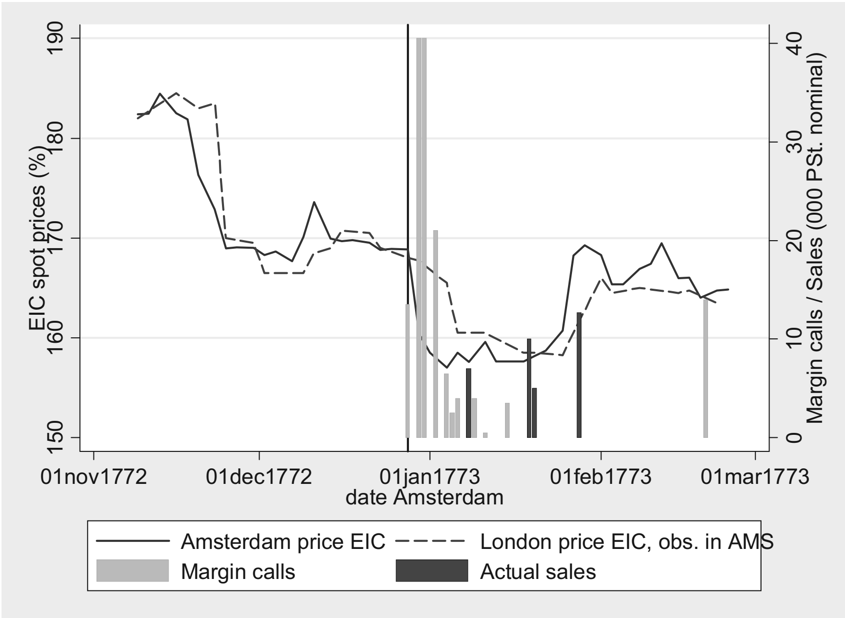
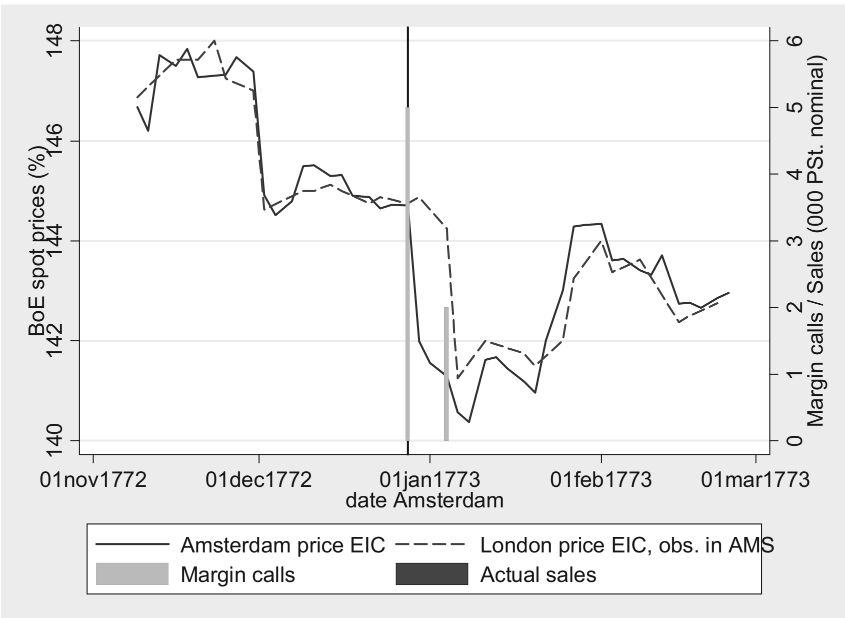


Figure 26: BoE prices, margin calls and sales around Clifford et al.'s default



to be provided. When the Van Seppenwoldes were unable to fulfill this requirement in January 1773, the Society had the right to liquidate the entire collateral. In addition, the margins on the repo agreements were sufficient to cover the loan amount and liquidation would have been loss-free. However, in the end the Society decided to liquidate only half of the Van Seppenwoldes' position. Initially, this was sufficient to cover the margin on the remaining repos that were based on EIC stock amounting to £ 1,700 and £ 1,200 respectively.

In March 1773 the Society decided to roll over the repo contracts for an additional year. Ex post this was not a wise decision. After March 1773 the EIC stock price kept falling. The margins implicit in the repo agreements with the brothers Van Seppenwolde evaporated before the Society could sell the remaining collateral. The Society did not want to liquidate the positions when they were under water and it continuously rolled over the repo agreements. It would take until 1778 before the Society finally decided to liquidate the positions, which they did at a small profit (OSA 4583; GAR 199, 5, 40).

The second example comes from the archives of Widow Meerman, a rich member of the Dutch elite. She had lent an amount of f. 100,000 guilders to Johannes van Seppenwolde on the collateral of £ 6,000 India stock. The repo contract was to expire on February 15, 1773. On that day the EIC price was 166%. Widow Meerman could have forced Van Seppenwolde to repay the loan, but at this time Van Seppenwolde would most likely have been unable to accommodate this. This left her two options: either sell the collateral, which at a price of 166% would have more than covered the amount loan. Alternatively she could have agreed with renewing the position.

She chose the latter. This is all the more remarkable since the conditions of this prolongation were riskier to her than before. The contract expiring on February 15, 1773 stipulated that below 170% Van Seppenwolde had to supply additional margin. However, Van Seppenwolde never paid up and he succeeded in renewing the contract without this stipulation. In other words, Van Seppenwolde succeeded in effectively lowering the haircut on the contract.[21] Ex post, it was not a great decision and it took until July 15, 1774 before everything was finally settled (NA, Staal van Piershil, 379,

[21] This is quite striking as haircuts on new repo contracts increased dramatically in the beginning of 1773, see figure 27.

386).[22]

The third example involves the City of Rotterdam that had lent Hermanus van Seppenwolde f. 300,000 guilders on collateral of £ 21,000 BoE stock (OSA 3710). This repo contract ended on Feb 1, 1773. Van Seppenwolde wanted to roll over the repo contract but the City refused. When Van Seppenwolde did not manage to repay the loan on Feb 1, the City of Rotterdam ordered the BoE stock to be sold. They decided to do this in London. However doing so was not easy. Their agents in London, Gerard and Joshua van der Neck, were worried that "the sale of such a considerable position in the spot market cannot take place without markedly depressing the price" (OSA 3710).[23] The Van der Necks did manage to sell £ 13,000 in the London spot market on February 6 and Febuary 8, but because of the serious price pressure £ 8,000 was sold through the Amsterdam futures markets.

In these first two examples the lenders chose to actively accommodate the Van Seppenwoldes. The Rotterdam Society only liquidated half of the collateral and Widow Meerman even settled on a new contract that provided her with a smaller margin than she had negotiated before. Apparently there was great reluctance to liquidate the collateral. An important reason behind this could have been that market conditions in the beginning of 1773 were far from favorable. Reports in Dutch periodical *De Koopman* indicate that selling collateral in the beginning of 1773 was not an easy task. One commentator argued that new repo agreements were very costly to obtain.[24] In addition, he argued that if stock was to be sold directly, this would be at a big discount (*De Koopman*, 1773, pp. 395, March 3, 1773).[25] Another commentator argued that there

[22] As EIC prices kept falling in the first half if 1773, the repo contract with Van Seppenwolde threatened to go under water. Again, instead of liquidating the position on the premise that Van Seppenwolde had supplied insufficient margins, she chose to settle amicably. They agreed that Van Seppenwolde would take over the EIC stocks at a price a 151% (a price at which the loan could more or less be recovered, including a small margin). Van Seppenwolde would then take the responsibility of selling the position. (Archival evidence indicates that he tried to settle another position of £ 7,000 EIC in the same way.) He managed to do so for the first £ 3,000, which he bought from Meerman on October 15. However by the time he was to take up the remaining £ 3,000, the EIC stock price has fallen below 151%. Since the bankrupt Van Seppenwolde did not have the cash to make up the difference he refused to fulfill his side of the transaction. It would take until July 15, 1774 before the EIC had risen sufficiently above 151% before Van Seppenwolde liquidated the final £ 3,000.

[23] "Dog dewijl den verkoop van soo een aensienelijke somme als L. 21,000 Bank Actiën niet wel voor Contant geld kan geschieden sonder de prijs merkelijk te drukken, zullen wij genoodzaakt zijn, soo niet het geheel, een goed gedeelte voor de naebijsijnde rescontres te verkoopen, die heeden aght dagen van Holland afkoomen & hier circa den 24 a 25e deeser worden geliquideert"

[24] Quantitative evidence of this will be provided in figure 27.

[25] "Veelen wilden niet beleenen als tot een schreeuwenden interest, andere weigerden het in het geheel, maar wilden wel half te geef koopen"

was sufficient capital available to accommodate trading demands but that market participants did not want to burn their fingers (*De Koopman* 1773, pp. 396-397, March 3, 1773). Under these conditions it may have seemed optimal to delay liquidating the asset and to keep the responsibility of liquidating the collateral with the main stake holders, the brothers Van Seppenwolde.

In this third example, the collateral was immediately liquidated. However, the sources indicate that doing so without seriously depressing the price was not an easy task. Interestingly enough, the largest part of liquidation from the third example took place in London. The information from notary Van den Brink (SAA, 5075, 10,593 – 10,613) suggests that this was an exception. All transactions recorded by Van de Brink took place in Amsterdam through the intermediation of well-known Amsterdam brokers. Widow Meerman of the second example even explicitly indicated that she wished to settle everything in the Netherlands (NA, Staal van Piershil, 379, 386).

To sum up, the positions in EIC and BoE stock that were seized after the defaults of the brothers Van Seppenwolde and Clifford and Sons, were mostly sold with a delay and in a gradual way. Because of the price impact it was difficult to liquidate these positions right away. Most of the transactions actually took place outside of the period for which we observe significant price differences between Amsterdam and London. This confirms the view from the Fordyce case that there was a disconnect between the timing of the distress, the reaction of stock prices in Amsterdam (immediate) and the settlement of positions (delayed).

3.5 Optimal delay?

What can explain this disconnect between price impact and actual transactions? In the first part of this section we review some of the evidence that we uncovered from the historical sources. We show that surrounding both events there was significant uncertainty about the exact size of the distressed shock. Hope & Co actually motivated their delayed trading by pointing to this uncertainty. The market seems to have taken seriously into account that the size of the shock was so big, that it would significantly affect prices in the near future. As a result prices responded dramatically, and it became very costly for distressed agents to trade. This markedly reduced the amount of trading they were willing to do.

In the second part of this section we formally model this mechanism in a rational expectations setting and we show that the model can generate the disconnect that we find in the data between the timing of distress and the resulting mispricing on the one hand, and the timing of actual transactions on the other. This model uses the framework of Kyle (1989) and it is directly related to the work by Vayanos (1999; 2001).[26]

3.5.1 Historical evidence

In its letter to Alexander Fordyce dated October 16, 1772, Hope & Co. explained the reasons for why they had waited a few weeks before they finally settled Fordyce' position.

> "The general knowledge of our having been sellers to [for] you, and the report of its being for at least 5 times the [true] amount, which was industriously propagated, raised the expectation of a very important rise" (SA, 735, 1510).

In other words, the market thought that Fordyce' short position was a lot larger than it actually was. Even if this was an exaggeration on the part of Hope, it does suggest that, at least, there was uncertainty in the market about the size of Fordyce' position that was held by Hope.

This statement is corroborated by other sources. The quote from the *Middlesex Journal* on June 13, 1772 on page 100 states that Alexander Fordyce held a short position of "a million and a half of India stocks". This is a lot more than it actually was. With a stock price of 225% this translates into a nominal value of £ 666,666 which is almost 12 times as much as Fordyce' actual position. Again, even if this was an exaggeration it does suggests that there was uncertainty in the market about Fordyce' position.

What do the events of January 1773 tell us? In the Dutch periodical *De Koopman* we find similar evidence that market participants thought that a large long position

[26] Vayanos develops two infinite horizon models in which endowment shocks are private information. His models are very similar to our framework. Our work differs in two respects. First of all, we look at a very simple 3 period setting where consumption only takes place in the third period, instead of every period. Secondly, we constrain the behavior of the distressed agent so that he can only trade in the first two periods (compare Admati and Pfleiderer 1988).

was hanging over the market. Although we are not sure what the entire position of the consortium was (remember that the information from table 14 is only based on the information from notary Van den Brink only), these estimates, again, seem to be far too large. More importantly, they are not consistent with each other. This implies that there was great uncertainty about the size of the shock.

On December 29, 1772, only one day after the consortium finally failed to meet its obligations, *De Koopman* suggested that the total outstanding position in the English stocks may have amounted to about f. 40 million guilders. This translates into a position of EIC stock of £ 2 million nominal and a position of BoE stock of £ 0.5 million nominal.[27] If this were true it must have been the case that the consortium only handled 10% of their repos through notary Van den Brink; 90% must have been handled through different notaries. Casual investigation of other notary archives suggest that this can never have been the case.

Less than a week later, on January 3, 1773, it was suggested that f. 3.3 million guilders had already been paid to fulfill the margin requirements of the securitized loans, which probably referred to earlier margin calls (*De Koopman* 1772, p. 310).[28] These margin calls must have been based on repos for EIC stock and this translates into an EIC stock position of £ 1 million nominal.[29] Again this seems to be an exaggeration. Most importantly, it is half of which was reported in the same periodical less than a week before. This suggests that there was great uncertainty about the size of the shock.

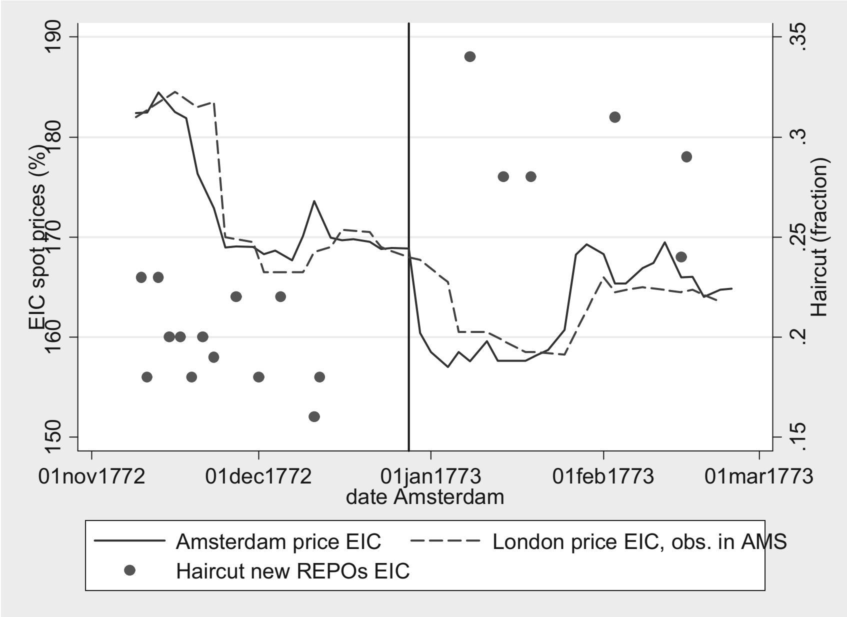
There is additional evidence supporting this view. Figure 27 presents the EIC stock price in Amsterdam and London and the haircuts implicit in the new repo contracts that were signed. The figure clearly shows that after the consortium's default, repo haircuts increased dramatically from about 20% to 30%. By March 1773 they returned to normal levels of 20% again. This is consistent with uncertainty about the size of

[27] De Koopman 1772, p. 295. Suppose that people thought that the position of the consortium in EIC stock was 4 times as big as the position in BoE stock, just as in table 14. Using Amsterdam prices for December 29, we arrive at these figures.

[28] "Men spreekt van 33 tonnen aan rescontres [afrekeningen] van één die al betaald zijn en van nog ongelijk meer die nog moeten volgen en betaald worden."

[29] In the second half of 1772 no additional margin was put up for repos in BoE stock. Most of the original repo contracts for EIC stock had stipulated a critical stock price of 200% below which additional margin or collateral had to be paid up and the consortium had managed to pay up additional margin (at 10%) three times for the price falls below 200%, 190% and 180%. With margin payments of 3.3 million guilders, this suggests that the total outstanding EIC stock amounted to 11 million guilders nominal, which is approximately £ 1 million.

Figure 27: EIC prices and REPO haircuts around Clifford et al.'s default



the consortium's position. If this turned out to be bigger than expected, the EIC stock could fall even further than it had already done. As a result additional margins were demanded. Over time, possibly when more precise information about the size of the shock was revealed, repo haircuts fell towards normal levels.

3.5.2 Model

The setup of the model is summarized in table 17. There is a single risky asset and a risk-free savings technology for which we normalize the interest rate to zero. The model features three periods. The terminal value of the risky asset in $t = 3$ is given by

$$v = v_0 + \eta + \varepsilon$$

η and ε are i.i.d. normally distributed disturbances with zero mean and variances σ_η^2 and σ_ε^2, i.e. $\eta; \varepsilon \sim N\left(0, \sigma_\eta^2; \sigma_\varepsilon^2\right)$. η is realized in $t = 2$ and ε is realized in $t = 3$.

Central to the model is a distressed agent, who receives an endowment w in the asset at the start of period $t = 1$. This endowment is privately observed. w is the realization of a normally distributed random process with zero mean and variance σ_w^2, i.e. $w \sim N\left(0, \sigma_w^2\right)$. The distressed agent must trade away its entire endowment over periods $t = 1$ and $t = 2$. There are no further constraints on the distressed agent's trading activity, which are indicated by x_1 and x_2.

In the first period a mass M^A of infinitely small liquidity providers are present, with whom the distressed agent can engage in risk sharing. These type A liquidity providers remain in the model throughout and are joined by an additional mass of infinitely small liquidity providers M^B in $t = 2$. The type A agents absorbs all trading demands in $t = 1$ and can off-load some of this in $t = 2$ onto the new batch of type B liquidity providers. Trading activity by the liquidity providers in $t = 1$ is indicated by y_1^A; trading activity in $t = 2$ by y_2^A and y_2^B. By the end of $t = 2$ the entire free float of the risky asset must be in the hands of the liquidity providers. We assume that $M^A > 0$ and $M^B \geq 0$.

Both the distressed agent and the liquidity providers have exponential utility functions with CARA A. We assume that the risk bearing capacity of liquidity providers in $t = 2$ is sufficiently large, i.e.

$$M^A + M^B \geq A\left(\sigma_\eta^2 + \sigma_\varepsilon^2\right) \tag{65}$$

In $t = 1$ there is an additional noise trading shock, $u \sim N\left(0, \sigma_u^2\right)$. We show in Appendix A that as a result, the equilibrium price in $t = 1$ will never fully reveal the realization of w. This is a crucial element of the model. It implies that the liquidity providers of type A face uncertainty about p_2, the equilibrium price in $t = 2$. In this period, the type A agents expect to off-load some the position they have absorbed in $t = 1$ onto the type B liquidity providers. If the price at which they can do this is uncertain, they effectively have to hold additional risk. This makes liquidity provision in $t = 1$ extra costly. This is the key friction that we will analyze in the remainder of this section.

Table 17: Setup of the model

time	$\mathbf{t = 1}$	$\mathbf{t = 2}$	$\mathbf{t = 3}$
liquidity providers	mass M^A	mass $M^A + M^B$	
risk	risks η, ε	η realizes	ε realizes
distressed trades	x_1	$x_2 = -(w + x_1)$	
noise trading	u	0	
liquidity provision	$M^A y_1^A = -(x_1 + u)$	$M^A y_2^A + M^B y_2^B = -x_2$	

Markets clear through a Walrasian auctioneer. This means that the distressed agent and the liquidity providers submit demand schedules to a central auctioneer who then sets prices so that markets clear. The distressed agent is relatively large with respect to the market as a whole and will take the impact of his own trading activity on equilibrium prices into consideration. The type A and B liquidity providers are all infinitely small and are price takers.

The distressed agent wants to minimize trading costs, or, equivalently, maximize the proceeds from liquidating its position. The liquidity providers act competitively and submit trading demands such that they are compensated for taking on the associated risks.

Proposition 10 *A linear Rational Expectations Equilibrium exists in which the actions of the distressed agent and the liquidity providers are jointly optimal and in which the equilibrium in $t = 1$ will only partially reveal the distressed's endowment w and noise trading shock u.*

Let $q = w - u$, $\overline{q} = E[w - u \mid p_1]$, and $\sigma_q^2 = var[w - u \mid p_1]$

Optimal demands are given by

$$x_1 = -\overline{\alpha_2} w + \overline{\alpha_3} u \tag{66}$$

$$x_2 = -(w + x_1) \tag{67}$$

$$y_1^A = \overline{\gamma_1} w - \overline{\gamma_2} u \tag{68}$$

$$y_2^A = \frac{q}{M^A + M^B} - y_1^A \tag{69}$$

$$y_2^B = \frac{q}{M^A + M^B} \tag{70}$$

And equilibrium prices are given by

$$p_1 = v_0 - \delta_1 w + \delta_2 u \tag{71}$$

$$p_2 = v_0 + \eta - \frac{q}{M^A + M^B} A \sigma_\varepsilon^2 \tag{72}$$

Where

$$\overline{\alpha_2} = \frac{A\sigma_\varepsilon^2 + (M_A + M_B)\,A\sigma_\eta^2}{(M_A + M_B)\left(2\lambda_1 + A\sigma_\eta^2\right)} \tag{73}$$

$$\overline{\alpha_3} = \frac{A\sigma_\varepsilon^2 - \lambda_1 (M_A + M_B)}{(M_A + M_B)\left(2\lambda_1 + A\sigma_\eta^2\right)} \tag{74}$$

$$\overline{\gamma_1} = \frac{\overline{\alpha_2}}{M_A} \tag{75}$$

$$\overline{\gamma_2} = \frac{1 + \overline{\alpha_3}}{M_A} \tag{76}$$

$$\delta_1 = \lambda_1 M_A \overline{\gamma_1} \tag{77}$$

$$\delta_2 = \lambda_1 M_A \overline{\gamma_2} \tag{78}$$

$$\lambda_1 = \frac{(M_A + M_B)\left(A\sigma_\eta^2 + A\sigma_\varepsilon^2\chi\right)}{M_A\left[M_A + M_B - A\sigma_\varepsilon^2 (1-\chi)\,\rho_{w-u}\right]} \tag{79}$$

$$\chi = \frac{A^2\sigma_\varepsilon^2\sigma_q^2}{(M_A + M_B)^2 + A^2\sigma_\varepsilon^2\sigma_q^2} \tag{80}$$

$$\rho_{w-u} = \frac{\delta_1\sigma_w^2 - \delta_2\sigma_u^2}{\delta_1^2\sigma_w^2 + \delta_2^2\sigma_u^2} \tag{81}$$

$$\sigma_q^2 = (1 - \rho_{w-u})\left(\sigma_w^2 + \sigma_u^2\right) \tag{82}$$

Proof. See Appendix A ■

The shape of equilibrium in $t = 2$ is quite standard. By the end of the period, the entire endowment w minus the first period's noise trading shock u are held by the type A and B liquidity providers. These agents are risk averse and act competitively and the expression for price p_2 (72) reflects this.

The equilibrium in $t = 2$ is slightly more complicated. Let's start with the expression for x_1 in (66). The distressed agent off-loads some of his position in $t = 1$. The extent to which he does so is measured by $\overline{\alpha_2} > 0$. The distressed agent also responds to the noise trading shock u.[30]

Expression (68) for y_1^A shows that the type A liquidity providers will absorb both the noise trading trading shock u and the distressed demand x_1. The accommodation of

[30] $\overline{\alpha_3} > 0$. This results form the fact that the distressed agent, based on his observation of shock u, can partly predict p_2 and he will try to benefit from this.

these trading demands is translated into price p_1 according to (71), in which aggregate demand is multiplied by the slope of the aggregate demand curve λ_1.

λ_1 is a critical parameter in this model. It measures the price impact of the distressed's demand, i.e. by how much the equilibrium price will move in response to his trades. As such it measures the trading cost faced by the distressed agent. According to the following lemma, this trading cost is increasing in σ_q^2.

Lemma 11 $\frac{\delta \lambda_1}{\delta \sigma_q^2} > 0$ *if condition (65) is met*

Proof. See Appendix A ■

This is a key result of the model and follows from the fact that the equilibrium in $t = 1$ is not fully revealing about the actual values of w and u. The equilibrium price in $t = 2$ is largely driven by $q = w - u$ (see expression (72)) and the type A liquidity providers care a lot about the exact realization of p_2. As long as $\delta_1 \neq \delta_2$ in $t = 1$, the liquidity providers do not directly observe q (although they do receive a noisy signal about its value through equilibrium price p_1). This means that the realization of price p_2 is uncertain. Consequently, the liquidity providers will demand an additional risk premium for absorbing trading demand in $t = 1$. This additional risk faced by liquidity providers is proportional to σ_q^2. The following two lemmas show how this σ_q^2 affects the equilibrium in $t = 1$.

Lemma 12 $\frac{\delta \overline{\alpha_2}}{\delta \sigma_q^2} < 0$

Proof. See Appendix A ■

This lemma shows that the distressed agent will submit less of his endowment to the market if uncertainty about q increases. His price impact is increasing in σ_q^2, and this makes liquidity provision more expensive.

Lemma 13 $\frac{\delta \delta_1}{\delta \sigma_q^2} > 0$

Proof. See Appendix A ■

This lemma shows that at the same time, the price impact of endowment w is increasing in σ_q^2. Liquidity providers face uncertainty about q and request a larger premium to accommodate liquidity demand. Taken together these lemmas imply that even when the distressed submits **less** of his endowment to the market in $t = 1$, price p_1 responds **more** to the endowment shock. In other words, when σ_q^2 increases, more distressed trade will be postponed to $t = 2$, while the sensitivity of price in $t = 1$ to this distressed trade increases.

To clarify this point, let us start from the situation in which $\sigma_u^2 = 0$ and consequently $\sigma_q^2 = 0$. It can be shown that in this case

$$\begin{aligned} \overline{\alpha_2} &= \frac{M_A}{2 + M_A} \\ \delta_1 &= \frac{A\sigma_\varepsilon^2 (2 + M_A) + A\sigma_\eta^2 (M_A + M_B)}{(M_A + M_B)(2 + M_A)} \end{aligned}$$

The fraction of its endowment w that the distressed agent submits to the market (measured by $\overline{\alpha_2}$) fully depends on the size of mass M_A. Suppose that $M_A = 2$, in that case, the distressed agent will submit half of its endowment in $t = 1$ and the other half in $t = 2$. If we now increase σ_q^2 from zero, Lemma 12 shows that $\overline{\alpha_2}$ will fall. The distressed agent will submit less of his endowment. At the same time we know from Lemma 13 that $\delta_1$will increase, in other words, the price in $t = 1$ becomes more responsive to the distressed agent's endowment. In other words, the degree of mispricing will increase. In the limit, when σ_q^2 approaches ∞, virtually no distressed trading will take place in $t = 1$, while mispricing in this period becomes very big.

To summarize, this model, which features short run uncertainty about the exact size of the distressed's endowment shock, can accommodate a situation in which there is a disconnect between the timing of distress, the price response (immediate) and the distressed's trading activity (delayed).

3.6 Conclusion

In this chapter, we analyse two periods of price overshooting on the Amsterdam stock market in 1772 and 1773. In both cases, news reached the market that a big market participant had to close his position as a result of major losses. We examine the price path of the stocks with respect to London and we document significant overshooting in the short term and an eventual reversal. Because we have access to the actual trading positions of the stricken investors, we can show that overshooting occurred with very little distressed sales actually taking place.

We use a theoretical model related to Vayanos (1999; 2001) to explain these facts. Key to the model is uncertainty about the size of the distressed positions; a feature that is borne out by the historical evidence, most clearly by an increase in repo rates in Januray 1773. This uncertainty effectively increases the risk premium distressed agents have to pay to obtain liquidity. At the same time this increases the price impact of the shock and reduces the amount of trading.

It might be possible to extrapolate these results to more recent events of financial distress. For example, one of the characteristics of the recent financial crisis was the uncertainty about the positions of financial intermediaries in certain assets. It is possible that this uncertainity contributed to the mispricing of these assets (compare Mitchell and Pulvino 2011; Garleanu and Pedersen 2011).

3.7 Appendix A: mathematical proofs

Proof. of proposition 10.

Start in $t = 2$. The distressed agent has to submit $x_2 = -(w + x_1)$. The only optimization problems of interest are those of type A and B liquidity providers. Following the usual trick for exponential utility functions, the optimization problem for a type A agent is given by:

$$\max_{y_2^A} \left(y_1^A + y_2^A\right)\{E_2[v] - p_2\} - \frac{A}{2}\left(y_1^A + y_2^A\right)^2 var_2[v]$$

When we substitute $E_2[v] = v_0 + \eta$ and $var_2[v] = \sigma_\varepsilon^2$ this results in

$$y_2^A = \frac{v_0 + \eta - p_2}{A\sigma_\varepsilon^2} - y_1^A \tag{83}$$

Remember that mass M^B only enter in $t = 2$, so in similar fashion we can write

$$y_2^B = \frac{v_0 + \eta - p_2}{A\sigma_\varepsilon^2} \tag{84}$$

For markets to clear in $t = 1$ and $t = 2$ we must have that

$$x_1 + M^A y_1^A + u = 0 \tag{85}$$

$$x_2 + M^A y_2^A + M^B y_2^B = 0 \tag{86}$$

Let $q = w - u$. Plugging (67), (83), (84) and (85) into (86) we obtain expressions (69), (70) and (72).

Proceed to $t = 1$ and start with the optimization problem of the liquidity providers of type A. The total return to these agents can be written as

$$\Pi^A = \frac{q}{M_A + M_B}(v_0 + \eta + \varepsilon) - p_1 y_1^A - p_2 y_2^A$$

Plugging in (72) and (69) and rewriting we obtain

$$\Pi^A = \frac{q\varepsilon}{M_A + M_B} + \frac{q^2}{(M_A + M_B)^2} A\sigma_\varepsilon^2 + y_1^A \left(\underbrace{v_0 + \eta - \frac{\overline{q}}{M^A + M^B} M_A + M_B}_{p_2} - p_1 \right)$$

Under the assumption that the equilibrium in $t = 1$ is not fully revealing, q will be a random variable with $q \sim N\left(\overline{q}, \sigma_q^2\right)$. This means that Π^A includes three random variables (η, ε, and q), with a square of random variable q and an interaction between random variables ε and q. Consequently the usual trick for exponential utility functions cannot be used. Instead we repeatedly apply the Law of Iterated Expectations (using the fact that η, ε, u, and w are independent) and the following rule (Holden and Subrahmanyam 1994, Lemma 1):

$$\begin{aligned} \text{Let } Z &\sim N\left(0, \sigma_Z^2\right). \text{ In that case} \\ E\left[\exp\left(aZ^2 + bZ\right)\right] &= \exp\left(\frac{b^2\sigma_Z^2}{2\left(1 - 2a\sigma_Z^2\right)}\right)\sqrt{\frac{1}{1 - 2a\sigma_Z^2}} \end{aligned}$$

We arrive at the following optimization problem

$$\max_{y_1^A} EU\left[\Pi^A\right] = \max_{y_1^A} \left[\begin{array}{c} \overline{q}^2 \frac{A\sigma_\varepsilon^2}{2(M_A+M_B)^2} - \overline{q}\frac{A\sigma_\varepsilon^2}{M_A+M_B} y_1^A - \frac{A}{2}\left(y_1^A\right)^2 \sigma_\eta^2 + y_1^A (v_0 - p_1) \\ -\frac{A}{2}\left(A\sigma_\varepsilon^2\right)^2 \left(y_1^A - \frac{\overline{q}}{M_A+M_B}\right)^2 \sigma_q^2 \left[(M_A + M_B)^2 + A^2\sigma_\varepsilon^2\sigma_q^2\right]^{-1} \end{array} \right]$$

which results in the optimal demand schedule

$$y_1^A = \beta_1 (v_0 - p_1) - \beta_2 \frac{\overline{q}}{M_A + M_B} \tag{87}$$

where

$$\beta_1 = \frac{1}{A\sigma_\eta^2 + A\sigma_\varepsilon^2 \chi} \tag{88}$$

$$\beta_2 = \frac{A\sigma_\varepsilon^2 (1 - \chi)}{A\sigma_\eta^2 + A\sigma_\varepsilon^2 \chi} \tag{89}$$

and where χ is given by (80).

From the perspective of the type A liquidity providers the equilibrium in $t = 1$ is partially revealing. This is only the case if $\delta_1 \neq \delta_2$. Later on we will shown that this is indeed the case. What is $E[(w-u) \mid p_1] = E[q \mid p_1]$? First guess the pricing rule in $t = 2$ is as in equilibrium (this will later be confirmed)

$$\widehat{p_1} = v_0 - \delta_1 w + \delta_2 u$$

We can write the signal that the type A agents observe as $v_0 - p_1 = \delta_1 w - \delta_2 u$. Using the usual rules for normally distributed variables we get

$$E[(w-u) \mid p_1] = \rho_{w-u}(v_0 - p_1) \tag{90}$$

where ρ_{w-u} is given by (81). σ_q^2 is given by (82). Plugging in (90) into (87) we obtain expression

$$y_1^A = \overline{\beta}(v_0 - p_1) \tag{91}$$

For now we write

$$\overline{\beta} = \beta_1 - \frac{\beta_2 \rho_{w-u}}{M_A + M_B} \tag{92}$$

Now move to the optimization problem of the distressed agent in $t = 1$. The total return to the distressed agent can be written as

$$\Pi^D = (w + x_1) p_2 - x_1 p_1$$

The distressed maximization problem can be written as

$$\max_{x_1} \left\{ (w + x_1) E[p_2] - x_1 p_1 - \frac{A}{2}(w + x_1)^2 \sigma_\eta^2 \right\}$$

where $E[p_2] = v_0 - \frac{q}{M^A + M^B} A \sigma_\varepsilon^2$, with $q = w - u$. Remember that the distressed agent takes his own impact on the equilibrium price into consideration. Because he is forced to liquidate his entire position in $t = 2$, and because p_2 does not depend on a specific mix of x_1 and x_2, he can ignore his price impact in $t = 2$. However, the price impact in $t = 1$ does matter crucially. Guess (this guess will later be confirmed) that from the perspective of the distressed $t = 1$ prices can be written as

$$p_1 = \widetilde{p_1} + \lambda x_1$$

where λ measures the price impact of trade x_1. Plugging this into the maximization problem we arrive at the following optimal demand schedule in $t = 1$

$$x_1 = \alpha_1 (v_0 - p_1) - \alpha_2 w + \alpha_3 u \tag{93}$$

with

$$\alpha_1 = \frac{1}{\lambda_1 + A\sigma_\eta^2} \tag{94}$$

$$\alpha_2 = \frac{A\sigma_\varepsilon^2 + (M_A + M_B)\, A\sigma_\eta^2}{(M_A + M_B)\left(\lambda_1 + A\sigma_\eta^2\right)} \tag{95}$$

$$\alpha_3 = \frac{A\sigma_\varepsilon^2}{(M_A + M_B)\left(\lambda_1 + A\sigma_\eta^2\right)} \tag{96}$$

We can now calculate the equilibrium in $t = 1$. Plugging in (93) and (87) into (85) we arrive at expression (72). For now we write δ_1 and δ_2 as

$$\delta_1 = \frac{\alpha_2}{M^A\overline{\beta} + \alpha_1} \tag{97}$$

$$\delta_2 = \frac{1 + \alpha_3}{M^A\overline{\beta} + \alpha_1} \tag{98}$$

Using the equilibrium price in $t = 1$ we can calculate the equilibrium demands of the distressed and type A agents.

Before doing so, two crucial elements are still missing: the derivation of λ_1 and proof that $\delta_1 \neq \delta_2$. Write market clearing in $t = 1$ from the perspective of the distressed:

$$x_1 + M^A \underbrace{\overline{\beta}(v_0 - p_1)}_{y_1^A} + u = 0$$

This can be rewritten as

$$p_1 = \underbrace{v_0 - \frac{u}{M^A\overline{\beta}}}_{\widetilde{p}_1} + \underbrace{\frac{1}{M^A\overline{\beta}}}_{\lambda_1} x_1$$

This means that

$$\lambda_1 = \frac{1}{M^A\overline{\beta}} \tag{99}$$

Plugging in for (92), using (88), and (89), we arrive at expression (79). Also note that

$$\overline{\beta} = \frac{1}{M_A\lambda_1} \tag{100}$$

With this expression for $\overline{\beta}$ in hand we can reformulate expressions (97) and (98) for δ_1 and δ_2 and write them in terms of λ_1. Using (94), (95) and (96) we arrive at

$$\delta_1 = \frac{\lambda_1\left[(M_A + M_B)\, A\sigma_\eta^2 + A\sigma_\varepsilon^2\right]}{(M_A + M_B)\left(2\lambda_1 + A\sigma_\eta^2\right)} \tag{101}$$

$$\delta_2 = \frac{\lambda_1\left[(M_A + M_B)\left(\lambda_1 + A\sigma_\eta^2\right) + A\sigma_\varepsilon^2\right]}{(M_A + M_B)\left(2\lambda_1 + A\sigma_\eta^2\right)} \tag{102}$$

These expressions clearly show that $\delta_1 \neq \delta_2$ if $\lambda_1 > 0$.[31]

We can now calculate the equilibrium demands submitted by the distressed agent and the type A liquidity providers in $t = 1$. Start with the expression for x_1 in (93). Plugging in (71) and using expressions (94), (95), (96), (97), (98) and (100), we arrive at (66), with (73) and (74).

Remember that market clearing in $t = 1$ is given by (85). Plugging in for the equilibrium demand of the distressed agent (66), we arrive at (68) with (75) and (76). Multiplying the the equilibrium liquidity supply (68) with the slope of the aggregate demand curve λ_1 and market capacity M^A, we arrive at the final expressions for δ_1 and δ_2 in (77) and (78). ■

Proof. of Lemma 11.

It can be shown that $\frac{\delta\lambda_1}{\delta\sigma_q^2} > 0$ if $M^A + M^B > A\rho_{w-u}\left(\sigma_\eta^2 + \sigma_\varepsilon^2\right)$. Since $0 < \rho_{w-u} < 1$ this condition is always met if $M^A + M^B > A\left(\sigma_\eta^2 + \sigma_\varepsilon^2\right)$ (see expression (65) on page 124). ■

Proof. of Lemma 12.

$\frac{\delta\delta_1}{\delta\sigma_q^2} = \frac{\delta\delta_1}{\delta\lambda_1}\frac{\delta\lambda_1}{\delta\sigma_q^2}$

From Lemma ... we know that $\frac{\delta\lambda_1}{\delta\sigma_q^2} > 0$ under condition (65). Now look at $\frac{\delta\delta_1}{\delta\lambda_1}$. Using (101) we get that

$$\delta_1 = \frac{A\sigma_\varepsilon^2 + (M^A + M^B)A\sigma_\eta^2}{M^A + M^B}\frac{\lambda_1}{2\lambda_1 + A\sigma_\eta^2}$$

It is easy to show that $\frac{\delta\frac{\lambda_1}{2\lambda_1 + A\sigma_\eta^2}}{\delta\lambda_1} > 0$. ■

Proof. of Lemma 13.

$\frac{\delta\overline{\alpha_2}}{\delta\sigma_q^2} = \frac{\delta\overline{\alpha_2}}{\delta\lambda_1}\frac{\delta\lambda_1}{\delta\sigma_q^2}$

From Lemma ... we know that $\frac{\delta\lambda_1}{\delta\sigma_q^2} > 0$ under condition (65). It is easy to show that $\frac{\delta\overline{\alpha_2}}{\delta\lambda_1} < 0$. ■

3.8 Appendix B: direction of news

[31] In the case that $\lambda_1 = 0$, both δ_1 and δ_2 will be equal to zero and price p_1 will still not reveal any information about q.

Figure 28: EIC stock price around Fordyce' default, London perspective

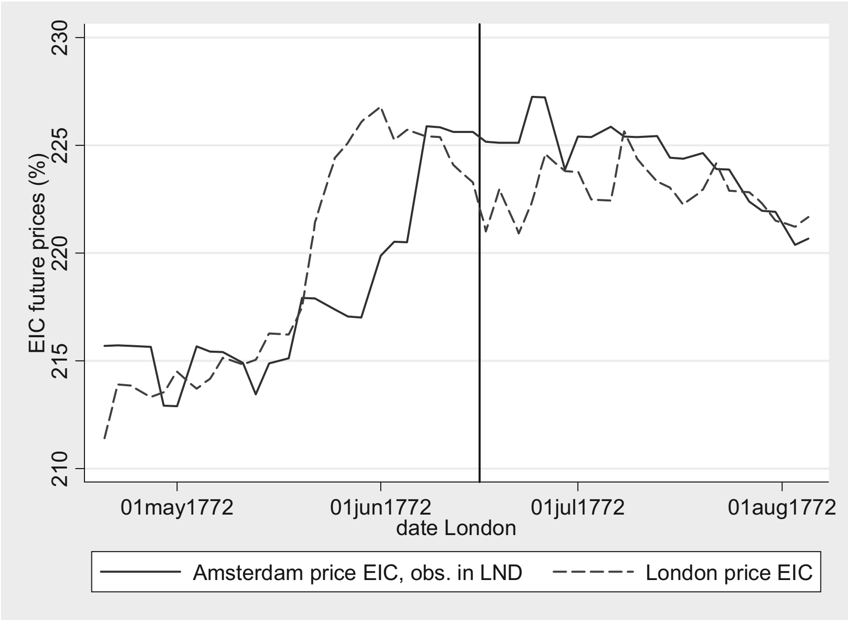


Figure 29: BoE stock price around Fordyce' default, London perspective

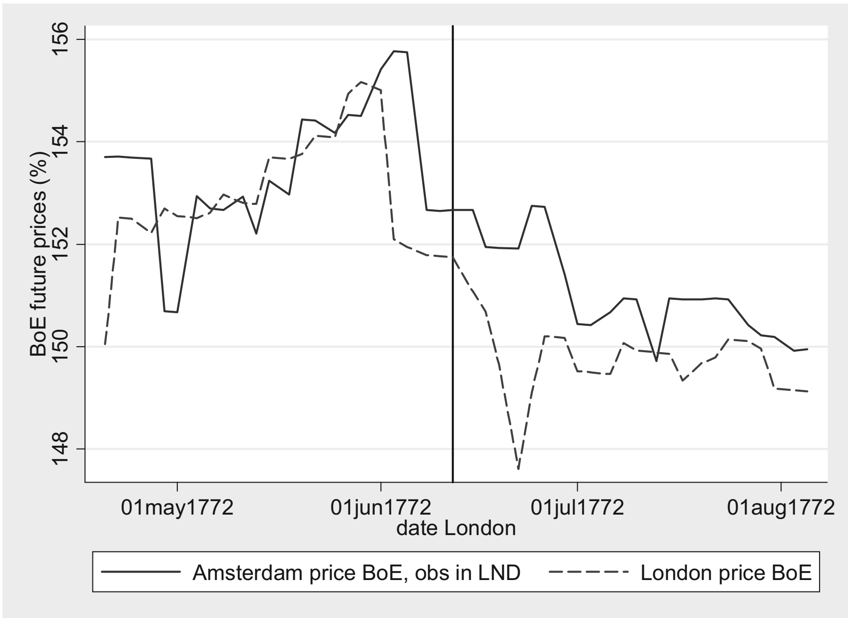


Figure 30: EIC stock price around Clifford et al.'s default, London perspective

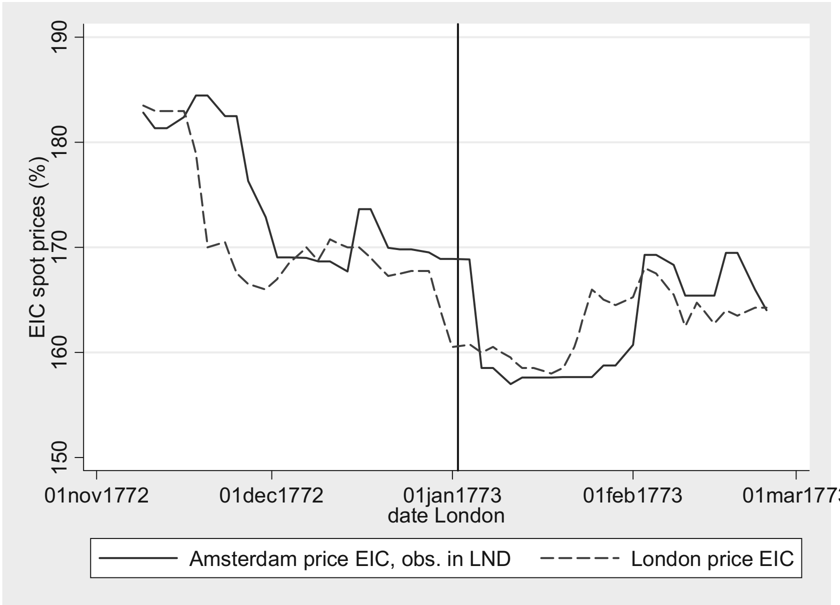
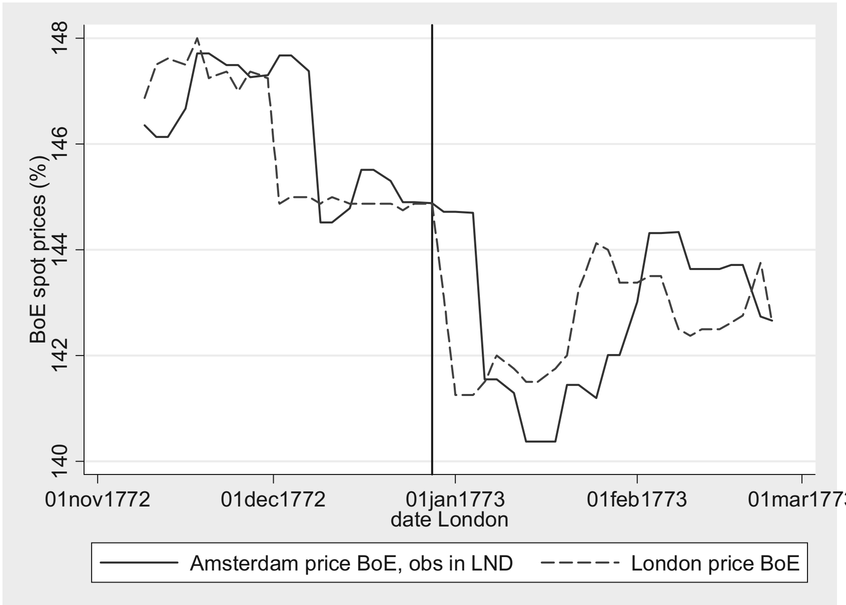


Figure 31: BoE stock price around Clifford et al.'s default, London perspective



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