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

Peter Koudijs

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### **ABSTRACT**

This paper studies how private information is incorporated into prices, using a unique setting from the 18th century that, in many dimensions, is simpler and closer to stylized models of price discovery than modern-day markets. Specifically, the paper looks at a number of English securities that were traded in both London and Amsterdam. Relevant information about these securities originated in London and was sent to Amsterdam on board of official mail packet boats. Anecdotal evidence suggests that these ships carried both public news and private information. They sailed only twice a week, and in adverse weather could not sail at all. The paper exploits periods of exogenous market segmentation to identify the impact of private information. The evidence is consistent with a Kyle (1985) model in which informed agents trade strategically. Most importantly, the speed of information revelation in Amsterdam depended on how long insiders expected it would take for the private signal to become public. As a result of this strategic behavior, private information was only slowly revealed to the market as a whole. This price discovery was economically important: private signals had almost as much impact on prices as public information shocks.

Peter Koudijs  
Stanford Graduate School of Business  
655 Knight Way  
Stanford, CA 94305  
and NBER  
koudijs@stanford.edu

A data appendix is available at:  
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Private information is central to our understanding of financial markets, and, according to the available evidence, has a significant impact on asset prices. However, it is not fully understood how private information is incorporated into prices. One of the most influential approaches to study this question is the Kyle (1985) model. In this framework, informed agents are strategic and take the price impact of their trades into account. They internalize that their profits fall as prices become more informative. This constrains their behavior. Trades are spread out over time and this prolongs price discovery. As a result, asymmetric information is persistent.<sup>1</sup> This approach continues to spur a large literature that analyzes how the strategic behavior of informed agents affects price discovery (this includes Admati and Pfleiderer 1988; Subrahmanyam 1991; Back 1992; Holden and Subrahmanyam 1992, 1994; Foster and Viswanathan 1994, 1996; Chau and Vayanos 2008; and Caldentey and Stacchetti 2010). Despite the breadth of this theoretical literature, the empirical evidence is limited. Private information is by definition unobserved: it is not clear how informed agents trade on their information and by what process their private signals are revealed to the market as a whole.

This paper studies the process of price discovery using a unique setting from the 18<sup>th</sup> century, and tests how well the Kyle model's predictions hold up in the data. The analysis is based on a number of English securities that were traded in both London and Amsterdam. Most relevant information about these securities originated in London, or reached London first, and later arrived in Amsterdam. Anecdotal evidence suggests that a significant fraction of this information was private in nature and held by insiders (Sutherland 1952). The paper compares the price dynamics in the two markets to identify how this private information was incorporated into prices.

The identification strategy relies on the communication technology of the time. In the 18<sup>th</sup> century people relied on sailing ships to transmit news across the North Sea (Neal 1990; Koudijs 2012). There was an official mail packet boat service that carried both public newspapers and private letters. Figure 1 shows the route of this news service. For all practical purposes this was the only way in which public and private information was transmitted from London to Amsterdam. The same packet boat service also brought Amsterdam news back to London. These sailing boats sailed twice a week. Under favorable conditions, it took them three days to transmit the news, but this arrival rate varied considerably due to adverse winds at sea. As a result, Amsterdam was frequently cut off from London.

[FIGURE 1 ABOUT HERE]

The paper uses these periods of exogenous market segmentation to study price discovery. Under the null hypothesis all information is public or, due to the competitive behavior of informed agents,

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<sup>1</sup>In the classical Kyle model there is a single insider. Foster and Viswanathan (1996) show that the main predictions of the model are robust to the introduction of multiple insiders, as long as agents' private signals are (sufficiently) heterogeneous.

private signals are immediately incorporated into prices.<sup>2</sup> Under this null, Amsterdam prices respond immediately to new information arriving on a packet boat. Any other price movements in Amsterdam between the arrivals of two boats are unrelated to information. The empirical tests reject this null: after the arrival of a boat, prices in Amsterdam tend to move in the same direction as London after the departure of that boat. In other words, price changes in Amsterdam are correlated with contemporaneous, but as of yet unreported, returns in London. This co-movement is consistent with the strategic behavior of privately informed traders as in Kyle (1985). Suppose that an insider in London observes a certain piece of information right before the departure of boat. Further, suppose that the insider sends this signal to a business partner in Amsterdam. If both agents spread their trades strategically over time, prices will only slowly reveal the underlying information. London and Amsterdam will tend to move in the same direction, even though information about these price changes is not (yet) communicated across markets.

It is unlikely that these co-movement patterns are the result of news slipping through other channels. There is no qualitative evidence that market participants relied on sources other than the official mail service. For example, Hope & Co, the most important Anglo-Dutch bank of the period, solely relied on the packet boats for their business. In addition, robustness tests suggest that carrier pigeons, the sailing of other boats (including smugglers) or news travelling via Dover-Calais cannot account for the empirical findings.

To determine whether co-movement was truly the result of strategic insider trading, I run a number of additional tests. To begin with, the optimal strategy of the informed agent in Amsterdam should have depended on when he thought the next boat would sail in. Boats arriving in Amsterdam relayed important information from London, including security prices. This (partially) revealed the private signal. If the informed agent expected the next boat to arrive in short order, he would have less time to benefit from his informational advantage, making it optimal to trade more aggressively early on (Caldentey and Stacchetti 2010). The empirical evidence supports this prediction. The initial co-movement of Amsterdam and London prices was stronger when weather conditions suggested that the next boat would arrive shortly. Furthermore, if the discovery of private information was important, we would anticipate feedback effects in London (Chowdry and Nanda 1990; Boulatov et al. 2011). If a private signal was not yet fully incorporated into prices, the London market could learn something from Amsterdam. This too is confirmed by the data. Conditional on its own price discovery, the London market updated its beliefs based on price changes in Amsterdam. If, due to weather conditions, it took longer for a private signal to “bounce back” from Amsterdam, the London market responded less. By that time, the pri-

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<sup>2</sup>If these agents are risk neutral, private information is immediately incorporated into prices (Grossman 1976; Holden and Subrahmanyam 1992, 1994). If they are risk averse, competition does not necessarily lead to full revelation (Grossman and Stiglitz 1980). However, Vives (1995) shows that in a dynamic setting insiders trade only once. There is no price discovery in subsequent periods.

vate signal was largely incorporated into prices. Finally, a Kyle model predicts that prices are a martingale (Banerjee et al. 2009). Perhaps contrary to intuition, price changes should not be positively auto-correlated. Otherwise, market participants would be able to predict future price changes, implying that prices did not incorporate all available information to begin with. The empirical evidence confirms that there is no positive auto-correlation of returns.

The absence of drift or return continuation is inconsistent with a number of other explanations for the co-movement patterns in the data. I consider three specific alternatives. First, co-movement could result from the slow incorporation of *public* information into prices due to trading costs, inattention, or differences of beliefs. This should lead to an observed drift in the Amsterdam price series (Hong and Stein 2001). Second, the trading environment in Amsterdam and London was not fully centralized. In such a setting, it might take time for traders to be matched with each other, and for prices to reflect new information. If this friction is important, we again expect that prices exhibit drift. Third, co-movement may be unrelated to information and could reflect slow moving capital (Duffie 2010). Suppose that a liquidity shock hits the market in London. Arbitrageurs will transmit this shock to Amsterdam. As intermediating capital slowly trickles into both markets, prices will gradually move back to their fundamental level, leading to a positive correlation between returns in London and Amsterdam. If a significant fraction of this capital comes from England, it is possible that prices in Amsterdam adjust faster when the next boat is expected to arrive shortly. Again, contrary to the empirical evidence, this explanation implies return continuation.

The strategic behavior of privately informed agents had important economic consequences. Informational asymmetries were persistent: the estimates indicate that it took almost two weeks for a private signal to be fully incorporated into prices. Results suggest that this price discovery had a significant impact on the market as a whole: the contribution of private information to overall price movements rivaled that of public information shocks.

This paper is related to other contributions that empirically test the Kyle model. Because private information is, by definition, unobservable, the empirical evidence is often indirect. Notable exceptions are Boulatov et al. (2011) and Hendershott et al. (2012) who show that the trading behavior of institutional investors is consistent with a Kyle model. Collin-Dufresne and Fos (2012) show that the trading patterns of activist investors also fit into this framework.

More generally, this paper is related to a large body of empirical work that documents the importance of private information for asset price movements. Most empirical work links private information to order flow imbalances (Hasbrouck 1991; Easley, Kiefer and O'Hara 1997; Madhavan et al. 1997; Evans and Lyons 2002; Vega 2006). It is not obvious that order flow imbalances are always the result of private information; they can also capture liquidity shocks (Duarte and Young 2009). There are a number of alternative approaches studying the impact of private information. Pasquariella and Vega (2007) and Tetlock (2010) look at the interaction of order flow imbalance

(or volume) and public information events. Marin and Olivier (2008) find that stock prices drop sharply after (reported) insider sales peak. Cohen et al. (2012) analyze reported insider trades and show that non-predictable trades outperform the market. Cohen et al. (2008; 2010) focus on the performance of institutional investors in stocks of companies that are run by former classmates. Kelly and Ljungqvist (2012) look at the impact of the closure of brokerage firms' research departments.

Relative to this literature, the paper makes the following contributions. First and foremost, it provides a test of the Kyle model that is based on information flows rather than order flow. The paper identifies when private information arrived to the market and when it expired. The time available to insiders to trade on their information varied exogenously and this allows for a clean identification of strategic behavior. Second, it provides new evidence for the relevance of private information in financial markets.

The rest of the paper is organized as follows. Section 1 discusses the historical background and microstructure of the two markets in more detail. In addition, it provides anecdotal evidence for the relevance of private information. To motivate the empirical analysis, Section 2 sets up a simple Kyle model. Section 3 presents empirical evidence supporting the model's predictions. Section 4 provides a number of robustness tests. Section 5 concludes.

# 1 Historical background

## 1.1 Securities and sample period

During the second half of the 18<sup>th</sup> century there were only a handful of securities traded on the London Stock Exchange. The most liquid and frequently traded were shares of the British East India Company (EIC) and the Bank of England (BoE), and the 3% Annuities; the most important form of government debt (Neal 1990). In addition, investors could trade in shares and bonds of the South Sea Company, bonds issued by the EIC and BoE and a number of smaller government debt issues. The paper focuses on the first group of securities because these are the only ones for which price observations in both London and Amsterdam are available at a high enough frequency. Together they represent about 60% of the entire British market (Cohen 1822).

The EIC was a trading company that governed large parts of India. The company was subject to government regulation, and during the second half of the 18<sup>th</sup> century political developments in England became of key importance (Sutherland 1952). The BoE was set up in 1694 to function as the government's banker and help it finance the public debt. The bank operated as a private commercial enterprise rather than a formal central bank. It had a *de facto* monopoly on the issuance of bank notes and discounted commercial bills. During the 1770s it had a significant exposure to the EIC through the provision of credit (Clapham 1944).

The paper focuses on the periods 1771-1777 and 1783-1787. Before 1771, information about boat arrivals is incomplete. After 1771, not all years can be used. The analysis of this paper rests on the assumption that all relevant information about the English securities originated in England. That was not necessarily the case when there were (military) conflicts on the European continent or when there was a significant risk of a war breaking out (Neal 1990; Dempster et al. 2000). The period between 1778 and 1782 featured military conflict between England, France and the Dutch Republic and is not suitable for the analysis. The period after 1787 is equally problematic because of increasing domestic tensions in the Dutch Republic and France.<sup>3</sup>

Figure D.1 in Appendix D confirms that during the sample years most relevant information about the English securities originated in England. The figure presents impulse response functions of price changes of EIC stock in Amsterdam responding to London and vice versa. The figure shows that Amsterdam responded strongly to London, with hardly any effect in the opposite direction. Koudijs (2012) presents more detailed evidence.

## 1.2 The flow of information between London and Amsterdam

England and the Dutch Republic were connected by a system of sailing ships, the so-called packet boats. Figure 1 shows that the ships sailed between the ports of Harwich and Hellevoetsluys. On both sides of the North Sea, mounted couriers transported the news over land. The system was set up in the late 17<sup>th</sup> century to ensure the fastest possible transmission of information between London and the Dutch Republic (Le Jeune 1851; Hemmeon 1912; Ten Brink 1957, 1969; Stitt Dibden 1965; Hogesteeger 1989; OSA 2599). The packet boats brought in newspapers and other public newsletters with information about developments in each city, including the most recent stock prices. In addition, they carried private letters that included political and economic updates and news about market conditions (examples in Van Nierop 1931; Wilson 1941, pp. 74-75; SAA 735; 78, 79, and 1510; SAA 334; 643). Private letters could also contain trading orders from London insiders (Van Nierop 1931, p. 68; SAA 735, 115).

The packet boats were scheduled to leave London on Wednesdays and Saturdays. Under normal circumstances it took a full 24 hours to sail across the North Sea. On both sides it took

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<sup>3</sup>The starting point of the sample, September 1771 is determined by data availability. The first 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 in August of that year. There had been an armistice between the Dutch Republic, France, and England since January 1783 and the accord meant a return to normality. The Dutch only signed a treaty with the English in 1784. This delay was due to prolonged negotiations over colonial possessions. The second sample period stops in March 1787, when domestic tensions in the Dutch Republic flared up. This “Patriotic Revolt” started in April 1787 with a radical change in the Amsterdam city government, eventually leading to minor skirmishes in May 1787 and an intervention by the Prussian army in September 1787.

an additional day to transport the news over land. During the period rivers were crossed by ferry and roads were particularly bad. As a result couriers on horseback could not go faster than 4 to 5 mph (Le Jeune 1851; Lewins 1865; Stitt Dibden 1965).<sup>4</sup> Upon arrival, the English news was normally three days old.

The sailing ships often encountered adverse winds and news could be delayed for days: around a third of the North Sea crossings from England to the Dutch Republic arrived late. The longest delay during the sample period was 17 days. As a result, there was considerable variation in the time between the arrival of boats. During these periods of bad weather, no news was transmitted across the North Sea. The *Tatler*, an English newspaper of the time, described that there could be a news blackout in London “when a West wind blows for a fortnight, keeping news on the other side of the Channel” (quoted in Dale 2004, p. 17). The same was true for Amsterdam if the wind blew from the East.

The packet boat system was the main source of English information for investors in Amsterdam, including insiders. The Dutch newspapers of the time all relied on the packet boat service to get news from England. Hope & Co., one of the biggest Dutch banks of the time and an agent for London insiders, relied solely on the packet boat system.<sup>5</sup> Virtually all newspaper articles about England can be linked to a particular packet boat crossing. During periods of particularly bad weather, English news arrived in Amsterdam through the port of Ostend in today’s Belgium, which had a regular packet boat service with Dover (see Figure 1 for the different locations). This happened infrequently during the sample period (a total of 9 times). The Dutch newspapers meticulously reported these episodes and the empirical analysis takes them into account.

The packet boats were not the only ships sailing between London and Amsterdam. Each week, freighter ships from England would dock in the Amsterdam harbor. In terms of keeping up with current affairs these ships always lagged the official packet boats. Amsterdam had no direct connection to the North Sea and freighters had to sail via the isle of Texel to enter Amsterdam from the East. This added a number of days to the journey.

Although the packet boat service was the most important source of information for Dutch investors, they may not have been the only conduit of news. It is possible that investors set up private initiatives to get information from London. For example, during the South Sea Bubble

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<sup>4</sup>In London, news was collected by the end of each Tuesday or Friday (day of departure: day 0). This was transported to Harwich during the night and morning. In the afternoon a packet boat set its sails for the Dutch coast (day 1) and the boat would usually arrive in Hellevoetsluys by the end of next day (day 2). From here it was quickly sent to Amsterdam, usually arriving the following day (day 3).

<sup>5</sup>Most English letters in the Hope records mention both the date a letter was written in London and the date it was received and opened in Amsterdam. For the sample periods used in this paper, there are 112 letters that Hope received from London. The great majority of these letters (99) were dated on mail days. Around three quarters of the letters (83) mention the day Hope received and opened them. All letters were opened on the day of arrival (73) or 1 or 2 days later (10) (Hope & Co, SAA 735: 78,79, 115 and 1510).



(1720), Dutch investors were rumored to have chartered their own fishing ships (Smith 1919; Jansen 1946 finds no evidence for this). It is reasonable to assume that if adverse conditions preempted the packet boats from sailing, other boats had difficulty crossing the North Sea as well. Alternatively, market participants may have used carrier pigeons to get information from London. The use of pigeons can be retraced to antiquity, but the historical record suggests that they were only introduced in northwestern Europe after 1800 (Levi 1977; Koudijs 2012, appendix D). According to legend, Nathan Rothschild received news about the outcome of the Battle of Waterloo in 1815, well before anyone else, by way of a carrier pigeon. Ferguson (1998) argues that this is a myth: Rothschild's courier used a boat and only arrived a few hours before the official dispatches (Dale 2004, p. 17). Notably, in the 1840s carrier pigeons on the European continent were not "in flight" during the winter months. The weather was simply too rough for the birds to cope (Ten Brink 1959). The paper will revisit these points in section 4.1.

### 1.3 Market microstructure

Both London and Amsterdam had active markets for English securities, with the Dutch getting involved around 1700 (Smith 1919, p. 107). Previously, during the 17<sup>th</sup> century, the Dutch elite amassed large amounts of wealth. Due to a lack of domestic investment opportunities and assets to diversify their portfolio, they started to look abroad (De Koopman 1775, p. 234; Spooner 1983, p. 63). Investors included "members of patrician families, magistrates and their wives, spinsters, widows and [the attorneys for] orphans" (Wilson 1941, p. 141). During the 1770s and 1780s these Dutch investors held between 20 and 30% of the English securities (Bowen 1989 and Wright 1999). Merchants also participated. In the absence of money market funds, these individuals instead invested cash surpluses in (liquid) English securities. Futures and options allowed them to hedge away any risk they were unwilling to hold (Michie 1999, p. 26). According to Michie, this accounts for a large share of trading activity on both sides of the North Sea, but this is impossible to quantify.

To support the market for English securities an extensive system of intermediaries emerged. London bankers or brokerage firms performed important functions for investors in Amsterdam. Securities had the form of entries in the companies' (or government's) ledgers and had to be transferred in London; there were no separate registries in Amsterdam. Whenever two traders agreed on a transaction, they sent orders to an agent in London to make the transfer. A transaction was only officially settled after the traders received conformation from London (usually within two weeks). The intermediaries also collected and remitted dividends, carried out limit orders in the London market, and provided valuable information about market conditions and general events (Wilson 1941). They often had their roots in Amsterdam and were connected to Dutch firms, often through family ties. A famous example is David Ricardo, who was sent to London by

his father, an Amsterdam broker (Michie 1999, p. 30). Likewise, there were intermediaries in Amsterdam with roots in Britain, such as Hope & Co., who served English principals (SAA 735, 1510; Sutherland 1952). These well-connected bankers and brokerage firms also traded for their own account, engaged in arbitrage, and often acted as liquidity providers (Wilson 1941, p. 141; Michie 1999, p. 23).

Apart from simple spot transactions, investors in Amsterdam and London also had access to futures that allowed them to take significant long or short positions, without having to raise cash or own any actual securities. Future markets functioned in largely the same way on both sides of the North Sea. Contracts were on individual securities and were settled four times a year during so-called *rescontres* or *rescounters*. These took place on the 15<sup>th</sup> of February, May, August or November. Contracts typically ran until the next *rescontre* (Wilson 1941, p. 82-87; De Pinto 1771, p. 291ff.; Mortimer 1769, p. 28-33). Actual delivery was rare; buyers and sellers usually settled profits and losses. An official “*rescontre committee*” calculated net payments and dealt with any possible disputes (Mortimer 1769, p. 32; Smith 1919, p. 129; Wilson 1941, p. 83-86). Payments had to be made within three weeks, otherwise someone was considered a bankrupt (Koopman 1775). Between settlement periods there was no central clearing party keeping track of transactions. Moreover, contracts had no margin requirements (Mortimer 1769, p. 36; Koopman 1775, p. 236; Wilson 1941, p. 83). To avoid default, investors had to ensure they kept a fraction of the underlying value in reserve. De Pinto (1771, p. 296) argues that 10-15% of the underlying value was usually sufficient. However, this reserve only had to be available during the next *rescontre*. In the interim, cash could be employed elsewhere.

The enforcement of contracts was based on reputation. Courts only upheld future contracts when the actual delivery of the underlying was intended (an example is in SAA 5075, 10527-382). “Naked” transactions were illegal; in London by Barnards Act (passed in 1733), and in Amsterdam by the “Placard of Frederik Hendrik” that went back to the 17<sup>th</sup> century (DeMarchi and Harrison 1994; Petram 2011). These laws proved ineffective in preventing naked transactions, but they did imply that the enforcement of contracts was left to the market (Wilson 1941, p. 91; Harrison 2004). For example, if a trader reneged, he would lose market access. As Adam Smith put it in 1766, “all the great sums that are lost are punctually paid; persons who game must keep their credit, else nobody will deal with them” (quoted in Harrison 2004, p. 680; more information in Mortimer 1769, p. 59 and Koopman 1775, p. 229-231, 244).<sup>6</sup>

The lack of official enforcement limited market access to well-connected, highly reputable

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<sup>6</sup>There are many examples of naked short selling in Amsterdam. De Pinto (1771, p. 309) reports that short selling was so intense in 1755-1757 that future prices frequently fell below the spot price (backwardation). Hope & Co.’s records indicate that they held a large naked short position in EIC stock in the futures market for the English speculator Alexander Fordyce in 1772 (SAA 735, 1510). There is no evidence that investors borrowed shares to go short; all shorting activity seems to have taken place in the futures market.

traders. Counterparty risk was a potentially important problem, especially in the absence of margins and a central clearing party. One default could trigger a chain of bankruptcies (Mortimer 1769, p. 51-52fn; Michie 1999, p. 30-1). In both Amsterdam and London, the scope of the market was limited: everyone knew each other, reputations could be formed, and monitoring was possible (Michie 1999, p. 31; Harrison 2004). For example, the Amsterdam futures market was dominated by a limited number of brokerage firms (approximately 40) and only a limited group of market participants had direct access to the futures market (Smith 1919, p. 129, 143). Outsiders, including British investors, could only gain access to this market through reputable intermediaries (SAA 735, 1510; Sutherland 1952, p. 208).

Brokers, acting on their principals' limit orders, dominated the trading process in Amsterdam and London. They never declared their principal. The future transaction was between two brokers, each signing a separate contract with the principal (SAA, 735, 1155; Mortimer 1769, p. 28, 113; Van Nierop 1931; Michie 1999, p. 20-21). There was no centralized market mechanism to aggregate the order flow. Instead, brokers came together at a certain location and actively searched for counterparties. This process was similar to a floor based open outcry system (Mortimer 1769, p. 74ff.; Quinn and Roberds 2012, p. 11). Prices were public information for anyone present. In London, security brokers traded EIC stock in coffee shops in Exchange Alley (mainly *Jonathan's*) and, from 1773 onwards, their own Stock Exchange Building. For BoE stock and the 3% Annuities, the Bank of England's *Rotunda* (a public "banking hall") was the dominant trading venue (Duguid 1901, p. 59-62). In Amsterdam, security brokers met in a separate hall of the Exchange building during official market hours (between noon and 2 p.m.; Le Long 1780, p. 66; Spooner, p. 20-21). Outside these hours, brokers met in coffee shops close to the Exchange (Smith 1919, p. 144). Jewish brokers had their own trading venue in the Jewish neighborhood (Koopman 1775, p. 243; Van Nierop 1931, p. 57).

In both Amsterdam and London, an official committee of brokers was responsible for reporting the day's going price by the end of the afternoon (Mortimer 1769, p. 112; Smith 1919, p. 109; Spooner 1983, p. 22). This official price primarily functioned as a control mechanism so that principals would know whether their brokers had managed to buy or sell at, or near, the going price (Polak 1924, Van Nierop 1931; p. 199; Hoes 1986, p.4). In case of no trade, no price was reported (Neal 1990; *Amsterdamsche Courant*).

## 1.4 Private information

There is ample anecdotal evidence that London insiders used the Amsterdam market to benefit from their private information. Insider trading in London and Amsterdam only became illegal in the 1980s (Franklin 2013) and it was well understood that it was an inherent part of the market (Mortimer 1769, p. 44; Koopman 1775, p. 238). The historical evidence suggests that it was

especially pronounced in EIC stock. On January 1731, in a letter to one of his clients, 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”.<sup>7</sup>

There is also evidence that EIC directors James Cockburn and George Colebrooke were “bulling” the Amsterdam market during 1772 (Sutherland 1952, p. 228; SAA 735, 1155). One of his contemporaries would later describe Colebrooke as he, “who was in the secret, knowing when to sell for his own advantage” (quoted in Sutherland 1952, p. 234). Such practices were not restricted to directors of the EIC. At times, political developments had an important impact on the Company’s prospects and British politicians would engage in insider trading as well. During the 1760’s a group of parliamentarians, amongst whom Lord Shelburne, a later prime-minister, and Lord Verney, member of the Privy Council, regularly engaged in insider trading in EIC stock. The Dutch banker Gerrit Blaauw traded for their account in the Amsterdam market (Sutherland 1952, pp. 206-8).

It is entirely possible that the same politicians also applied their superior knowledge to trading BoE stock and the 3% Annuities. The market was aware of adverse selection problems in government securities:

“whenever [investors] offer to sell, they will always find buyers whose desire of buying (...) plainly makes a doubt of the matter: for it shews that the purchasers (or their brokers for them) have as good an opinion of the annuities the sellers are going to part with” (Mortimer 1769, p. 22).

The records of Hope & Co reveal how insider trading worked in practice. In the fall of 1772 Hope went into business with Thomas Walpole to speculate on EIC stock. As a London banker, the nephew of former Prime-Minister Robert Walpole, and a prominent Member of Parliament (Sutherland 1952, pp. 101 and 109), Walpole was undoubtedly a political insider. On December 22, 1772, Hope received a letter from Walpole dated the 18<sup>th</sup> 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

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<sup>7</sup>Translation from the original Dutch: “Hier is gisteravond 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.

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" (SAA 735, 115).

Walpole's intelligence proved to be accurate. On January 14, 1773 the directors of the EIC asked for a government loan and unlimited access to the tea market in the American colonies, both of which were granted (Sutherland 1952, pp. 249-251). Most importantly, Walpole's predicted price trajectory was largely correct. On December 30<sup>th</sup>, the price of EIC stock in Amsterdam fell from 169.5 to 161, and reached its lowest point on January 4 at 157.50 (in London the EIC stock price did fall to 154). After that, the price of EIC rose back to 169.5 on January 29, 1773.

Hope had to apply 'the usual dex[t]erity' when executing the transactions. They likely had to be careful not to trade too aggressively and reveal the information to other market participants. Hope achieved this by going through intermediaries. Hope's records indicates that all share transactions on the Amsterdam exchange were handled by brokers such as David Pereira and Sons (SAA 735, 1492).

It is impossible to reconstruct the exact trades that Hope made. However, quarterly profit and loss statements indicate that on February 15, 1773, Hope credited Walpole £679 for profits on a short position in EIC stock with a "par" value of £18,500 (SAA 735, 1155, the price at par was 100). It is unknown when Hope exactly entered and exited the market, but this must have been somewhere between December 15 and February 15. Assuming that Hope and Walpole shared the proceeds of this transaction 50/50, profits are consistent with a price fall of 7.3 (so for example from 165 to 157.7).

## 1.5 Data

The empirical analysis of this paper uses detailed price data in Amsterdam and London and information about the arrival of packet boats in Hellevoetsluys and Harwich. I collected the Amsterdam prices by hand from the *Amsterdamsche Courant* and, where necessary, supplemented the data with information from the *Opregte Haerlemsche Courant*. Prices are available for Monday, Wednesday and Friday<sup>8</sup> and are reported in Pound Sterling (as a percentage of par value). London price data is available on a daily basis (Monday - Saturday) and comes from Neal (1990), and,

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<sup>8</sup>Previous research by Neal (1990) and Dempster et al. (2000) use Amsterdam prices with a frequency of 2 observations a month.

where necessary, is supplemented with information from Rogers (1902). By the second half of the 18<sup>th</sup> century, Dutch newspapers started to publish futures prices (Van Dillen 1931). Prices in London refer to spot transactions. To facilitate comparison between London and Amsterdam, Amsterdam future prices are converted into spots (details are in Appendix B).

I hand-collected information about the arrival of boats in Hellevoetsluys from the *Rotterdamsche Courant*.<sup>9</sup> This newspaper not only mentions the day a specific boat arrived but also the date of the news it carried, indicating what London price information was available to Amsterdam investors at certain points in time. Information about the arrival of Amsterdam news in London was also collected by hand from a series of English newspapers (*General Evening Post*, *Lloyd's Evening Post*, *Lloyd's Lists*, *London Chronicle*, and *Middlesex Journal*).

Finally, the paper uses information about weather conditions. Dutch data come from the Zwanenburg observatory, located 6 miles from Amsterdam. For every day there are two or three observations including the direction and speed of the wind, type and quantity of precipitation, and temperature (Royal Dutch Meteorological Institute, *KNMI*). English information comes from *Lloyd's Lists* that published wind directions at Deal, a town close to Dover, 69 miles from London.

## 2 Model

This section develops a simple model in the flavor of Kyle (1985) to analyze what the theoretical predictions are if privately informed agents trade strategically. The next section tests these predictions empirically.

The model features the trade of a single risky asset in two different markets, London (L) and Amsterdam (A). All relevant information originates in London. It abstracts from public information and focuses on private signals. The full model consists of an infinite number of episodes, indexed by  $k$ . An individual episode is diagrammed in Figure 2. At the beginning of episode  $k$ , nature determines the true value of the asset  $v_k$ , where  $v_k$  is a random walk, i.e.  $v_k = v_{k-1} + \varepsilon_k$  with  $\varepsilon_k \sim N(0, \sigma_\varepsilon^2)$ . A single London insider observes innovation  $\varepsilon_k$ ; this is not known to the wider public. At the end of the episode  $\varepsilon_k$  is publicly revealed in London and the next episode begins.

[FIGURE 2 ABOUT HERE]

For simplicity the model focuses on Amsterdam. I assume that right after nature decides on  $\varepsilon_k$  (and before any trade takes place) the London insider sends the signal to his agent in Amsterdam. Episode  $k$  starts the moment this information arrives. When, at the end of the

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<sup>9</sup>In general, information was only available to Amsterdam investors the day after arrival. If a boat arrived in Hellevoetsluys very early in the morning, it was possible that the information from London was already available in Amsterdam on the same day. I use the publication dates of English news in the *Amsterdamsche Courant* and *Rotterdamsche Courant* to identify these cases.

episode,  $\varepsilon_k$  is revealed in London, this information is also sent to Amsterdam straight away as public information. This news either arrives shortly after just one round of trade (referred to as  $t = 1$ ), or is delayed and arrives after an additional trading period ( $t = 2$ ). The probability of news arriving after  $t = 1$  is  $1 - \pi_k$ . The probability of it arriving after  $t = 2$  is  $\pi_k$ . After the arrival of this news, the Amsterdam agent loses the informational advantage.

Parameter  $\pi^k$  varies over time and is determined by weather conditions and the speed of boats crossing the North Sea. If the first boat happens to be quick, there will be a longer wait for the next boat since they depart on fixed days. In addition, the expected period between the two boat arrivals depends on current weather conditions that determine the current sailing speed.

The model proceeds as a two period version of Kyle (1985). Herein subscript  $k$  is dropped. There is a single risk neutral agent in Amsterdam who privately observes  $\varepsilon$ . The only modification to the Kyle (1985) setup is the uncertainty about having a second period to trade on the private information.<sup>10</sup> There is a competitive risk neutral market maker and every period there is a noise trading shock  $u_t$  with  $u_t \sim N(0, \sigma_{u_t}^2)$ . Shocks  $u_1$  and  $u_2$  are iid and independent of  $\varepsilon$ . The variance of these noise trading shocks can differ between periods. The informed agent submits a market order  $x_t$  to the market maker. The market maker also receives the liquidity shock  $u_t$  and cannot discriminate between  $x_t$  and  $u_t$ , only observing  $y_t = x_t + u_t$ . He sets the price at which orders are executed at  $p_1 = v_0 + E[v|y_1]$  and  $p_2 = v_0 + E[v|y_1, y_2]$  ( $v_0$  is the unconditional expectation of the price, i.e.  $v_{k-1}$ ). There are no constraints on the position the market maker can take.<sup>11</sup> The model is arbitrage free. At any point in time the Amsterdam price reflects the expected value of the asset which coincides with the (expected) price in London.

The following proposition characterizes linear equilibria (all proofs are in Appendix A).

**Proposition 1** *A unique linear equilibrium exists and has the following form:*

$$x_1 = \beta_1 \varepsilon \tag{1}$$

$$x_2 = \beta_2 (v_0 + \varepsilon - p_1) \tag{2}$$

$$p_1 = v_0 + \lambda_1 y_1 = v_0 + \lambda_1 (x_1 + u_1) \tag{3}$$

$$p_2 = p_1 + \lambda_2 y_2 = p_1 + \lambda_2 (x_2 + u_2) \tag{4}$$

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<sup>10</sup>Both Back and Baruch (2004) and Caldentey and Stacchetti (2010) analyze random deadlines in greater detail.

<sup>11</sup>Note that this specific market microstructure differs from the historical setting that looks more like a limit order market. An alternative setup would be a stylized two period limit order market model in the vein of Kyle (1989). Such a model adds significant complications. Numerical analysis indicates that results are qualitatively similar.

with

$$\beta_1 = \frac{1}{2\lambda_1} \left( \frac{\lambda_2 - \frac{1}{2}\pi\lambda_1}{\lambda_2 - \frac{1}{4}\pi\lambda_1} \right) \quad (5)$$

$$\beta_2 = \frac{1}{2\lambda_2} = \sqrt{\frac{\sigma_{u_2}^2}{(1 - \lambda_1\beta_1)\sigma_\varepsilon^2}} \quad (6)$$

$$\lambda_1 = \frac{\beta_1\sigma_\varepsilon^2}{\beta_1^2\sigma_\varepsilon^2 + \sigma_{u_1}^2} \quad (7)$$

$$\lambda_2 = \frac{\beta_2(1 - \lambda_1\beta_1)\sigma_\varepsilon^2}{\beta_2^2(1 - \lambda_1\beta_1)\sigma_\varepsilon^2 + \sigma_{u_2}^2} = \sqrt{\frac{(1 - \lambda_1\beta_1)\sigma_\varepsilon^2}{4\sigma_{u_2}^2}} \quad (8)$$

This equilibrium is similar to the one in Kyle (1985). The first key result is summarized by the following corollary:

**Corollary 2** (a)  $cov(p_1 - v_0, \varepsilon) > 0$  and (b)  $cov(p_2 - p_1, \varepsilon) > 0$ , while (c)  $cov(p_2 - p_1, p_1 - v_0) = 0$

Corollary 2 states that price changes in Amsterdam in both  $t = 1$  and  $t = 2$  are correlated with the private signal  $\varepsilon$ . The monopolistic behavior of the insider leads to a slow revelation of the private signal. The insider takes his own price impact (Kyle's  $\lambda$ ) into account and this constrains his behavior. In other words, the equilibrium in  $t = 1$  is not fully revealing and asymmetric information is persistent. As a result, there is additional price discovery in  $t = 2$ .

Price changes in London after the departure of a boat are also correlated with  $\varepsilon$ . The private signal will be publicly announced in London by the time the next boat is set to depart for Amsterdam. Before that happens the London insider trades on his private information and  $\varepsilon$  will be (largely) revealed before the actual public announcement. As a result, price changes in Amsterdam after the arrival of a boat should be positively correlated with the returns in London after the departure of that boat. In other words, price changes in Amsterdam should be correlated with contemporaneous, but as of yet unreported, returns in London. Hereafter this is referred to as co-movement. Price changes in London remain unreported in Amsterdam until the sailing of the next boat. Co-movement is therefore not driven by the transmission of public information.

The corollary also states that, even though prices slowly incorporate private information, they follow a martingale process. The intuition comes from market efficiency. If there is positive auto-correlation, prices in  $t = 1$  would not fully incorporate all available information. The market maker would be able to predict the price change in  $t = 2$  based on the price change in  $t = 1$ . This is inconsistent with risk neutrality and competitive behavior (Banerjee et al. 2009 provide a detailed discussion).

The second key result is summarized by the following:

**Corollary 3**  $\delta cov(p_1 - v_0, \varepsilon) / \delta \pi < 0$



Co-movement between  $\varepsilon$  and the price change in  $t = 1$  is decreasing in  $\pi$ . The intuition follows from a trade-off facing the informed agent. If he has only one period to trade, he balances the volume of trades he can get executed with the impact on prices that this has. One specific combination of price impact and volume maximizes profits. If he gets a second period to trade, the optimal price impact-volume combination changes. The insider would now prefer to trade less in period  $t = 1$ . In this way he reveals less of his information and he can obtain higher profits in period  $t = 2$ . In the model, period  $t = 2$  only occurs with probability  $\pi$ . If  $\pi$  is low, the insider wants to trade more aggressively in  $t = 1$ , implying stronger co-movement with  $\varepsilon$ .

There are a number of assumptions that merit further discussion. First, all private information is publicly revealed in London by the time the next boat sets its sails for Amsterdam. This is a simplification to ensure that (a) there is only one private signal at a given point in time and (b) that trades in Amsterdam have no impact on insider profits in London. It is certainly possible that the private signal is not revealed until later. This does not change the model's qualitative predictions. London prices still reveal private information, albeit imperfectly, and the two markets move in the same direction. In addition, it is optimal for the Amsterdam insider to trade more aggressively if he expects news from London to arrive shortly. Though this news is not fully revealing, it still divulges part of the private signal. Second, the London insider does not trade on the private signal before it is sent to Amsterdam. It is easy to allow for informed trading before the departure of a boat. As long as the private signal is not perfectly revealed before a boat departs for Amsterdam, this does not change the model's predictions. Third, the insider is a monopolist. There may in fact be multiple insiders. The model's predictions should be the same as long as the different private signals are sufficiently heterogeneous and privately informed agents have an incentive to delay their trades (see Foster and Vishwanathan 1996 for a detailed discussion). If multiple agents observe the same private signal, competition between agents would quickly undo the model's predictions (Holden and Subrahmanyam 1994).

### 3 Empirical evidence

#### 3.1 Introduction

Figure 3 explains the empirical setting. There are two relevant boat crossings. The first crossing transmits private signal  $\varepsilon_k$  and publicly reveals previous private signal  $\varepsilon_{k-1}$ . The second crossing reveals private signal  $\varepsilon_k$  and brings in new private signal  $\varepsilon_{k+1}$ . With probability  $\pi_k$  the second boat arrives relatively late.

[FIGURE 3 ABOUT HERE]

Returns in London and Amsterdam are defined as follows. The London post-departure return,  $R_k^L$ , is the return in London after the departure of the first boat. To be clear, information about

this return is *not* publicly transmitted by the first boat. Returns are calculated over different periods (2, 3, 4, and 5 days). The baseline results use the 3 day returns. The Amsterdam news return,  $R_{k,t=1}^A$ , is the return in Amsterdam after the arrival of this boat. This corresponds to period  $t = 1$  in the model. News about this return is transmitted back to London, but always arrives *after* the 2-5 day post-departure period. This means that  $R_k^L$  and  $R_{k,t=1}^A$  are not spuriously correlated due to possible public information shocks in Amsterdam. Finally, if it occurs,  $R_{k,t=2}^A$  is the return in Amsterdam over the subsequent period without news (period  $t = 2$  in the model). Price information in Amsterdam is only available for Mondays, Wednesdays and Fridays. Returns are therefore calculated over 2 or 3 day periods, depending on the day of the week.<sup>12</sup> Returns are defined as  $\Delta p_t = 100 * \ln(p_t/p_{t-1})$ .

### 3.2 Baseline results

How well do the corollaries established by the model hold up? Corollary 2 predicts that returns in Amsterdam are correlated with contemporaneous, but as of yet unreported, returns in London. This should be true for both  $t = 1$ , the period right after the arrival of a boat ( $R_{k,t=1}^A$ ), and  $t = 2$ , the subsequent no-news period ( $R_{k,t=2}^A$ ). For each of the three securities, I estimate the following regressions:

$$R_{k,t=1}^A = \alpha_0 + \alpha_1 R_k^L + u_t \tag{9}$$

$$R_{k,t=2}^A = \alpha_0 + \alpha_1 R_k^L + v_t \tag{10}$$

The model predicts that  $\alpha_1 > 0$ . Estimates are in columns 1, 3, and 5 of Table 1.

[TABLE 1 ABOUT HERE]

The results indicate that both Amsterdam news (Panel A) and no-news returns (Panel B) are strongly correlated with London post-departure returns. This is the case for all three securities. Coefficients are statistically significant at the 1 or 5% level. Statistically speaking, there is no significant difference in co-movement between news and no-news returns. The model has no clear-cut predictions about this dimension; it depends on the variance of the noise trading shocks in the two periods.

It is possible that the co-movement patterns are driven by return continuation or momentum. If, for whatever reason, prices in both markets drift in the same direction, returns will automatically be correlated. This would be fundamentally different from a model of strategic insider trading that predicts that prices are a martingale (Corollary 2). To differentiate between these two explanations, I condition the co-movement estimates on past returns, both in London and Amsterdam.

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<sup>12</sup>The 3 day period includes the weekend during which trading was restricted. Jewish traders did not trade during the Shabbat and Christians did not trade on Sundays (Spooner 1983). I therefore treat the weekend return the same as the 2 day return.

Figure 3 defines past returns. Return  $R_{k-1}^L$  is the price change in London *before* the departure of a boat. This can be interpreted as a public information shock; it tells Amsterdam investors how much prices in London have moved since the last shipment of news. Return  $R_{k-2}^L$  is the pre-departure return associated with the previous boat. With a slight abuse of notation,  $R_{k-1}^A$  captures the previous Amsterdam return that can either reflect the arrival of a boat or not.

Table 1 presents estimates of the following two regressions

$$R_{k,t=1}^A = \alpha_0 + \alpha_1 R_k^L + \alpha_2 R_{k-1}^L + \alpha_3 R_{k-1}^A + \alpha_4 R_{k-2}^L + u_t \quad (11)$$

$$R_{k,t=2}^A = \alpha_0 + \alpha_1 R_k^L + \alpha_2 R_{k-1}^L + \alpha_3 R_{k,t=1}^A + v_t \quad (12)$$

where coefficients  $\alpha_1$  again measure co-movement. Specification (11) for news returns includes  $R_{k-1}^L$ , the London pre-departure return that captures public information. The model abstracts away from public news shocks, but in reality they likely played an important role for security prices, that is  $\alpha_2 > 0$ . The specification also includes the pre-departure return associated with the previous boat ( $R_{k-2}^L$ ). If there is any continuation of previous news returns then  $\alpha_4 > 0$ . Finally,  $R_{k-1}^A$  captures drift in the Amsterdam return series. Specification (12) for no-news returns is similar. It includes the news shock associated with the most recent boat arrival ( $R_{k-1}^L$ ). The associated coefficient  $\alpha_2$  picks up the continuation of the London news return into no-news periods. The specification also includes lagged Amsterdam returns ( $R_{k,t=1}^A$  in this case).

Results are in columns 2, 4 and 6 of Table 1. Most importantly, for both specifications the inclusion of past returns has no impact on the coefficient on  $R_k^L$ . After controlling for past returns, there is still strong evidence for co-movement. If anything,  $\alpha_1$  increases. This indicates that co-movement is independent of any drift that might be present in the return series. The estimates for Amsterdam news returns ( $R_{k,t=1}^A$ ) are in Panel A. As expected, the impact of public information  $R_{k-1}^L$  is highly economically and statistically significant. The effect of the previous public news shock  $R_{k-2}^L$  is close to zero. The coefficient on the previous Amsterdam return,  $R_{k-1}^A$ , has a negative sign, indicating that returns partly revert, rather than exhibit drift. This could be consistent with liquidity shocks having transitory price impact (Grossman and Miller 1988). Results for no-news returns ( $R_{k,t=2}^A$ ) are in panel B. In this case, there is some continuation of London news returns into no-news periods. This is statistically significant for EIC stock and the 3% Annuities. Again, there is evidence that previous returns in Amsterdam partly revert.

This 18<sup>th</sup> century pattern of return reversals is strikingly similar to those of modern markets. There is a large literature going back to Niederhoffer and Osborne (1966) demonstrating that returns exhibit reversals in the short run. Using daily returns on large and liquid equities between 1979 and 2007, Tetlock (2010, Table 1) presents reversal coefficients of around  $-0.10$ .<sup>13</sup> This number lies very close to the estimates in Table 1.

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<sup>13</sup>Jegadeesh and Titman (1993) provide evidence for momentum over longer horizons, specifically periods between 3 and 12 months.

Appendix D presents estimates of two other robustness tests for EIC stock. In Table D.1 the London post-departure return  $R_k^L$  is calculated over 2, 4 or 5 days after a boat departure. Varying this period does not matter substantially for the estimates. Estimates in Table D.2 exclude the first day of the London post-departure return to ensure that the positive co-movement between  $R_k^L$  and  $R_{k,t=1}^A$  is not driven by boats carrying public information more recent than indicated by the historical sources. Results indicate that this does not significantly change the results.

The co-movement estimates in Table 1 are economically important. Suppose, for example, that prices in London increase by 1% after the departure of a boat. Then, on average, prices in Amsterdam increase by about 0.25% in the first days after the arrival of that boat and an additional 0.25% in the subsequent no-news period (if it occurs). We can compare this to the response to public information shocks (the coefficient on  $R_{k-1}^L$ ) to get a sense of the relative magnitude. On average, a 1% return in London before the departure of a boat leads to an instantaneous price increase in Amsterdam of 0.5%. This means that the cumulative effect of private information is comparable to the impact of public news shocks.

The presence of private information also increased trading costs. Evidence suggests that uninformed agents shied away from trading right after the arrival of a boat when adverse selection costs would have been the highest. Detailed trading data is difficult to come by. There are two sources that mention exact transaction dates. The first contains trading records of Abraham Cohen de Lara, a Portuguese-Jewish merchant based in Amsterdam (SAA 334, 722-723). The second has information about the liquidation of securities that were pledged as collateral in margin loans (SAA 5075, 10603-10611). In total there is information about 32 transactions of which only 4 took place on days with news. If traders were indifferent between trading on days with or without news this number should be close to 9 (on average two boats arrived each week;  $2/7 * 32 \approx 9$ ). The difference is statistically significant with a p-value of 0.028 (one sided binomial test).

### 3.3 Different expectations about the next boat arrival

Corollary 3 predicts that the co-movement with London in period  $t = 1$  should be stronger if the next boat is expected to arrive shortly. This corollary is a consequence of the strategic behavior of insiders.<sup>14</sup>

Before moving to the empirical tests a quick note on the estimation of  $\pi_k$ . This parameter captures the probability that there is a second period of trade. We can calculate an empirical counterpart by looking at the number of days between the arrivals of two news shipments, denoted by  $A$ . The longer this period, the more trading opportunities an informed agent expects to have.

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<sup>14</sup>The model also holds predictions for co-movement in period  $t = 2$ . Specifically, we expect to observe less co-movement if the insider initially expected the next boat to arrive right after  $t = 1$ . Unfortunately, there are too few observations to test this. It is rare that period  $t = 2$  took place unexpectedly.

At the beginning of a period he does not know what the realization of  $A$  will be, but he has some expectation,  $E[A]$ , that we can approximate. This expectation depends on two factors. First, how many days ago did a news shipment leave London? Or, if it didn't depart yet, when is it set to do so? This information comes directly from the sailing schedule. Second, how long will the shipment of news take to arrive in Amsterdam? This is not known with certainty. The first definition,  $E[A|simple]$ , simply uses the median travelling time. The second definition,  $E[A|extended]$ , is based on a duration model with a flexible Gamma distribution that uses information about weather conditions, most importantly the direction of the wind. A sailing boat adjusts its sails to the prevailing winds. However, when it gets "too close to the wind", it enters the so-called "no-go zone". In order to advance it needs to tack (constantly change direction). This slows down sailing and increases the effective distance. Information on wind directions is available for 2 or 3 observations a day. For every observation we can determine whether a boat sailing East faces a no-go zone. This includes winds that lie within 55 degrees of an Eastern direction. To capture the possible presence of ice, the model includes a dummy for low temperatures.<sup>15</sup> It also includes month dummies to account for additional seasonalities. Both procedures yield reasonable estimates of  $E[A]$ , although the extended model does significantly better. The correlation between  $E[A|simple]$  and the actual realization of  $A$  is 0.36. For  $E[A|extended]$  this is 0.52. Figures D.2 and D.3 in Appendix D present these results graphically.

Table 2 presents empirical tests of whether Amsterdam news returns ( $R_{k,t=1}^A$ ) co-move more strongly with London if the next news shipment is expected to arrive relatively soon. For simplicity the estimation differentiates between  $E[A]$  higher or lower than the unconditional expectation. Two boats were scheduled to depart each week, so this is 3.5 days. The regression of interest is

$$R_{k,t=1}^A = \alpha_0 + \alpha_1 R_k^L + \alpha_2 R_k^L \times (E[A] < 3.5) + \alpha_3 (E[A] < 3.5) + X_{k,t=1} + u_t,$$

where  $X_{k,t=1}$  includes past returns. Corollary 3 predicts that  $\alpha_2 > 0$ . Table 2 presents results for both  $E[A|simple]$  and  $E[A|extended]$ . The interaction effect is positive and statistically significant for EIC and BoE stock. As expected, the interaction with  $E[A|extended]$  is stronger, although the difference with  $E[A|simple]$  is not statistically significant. The impact is economically important: co-movement roughly doubles if the next boat is expected to arrive within 3.5 days. For the 3% Annuities the interaction terms are positive but statistically insignificant. The interaction with  $E[A|extended]$  only has a p-value of 0.203 but its magnitude is similar to the other two securities.

[TABLE 2 ABOUT HERE]

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<sup>15</sup>Hellevoetsluys is situated in the mouth of several rivers. Ice floating downstream could make it hard to reach the harbor. A dummy for temperatures below 3 degrees Celcius has the best fit in the duration model; inland temperatures were lower than the ones measured at the Zwanenburg observatory which was relatively close to the sea.

### 3.4 Feedback effects and price discovery in London

Thus far, the analysis has focused on Amsterdam. However, the presence of private information also implies a number of testable predictions for price discovery in London. Specifically, there may be feedback effects since both markets face the same private signal. If noise in the price discovery process is not perfectly correlated, a combination of the two markets' signals is more informative than each signal individually (Chowdry and Nanda 1991; Boulatov et al. 2011). In other words, London investors update their beliefs based on price changes in Amsterdam. The theoretical model proposed in Section 2 assumes that the private signal in London is revealed before any of this can happen. This is an abstraction that facilitates the analysis of price discovery in Amsterdam. It is likely that private information in London was longer lived. In that case, price changes in Amsterdam might affect price discovery in London. Figure 4 formalizes this intuition. At London time  $t^*$ , a boat with private signal  $\varepsilon$  sets sail to Amsterdam where it arrives at time  $t$ . A few days ( $a$ ) later, a boat departs for London, transmitting Amsterdam prices at time  $t + a$ . The concrete price signal that this boat carries can be expressed as  $p_{t+a}^A - p_t^A$ , where  $p_t^A$  is the Amsterdam price recorded right before the arrival of the boat. This information reaches London at  $t^* + l$ , where  $l$  is the number of days since the departure of the first boat from London. Between  $t^*$  and  $t^* + l$ , the London market observes its own (noisy) signal and the price changes by  $p_{t^*+l}^L - p_{t^*}^L$ . After the arrival of the boat, the London market maker updates his beliefs based on the news from Amsterdam and sets a new London price  $p_{t^*+l+1}^L$ .

[FIGURE 4 ABOUT HERE]

This section of the paper analyzes this situation in reduced form. Appendix E develops a full-fledged Kyle model and under a number of reasonable assumptions predictions are equivalent. Without loss of generality Amsterdam and London signals can be written as

$$\theta^A = \varepsilon + \zeta \tag{13}$$

$$\theta^L = \varepsilon + \phi \tag{14}$$

where  $\varepsilon_k \sim N(0, \sigma_\varepsilon^2)$ ,  $\zeta \sim N(0, \sigma_\zeta^2)$  and  $\phi \sim N(0, \sigma_\phi^2)$ . Disturbances  $\zeta$  and  $\phi$  are independent of  $\varepsilon$ , and can be correlated as long as

$$0 < cov(\theta^A, \theta^L) < var(\theta^i) \text{ for } i = A, L,$$

where the second inequality simply implies that signals  $\theta^A$  and  $\theta^L$  cannot be identical. Assuming away any additional innovations in the price process, price changes in Amsterdam and London can be written as

$$\begin{aligned} p_{t^*+l}^L - p_{t^*}^L &= \rho^L \theta^L; & p_{t+a}^A - p_t^A &= \rho^A \theta^A \\ p_{t^*+l+1}^L - p_{t^*+l}^L &= \rho^{A|L} \theta^A - (\rho^L - \rho^{L|A}) \theta^L, \end{aligned}$$

where

$$\rho^i = \frac{\sigma_\varepsilon^2}{\text{var}(\theta^i)} \quad (15)$$

$$\rho^{i|j} = \rho^i - \rho^{j|i} \frac{\text{cov}(\theta^A, \theta^L)}{\text{var}(\theta^i)}, \text{ for } i, j = A, L. \quad (16)$$

This implies that

$$\theta^L = \frac{p_{t^*+l}^L - p_{t^*}^L}{\rho^L}; \quad \theta^A = \frac{p_{t+a}^A - p_t^A}{\rho^A},$$

and

$$p_{t^*+l+1}^L - p_{t^*+l}^L = \frac{\rho^{A|L}}{\rho^A} (p_{t+a}^A - p_t^A) - \frac{(\rho^L - \rho^{L|A})}{\rho^L} (p_{t^*+l}^L - p_{t^*}^L). \quad (17)$$

Equation (17) has three testable predictions (proofs are included in Appendix A).

**Prediction 1:** (a) Price changes in London  $p_{t^*+l+1}^L - p_{t^*+l}^L$  respond positively to price changes in Amsterdam:  $\rho^{A|L}/\rho^A > 0$ . In addition, (b)  $p_{t^*+l+1}^L - p_{t^*+l}^L$  is negatively correlated with the previous London price change:  $(\rho^L - \rho^{L|A})/\rho^L > 0$

If the Amsterdam and London signal are both correlated with  $\varepsilon$ , and not perfectly correlated with each other, then the London market maker can learn from the Amsterdam signal. In addition, since the signals partly reveal the same information, it is optimal for the London market maker to put less weight on the signal he observed earlier (expression 16). This implies that after observing the Amsterdam signal, the earlier price change in London partially reverts.

**Prediction 2:** In the empirical estimation of (17), the coefficient on the Amsterdam signal  $p_{t+a}^A - p_t^A$  is smaller if the previous London price change  $(p_{t^*+l}^L - p_{t^*}^L)$  is **not** included in the regression.

The lagged London return enters the regression with a negative coefficient. It is positively correlated with the signal from Amsterdam. Omitting it from the regression leads to a downward bias of the coefficient on the Amsterdam signal,  $p_{t+a}^A - p_t^A$ . This is critical: if London prices simply respond to an independent public news shock from Amsterdam, the impact of this shock should not depend on past London price changes.

**Prediction 3:** Finally,  $\frac{\rho^{A|L}}{\rho^A}$ , the coefficient on  $p_{t+a}^A - p_t^A$ , is (a) increasing in the precision of signal  $\theta^A$ :  $\delta(\rho^{A|L}/\rho^A)/\delta\sigma_\zeta^2 < 0$ , and (b) decreasing in the precision of signal  $\theta^L$ :  $\delta(\rho^{A|L}/\rho^A)/\delta\sigma_\phi^2 > 0$ .

As expected,  $\rho^{A|L}/\rho^A$  drops when  $\theta^L$  becomes more informative. Parameter  $\rho^A$  is unaffected, but  $\rho^{A|L}$  falls as more weight is put on  $\theta^L$ . Part (a) of the result is less intuitive. When  $\theta^A$  becomes less precise, both  $\rho^A$  and  $\rho^{A|L}$  fall: overall, there is less to learn from the signal. The drop in the (bivariate) coefficient  $\rho^{A|L}$  dominates because the London market maker also has access to the London signal  $\theta^L$ . Since  $\text{cov}(\theta^A, \theta^L) > 0$  this means that more weight is put on  $\theta^L$  and  $\rho^{A|L}$  falls more than  $\rho^A$ .

How does the precision of the Amsterdam and London signals vary over time? First, the price in Amsterdam is arguably more informative when there are many days (denoted  $a$ ) between the arrival and departure of a boat. In a simple Kyle model more opportunities to trade lead to the dissemination of more information. Period  $a$  is longer when news from London happens to come in right after a boat has just set sail for England. At that point, it will take 3 or 4 days for the next boat to depart. In the same vein, if there are many days in London (denoted  $l$ ) between the initial departure of a boat and the eventual arrival of news from Amsterdam, London prices are likely to be more informative. Period  $l$  is longer when sailing times on the North Sea (in either direction) happen to be long.

The regression of interest is

$$p_{t^*+l+1}^L - p_{t^*+l}^L = \alpha_0 + \alpha_1 (p_{t+a}^A - p_t^A) + \alpha_2 (p_{t+a}^A - p_t^A) \times a + \alpha_3 (p_{t+a}^A - p_t^A) \times l \quad (18) \\ + \alpha_4 (p_{t^*+l}^L - p_{t^*}^L) + \alpha_5 (p_{t^*}^L - p_t^A) + \alpha_6 a + \alpha_7 l + u_t$$

Coefficient  $\alpha_1$  captures the effect of the Amsterdam signal; the model predicts that  $\alpha_1 > 0$ . This coefficient is downwardly biased since prices in Amsterdam respond to earlier (public) news from London. To reduce this bias, the estimates include  $p_{t^*}^L - p_t^A$ , the difference between the London price observed in Amsterdam after the arrival of a boat at time  $t$  and the Amsterdam price recorded right before (see Figure 4 for details). Coefficient  $\alpha_4$  measures whether the London market puts less weight on its own signal after the arrival of news from Amsterdam. The model predicts that  $\alpha_4 < 0$ . Coefficients  $\alpha_2$  and  $\alpha_3$  (interactions between the Amsterdam signal and periods  $a$  and  $l$ ) pick up changes in the relative precision of the Amsterdam signal; according to the model  $\alpha_2 > 0$  and  $\alpha_3 < 0$ .

[TABLE 3 ABOUT HERE]

Table 3 presents the regression results. Columns 1, 3, and 5 only include the Amsterdam signal  $p_{t+a}^A - p_t^A$ , and earlier news from London  $p_{t^*}^L - p_t^A$ . For all three securities coefficient  $\alpha_1$  is positive, but it is only statistically significant for EIC stock. Consistent with the impulse responses in Figure D.1 in Appendix D, the coefficients are relatively small. Columns 2, 4 and 6 include the other variables. The results are in line with Predictions 1 and 2. Coefficient  $\alpha_1$  on the Amsterdam signal increases; this increase is statistically significant for EIC stock.<sup>16</sup> Coefficient  $\alpha_4$ , the coefficient on previous London returns, has a negative sign, but is statistically insignificant for all three securities. The interaction effects with periods  $a$  and  $l$  are introduced as deviations from the median. Coefficient  $\alpha_1$  in columns 2, 4 and 6 therefore measures the impact of Amsterdam news at median values of  $a$  (2 days) and  $l$  (10 days). The interaction terms measure the impact on  $\alpha_1$  when moving away from the median. For all securities, the signs on the coefficients are as

<sup>16</sup>In a specification omitting the interaction terms with  $a$  and  $l$ , the coefficients on  $\alpha_1$  slightly increase to 0.129\*\*\* (EIC), 0.102\* (BoE) and 0.066 (3% Ann.). In this specification the increase in  $\alpha_1$  is still only statistically significant for the EIC.



predicted. A longer time period  $l$  reduces the impact of the Amsterdam signal, whereas a longer period  $a$  increases the effect. The coefficients are statistically significant for the EIC and the 3% Annuities.

The economic impact of the interaction effects is considerable. Consider EIC stock. The 75<sup>th</sup> percentile of the distribution of  $[a - \text{median}(a)]$  is 1 day and moving to the 75<sup>th</sup> percentile almost doubles  $\alpha_1$  from 0.122 to 0.214. The 25<sup>th</sup> percentile of the distribution of  $[l - \text{median}(l)]$  is  $-2$  days. Moving to the 25<sup>th</sup> percentile also nearly doubles  $\alpha_1$  from 0.122 to 0.234. Note that  $a$  and  $l$  are positively correlated. If  $a$  increases,  $l$  tends to increase as well, cancelling some of the effect on  $\alpha_1$ . Based on these estimates it appears that, at median values of  $a$ , the London market stopped responding to news from Amsterdam after approximately 12 days ( $\beta_1 + 2 * \beta_5 \approx 0$ ). At this point, private information seems to have been fully incorporated into London prices.

To summarize, the empirical evidence is consistent with the idea that discovery of private signals in Amsterdam has subsequent impact on London. This confirms that informational asymmetries were persistent. It is unlikely that these empirical findings are driven by public information shocks originating in Amsterdam. First, London’s response to Amsterdam increases after conditioning on past London returns. Second, the effect is larger when there was more time to trade in Amsterdam or when the “round-trip” of a signal was relatively short. This is inconsistent with a public information story.

### 3.5 Amsterdam as a source of private information

Thus far, the underlying assumption of the paper is that private information exclusively originated in London. It is not obvious that this was always the case. Private information could have reached Amsterdam before London, especially when it concerned the EIC. The Dutch had their own East India company and their network might have generated relevant information about their British competitor. There is a straightforward way to test this: switching Amsterdam and London in the regressions. If Amsterdam was a significant source of private information, we expect that returns in *Amsterdam* after the departure of a boat are correlated with price changes in *London* after the arrival of that boat.

Table 4 replicates the results from Table 1 after swapping the identities of the two cities. Results do not suggest that Amsterdam was an important source of private information. The London no-news returns are not correlated with the Amsterdam post-departure returns: coefficients are close to zero. The London news returns co-move somewhat with Amsterdam, but the coefficients are small and statistically insignificant for all three securities. The differences with the baselines estimates of Table 1 are highly statistically significant. Table D.3 in Appendix D analyzes the co-movement of London news returns in more detail. If Amsterdam was an important source of private information, we would expect that co-movement increases if the next boat from the Dutch

Republic is expected to arrive in short order. Table D.3 replicates the results from Table 2 with the two cities switched around. There is no evidence that co-movement in London varied with expectations about the next boat arrival from Amsterdam.<sup>17</sup> This confirms that Amsterdam was not an important source of private information.

[TABLE 4 ABOUT HERE]

## 4 Robustness tests

The baseline findings of section 3.2 might be driven by other factors than private information. This section discusses four alternative explanations: (1) public news slipping through other channels, (2) the slow incorporation of public information, (3) search frictions, and (4) correlated liquidity shocks.

### 4.1 Slipping through of news

The co-movement of Amsterdam and London security prices could simply be the result of the arrival of news through channels other than the official packet boats. The first possibility is the crossing of other ships. This alternative explanation is most relevant for Amsterdam no-news returns ( $R_{k,t=2}^A$ ). We can test for this with the following robustness exercise. All ships relied on the right wind direction to cross the North Sea. This suggests that, if other ships are responsible for the co-movement results, the estimates should be significantly stronger when winds were favorable. Table 5 presents estimates of the following regression:

$$R_{k,t=2}^A = \alpha_0 + \alpha_1 R_k^L + \alpha_2 R_k^L \times \text{favorable} + \alpha_3 \text{favorable} + X_{k,t=2} + u_t,$$

where  $X_{k,t=2}$  includes past returns. Baseline coefficient  $\alpha_1$  measures co-movement during periods of adverse winds. The interaction term between  $R_k^L$  and the dummy for favorable winds measures by how much co-movement increases when the winds turn for the better. If sailing boats other than the packets played an important role we would expect that good weather periods drive most of the results; i.e.  $\alpha_2 > 0$ . In that case  $\alpha_1$  should be close to zero. There are three different definitions for favorable winds. Under definition A, a return period had favorable winds if the next packet boat arrived according to schedule. Under definition B winds have to blow from the West (from 180 to 360 degrees) on every single day of a no-news period. The starting point for definition C is the “no-go zone”: for every day of a return-period, at least two wind observations within that day (out of a total of 2 or 3) have to be *outside* the no-go zone. Table 5, Columns 1, 3, and 5,

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<sup>17</sup>These expectations are calculated in the same way as for Amsterdam. Due to data limitations,  $E[A|extended]$  is only based on the no-go zone and month dummies. Weather observations come from Deal, a town 69 miles from London.

present the estimates for definition A. Results for definitions B and C are in Table D.4 in Appendix D. The results indicate that the degree of co-movement is equally strong in periods of good and bad weather:  $\alpha_1$  is just as large and statistically significant as the baseline estimates in Table 1. Coefficient  $\alpha_2$  is economically small (or negative) and statistically insignificant. Exceptions are definitions B and C for the 3% Annuities. Coefficient  $\alpha_1$  is still significantly different from zero in these specifications, but  $\alpha_2$  is positive (albeit statistically insignificant).

[TABLE 5 ABOUT HERE]

Carrier pigeons are another potential source of information. The historical evidence suggests that they were not introduced until after 1800. At that point, they could only be used during periods of reasonable weather; they did not fly in the winter. We can test for their possible impact during the 1770s and 1780s by running the following regression

$$R_{k,t=2}^A = \alpha_0 + \alpha_1 R_k^L + \alpha_2 R_k^L \times non - winter + \alpha_3 non - winter + X_{k,t=2} + u_t,$$

where the “non-winter” dummy has a value of one from March to October and  $X_{k,t=2}$  again includes lagged returns. Baseline coefficient  $\alpha_1$  measures co-movement from November to February. If carrier pigeons played an important role in transmitting information, we would expect that co-movement is stronger during the rest of the year, i.e.  $\alpha_2 > 0$ . Results in columns 2, 4, and 6 in Table 5 indicate that, if anything, co-movement is weaker from March to October. This suggests that carrier pigeons did not play an important role.

A third possible alternative is the arrival of news via Dover and Calais. When winds on the North Sea were unfavorable, boats may have managed to cross the Strait of Dover, which is only 26 miles wide.<sup>18</sup> Table 6 replicates the estimates of Table 1 after omitting price information that could have been affected by this channel. Under favorable conditions, news travelling over Dover and Calais took a week to arrive in Amsterdam: 4 days longer than the regular mail. It took at least a full day to ship the news from London to Calais and the subsequent route over land to Amsterdam took 6 days. Road conditions were poor and rivers had to be crossed by ferry (Le Jeune 1851; Ten Brink 1969, p. 21). This is supported by the newspapers of the time. News from England that arrived in Amsterdam via Ostend, a port situated 60 miles northeast of Calais, was at least 1 week old (*Rotterdamsche* and *Amsterdamsche Courant*; see Section 1.2 for further discussion). Table 6 excludes periods in Amsterdam when the most recent information from London (that had arrived through the regular packet service) was older than 6 days. The number of observations drops considerably, but the co-movement estimates are similar to those in Table 1 and statistically

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<sup>18</sup>Crossing the Strait of Dover is far from straightforward. It is infamous for its strong currents and quickly changing weather. Even with light winds, the sea can be rough. Visibility is often limited and dense fogs occur regularly, making it difficult to navigate. Risks could be enormous: on November 20, 1775 the official Dover-Calais packet boat sank in a storm, killing “16 English gentlemen and their entourage”, *Rotterdamsche Courant*, Nov. 24, 1775.

significant. Co-movement is *not* as weak as we would expect if news arriving via the Strait of Dover played an important role.<sup>19</sup>

[TABLE 6 ABOUT HERE]

## 4.2 Trading costs, inattention, or heterogeneous beliefs

It is possible that the co-movement of prices between Amsterdam and London was driven by the slow incorporation of public news. This might have been the result of trading costs. If it is costly to trade on new public information, prices might not be fully updated right away. Alternatively, market participants may have “agreed to disagree” or there may have been a lack of attention, leading some agents to initially ignore certain news. It is possible to distinguish between this alternative explanation and the strategic behavior of insiders. The slow incorporation of public news generally leads to return continuation (Hong and Stein 1999; Huberman and Regev 2001; DellaVigna and Pollet 2009). Results in Table 1 suggest that, consistent with a model of strategic insider trading, there is hardly any drift in the return series. Most importantly, the co-movement results are independent of any return continuation that is present.

## 4.3 Search frictions

The co-movement patterns could be explained by the decentralized trading environment in Amsterdam and London (see Section 1.3 for details). In such a setting, it might take time for traders to find each other, transactions to take place, and for prices to reflect new information. If search is particularly difficult during spells of bad weather, this might also explain why initial co-movement is weaker when the next boat is delayed. This section considers two different cases.

### 4.3.1 Public news

In the first case all information is public. Conditional on trade taking place, prices will immediately incorporate news. However, if transactions are delayed, it will take time for prices to reflect new information. This can give rise to co-movement. For example, suppose that a new piece of information arrives in London one day before a boat is set to depart for Amsterdam. Due to search frictions, no trade takes place until after departure. The boat transmits the information to Amsterdam where prices respond, either immediately after arrival or, if transactions are delayed,

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<sup>19</sup>In the no-news estimates, the coefficients on past Amsterdam and London returns,  $R_{k,t=1}^A$  and  $R_{k-1}^L$ , significantly increase in size compared to Table 1. This is due to collinearity problems. The two returns are strongly correlated with  $\rho = 0.58$  (EIC),  $\rho = 0.37$  (BoE), and  $\rho = 0.49$  (3% Ann.). With only a limited number of observations, the regression cannot fully distinguish between the two: the coefficients largely cancel each other out. In a regression without past returns, the coefficients on  $R_k^L$  are 0.310\*\*\* (EIC), 0.310\*\*\* (BoE), and 0.407\*\* (3% Ann.).

in the subsequent no-news period. As a result, London post-departure and Amsterdam post-arrival returns are positively correlated. The key prediction from this framework is that co-movement is only present after periods without transactions.

It is not obvious that this mechanism can explain the empirical findings. The historical evidence suggests that London newspapers only published actual transaction prices: no trade implied no price. The co-movement regressions include price changes in London before the departure of a boat and therefore omit any observations for which there is no such price change available.

The London newspapers may have occasionally reported stale prices (Lesmond et al. 1999; Bekaert et al. 2007). In that case, search frictions might still be relevant. To test this alternative, we can check whether co-movement between Amsterdam and London is stronger after the reporting of a (potentially) stale price. Table 7 presents estimates of the following regressions for Amsterdam news and no-news returns:

$$\begin{aligned} R_{k,t=1}^A &= \alpha_0 + \alpha_1 R_k^L + \alpha_2 R_k^L \times I [R_{k-1}^L = 0] + \alpha_3 [R_{k-1}^L = 0] + X_{k,t=1} + u_t \\ R_{k,t=2}^A &= \alpha_0 + \alpha_1 R_k^L + \alpha_2 R_k^L \times I [R_{k-1}^L = 0] + \alpha_3 [R_{k-1}^L = 0] + X_{k,t=2} + v_t, \end{aligned}$$

where  $X_{k,t=1}$  and  $X_{k,t=2}$  include past returns and  $R_{k-1}^L$  is the London pre-departure return (see Figure 3 for details). The reporting of a stale price implies a zero return. The interaction term between  $R_k^L$  and  $I [R_{k-1}^L = 0]$  captures whether there is more co-movement if  $R_{k-1}^L = 0$ . Estimates are in Table 7. The results suggest that zero returns are not associated with stronger co-movement: coefficient  $\alpha_2$  is small or negative and statistically insignificant.

[TABLE 7 ABOUT HERE]

It is possible that zero returns are an imperfect measure of search frictions in London: even if prices move, they may not reflect the most recent information. Using a similar approach, we can check whether there is evidence for search frictions in Amsterdam. In this particular mechanism, news is only slowly incorporated into prices if there are no transactions. This means that Amsterdam *no-news* returns should only co-move with London if the preceding *news* return was zero. Table D.5 in Appendix D reports the corresponding regression results. There is no evidence that co-movement for no-news returns was stronger after zero news returns: for the EIC there is a slight increase, but this is not statistically significant. For the BoE the effect is close to zero; for the 3% Annuities it is negative (but statistically insignificant).

Search frictions might explain why Amsterdam news returns exhibited less co-movement when the next boat was expected to arrive relatively late. The idea is that adverse sailing conditions were associated with bad weather in Amsterdam, making it more difficult for agents to find each other and transact. Table D.6 in Appendix D reports simple tests of whether news returns were more likely to be zero when the next boat was expected to be late. The table shows that this was not the case. In sum, the evidence does not suggest that search frictions in combination with public news shocks can explain the co-movement results.

### 4.3.2 Private signals

In the second case, a boat transmits many different individual signals. One way to interpret this is that there is one single information event, but everyone interprets this differently due to differences in the initial information set. Agents do have homogeneous beliefs, so the market converges to a single valuation (Kim and Verrecchia 1994). This section uses a simplified version of the model in Duffie and Manso (2007) to analyze this situation.

For simplicity, new information only becomes available in London right before a boat is set to depart. After its arrival in Amsterdam, there are 3 trading rounds: together  $t = 1, 2$  can be thought of as the news period;  $t = 3$  as the no-news period. There is a continuum of agents with unit mass that have subscript  $i$ . There is a single risky asset that pays out  $v_0 + \varepsilon$  after  $t = 3$ , where  $v_0$  is common knowledge. At the beginning of  $t = 1$  a boat arrives and all agents observe an individual signal about  $\varepsilon$ :

$$\eta_i = \varepsilon + \omega_i$$

where  $\omega_i$  are iid,  $\omega_i \sim N(0, \sigma_\omega^2)$  and  $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ . For exogenous reasons, half of the agents want to buy stock and the other half want to sell. Buyers are randomly matched to sellers with matching intensity  $0 < \mu < 1$ . When they meet they share their information and transact at their common posterior (as in Duffie and Manso 2007). Almost surely, they will never run into the same agent again.

In  $t = 1$ , there is a continuum of transactions with prices  $\tilde{p}_1 = v_0 + \gamma_2(\eta_i + \eta_j)$  for  $i \neq j$ , where

$$\gamma_2 = \frac{\sigma_\varepsilon^2}{\sigma_\eta^2 + \sigma_\varepsilon^2}. \quad (19)$$

Through this trading process a fraction  $\mu$  of the agents will have observed an additional signal at the end of  $t = 1$ . As a result, there are three types of possible matches in period  $t = 2$  that result in the following prices

$$\tilde{p}_2(n) = v_0 + \gamma_n \sum_{i=1}^n \eta_i, \quad (20)$$

where  $n \in \{2, 3, 4\}$  is the number of signals a price is based on and

$$\gamma_n = \frac{\sigma_\varepsilon^2}{\sigma_\eta^2 + (n-1)\sigma_\varepsilon^2}. \quad (21)$$

Similar to the historical setting, there is an official committee that collects information about the going price. For tractability, I assume that they report the simple mean of a *continuous* subset of transaction prices at the end of  $t = 2$ . Using the law of large numbers

$$\bar{p}_2 = v_0 + \int \tilde{p}_2(n) = v_0 + \underbrace{[2\gamma_2(1-\mu)^2 + 6\gamma_3\mu(1-\mu) + 4\gamma_4\mu^2]}_{\Gamma} \varepsilon, \quad (22)$$

where (proofs are included in Appendix A):

**Lemma 4**  $0 < \Gamma < 1$ .

This means that  $\bar{p}_2$  “underreacts” to the available information: the coefficients  $\gamma_n$  on the individual signals are all smaller than one. This reflects the fact that, for each individual, signals are noisy. The reported price is based on a continuum of those signals and therefore reveals the true value of  $\varepsilon$ . After observing  $\bar{p}_2$ , all agents update their beliefs and set  $p_3 = v_0 + \varepsilon$ .

This simple model has the following predictions

**Lemma 5** *(a)*  $cov(\bar{p}_2 - v_0, \varepsilon) = \Gamma \sigma_\varepsilon^2 > 0$  *and* *(b)*  $cov(p_3 - \bar{p}_2, \varepsilon) = (1 - \Gamma) \sigma_\varepsilon^2 > 0$ , *while* *(c)*  $cov(\bar{p}_2 - v_0, p_3 - \bar{p}_2) = \Gamma(1 - \Gamma) \sigma_\varepsilon^2 > 0$ .

In other words, this simple model can explain the co-movement patterns between Amsterdam and London. At the same time, price changes are auto-correlated. After an initial “underreaction”, the price drifts in the same direction as  $\bar{p}_2 - v_0$ . The estimates in Table 1 indicate that there is little evidence for return continuation in the return series. Most importantly, the inclusion of past returns does not lead to a drop in the co-movement estimates. This is inconsistent with this model. To see this, write the London post-departure return as  $\theta = \varepsilon + \varsigma$ , where  $\varsigma$  is an iid information shock that is not yet transmitted to Amsterdam. In the baseline regression

$$p_3 - \bar{p}_2 = \alpha_1 \theta + u,$$

coefficient  $\alpha_1$  is strictly positive. If we include  $\bar{p}_2 - v_0$ ,  $\alpha_1$  will fall to 0:  $\bar{p}_2 - v_0$  is perfectly correlated with  $\varepsilon$  and subsumes the entire effect of  $\theta$ . If  $\bar{p}_2$  does not perfectly reflect  $\varepsilon - v_0$ ,  $\alpha_1$  will remain positive but it will be significantly smaller.

These predictions are robust to changing the way the official committee reports prices. Take the example where they report a single transaction price. For simplicity, suppose that the price in  $t = 2$  is based on a transaction between two individuals who haven’t traded before:

$$\tilde{p}_2(2) = \gamma_2(\eta_i + \eta_j)$$

for some  $i \neq j$ . In  $t = 3$ , the committee again reports a single price that is based on a transaction between two traders who have not been matched to a counterparty before, but who have observed the price  $\tilde{p}_2$ . In this case,

$$\tilde{p}_3(4) = \gamma_4(\eta_i + \eta_j + \eta_k + \eta_l)$$

for some  $i \neq j \neq k \neq l$ . Price changes in both  $t = 2$  and  $t = 3$  are correlated with  $\varepsilon$ ; it is easy to show that  $\gamma_2 > 0$  and that  $2\gamma_4 - \gamma_2 > 0$ . In addition, there is return continuation. This follows from the fact that

$$cov(\tilde{p}_2 - v_0, \tilde{p}_3 - \tilde{p}_2) = \gamma_2 \gamma_4 (\sigma_\eta^2 - \sigma_\varepsilon^2) > 0$$

The model also links search frictions to the degree of co-movement:

**Lemma 6** *The correlation between  $\bar{p}_2 - v_0$  and the true value of the asset  $\varepsilon$  is increasing in  $\mu$ :  $\delta cov(\bar{p}_2 - v_0, \varepsilon) / \delta \mu > 0$*

As search gets easier, more agents observe an additional signal in period  $t = 1$ . Agents' signals in  $t = 2$  become (weakly) more precise, and coefficient  $\Gamma$  increases. If search frictions and sailing conditions are related, this could explain why co-movement is stronger when the next boat is expected to arrive in short order. Table 8 documents how expected arrival times correlate with a wide range of weather variables, other than the wind direction. Overall, the evidence for a link with weather induced search frictions is weak. Expected arrival times are only significantly correlated with wind speed and rainfall. It is not obvious that traders would have had more difficulty finding each other if it rained or if the wind was stronger. Table 8 shows that longer expected boat arrivals were *not* correlated with a combination of rainfall (or any other type of precipitation) and high wind speeds, or more extreme forms of weather such as (thunder)storms. As a final robustness check, the estimates in Table D.7 in Appendix D include interaction terms between the London post-departure return,  $R_k^L$ , and the rainfall and wind speed variables. The additional interaction terms are small, statistically insignificant, and do not affect the key finding that co-movement increases when the next boat is expected to arrive in short order. In sum, even though a simple model of matching frictions goes quite some way in explaining the patterns in the data, it is inconsistent with other elements of the empirical evidence.

[TABLE 8 ABOUT HERE]

#### 4.4 Correlated liquidity shocks and slow moving capital

The co-movement of prices in London and Amsterdam could also reflect slow moving capital. If the market has limited risk-bearing capacity, shifts in the demand or supply of an asset will have an impact on prices (Grossman and Miller 1988; Duffie 2010). Suppose that a liquidity shock hits the London market and is transmitted to Amsterdam. This has an immediate impact on prices. Later, as capital (or securities) slowly trickle into the market, prices recover. This might explain why Amsterdam post-arrival and London post-departure returns are positively correlated: after the initial impact of the liquidity shock, prices in both markets move back to their fundamental level. If London was an important source of capital or securities, the anticipated arrival of a boat might have relaxed the constraints of liquidity providers in Amsterdam, leading to stronger co-movement.

It is not immediately obvious that this mechanism was of first order importance in this specific context. Market participants had access to the futures market where neither cash nor securities were immediately necessary to transact (see Section 1.3 for details). However, these futures were only available to a select number of reputable traders and it is possible that the marginal investor did not always come from this group. In that case, the supply of securities or capital did matter.



Alternatively, if free entry to the futures market was indeed restricted, it is possible that liquidity provision was not fully competitive. In such an oligopolistic setting, liquidity shocks could have a significant impact on prices, even if the market is frictionless in other dimensions. The inflow of capital or securities may have substituted for a good reputation, enabling more liquidity providers to participate. This would have made the Amsterdam and London markets more competitive, bringing prices closer to fundamentals.

I use a model in the spirit of Biais et al. (1998) to evaluate whether slow moving capital can explain the patterns in the data. For simplicity, I focus on a setup with oligopolistic liquidity provision without any other frictions. This is a useful abstraction: introducing additional constraints does not change the model's qualitative predictions. Results are generalizable to other models of slow moving capital.

Figure 5 shows that the setup of the model is slightly different from the one considered in Section 2. There is a single risky security with a normally distributed payoff  $v_0 + \varepsilon$ , with  $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ . Information is symmetric. There are three periods,  $t = 0, 1, 2$ . In London time is indexed as  $t^*$ . The payoff of the risky asset is realized after  $t^* = t = 2$ . In  $t^* = 0$  a liquidity shock of size  $U$  hits the London market,  $U \sim N(0, \Sigma^2)$ . English investors absorb fraction  $\delta$  of this shock. The remainder is transmitted to the Amsterdam market, where it arrives in  $t = 0$ . In periods  $t^* = t = 0$ , there are no liquidity providers present. There are only long term, price taking investors in the market who can absorb this liquidity shock. At any point in time they have an aggregate demand of

$$Y^A = \frac{1}{\varphi^A}(v_0 - p_t); \quad Y^L = \frac{1}{\varphi^L}(v_0 - p_{t^*})$$

This pins down prices  $p_0^A$  and  $p_0^L$ . Note that  $\delta$  can be set such that  $p_0^A = p_0^L$ , i.e.

$$\varphi^A(1 - \delta) = \varphi^L\delta \Leftrightarrow \delta = \frac{\varphi^A}{\varphi^A + \varphi^L}$$

so that there are no arbitrage opportunities. The aggregate demand functions can be interpreted in a number of ways (Brunnermeier and Pedersen 2005). For example, long run investors might be relatively risk averse and demand additional compensation for taking a position in the risky security.<sup>20</sup>

From period  $t = t^* = 1$  onwards a number of risk neutral, non-competitive liquidity providers (or market makers) enter the market. Crucially, they compete on quantity rather than price and

---

<sup>20</sup>This specific definition of the aggregate demand functions does not allow long term investors to arbitrage between  $t = 0$ ,  $t = 1$  and  $t = 2$ . If they were allowed to arbitrage many results would go away. This assumption can be motivated as follows. In the simple setup analyzed here, the only source of risk is related to the payoff of the risky asset that only materializes after  $t = 2$ . In a more realistic setup, there would be additional risk in the form of public news or liquidity shocks that materialize before  $t = 2$  and make arbitrage risky. If the long term investors are risk averse, this will limit arbitrage. As long as arbitrage is imperfect, results will be qualitatively similar.

act strategically. In  $t^* = 1$ , capital flows into the London market, enabling a single risk neutral market maker to supply liquidity to the market. In addition, a certain amount of capital is shipped to Amsterdam. This arrives in  $t = 1$  so that a single liquidity provider can also set up shop here. In  $t^* = 2$ , more capital flows into London and this enables an additional group of  $L$  market makers to provide liquidity. Some of this capital is again shipped to Amsterdam. With probability  $1 - \pi$ , the boat arrives before the beginning of  $t = 2$  (superscript  $b$ ) and this enables an additional  $M$  agents to provide liquidity in this period. With probability  $\pi$  the boat arrives only after  $t = 2$  (superscript  $nb$ ). In  $t = 2$ , the Amsterdam market also receives fresh capital from a location other than London. This happens with certainty and enables  $N$  additional market makers to provide liquidity.

[FIGURE 5 ABOUT HERE]

The equilibrium is constructed as follows. Every period, long term investors and liquidity providers submit demand curves to a Walrasian auctioneer. The long term investors effectively set the price, conditional on the liquidity shock and the amount of liquidity that the market makers find optimal to provide. The following proposition characterizes the equilibrium in Amsterdam; results for London are analogous (proofs are included in Appendix A).

**Proposition 7** *In Amsterdam there is a unique linear equilibrium with prices*

$$p_0^A = v_0 + \varphi^A(1 - \delta)U \quad (23)$$

$$p_1^A = v_0 + \frac{\varphi^A(1 - \delta)}{2(1 - \Psi)}U \quad (24)$$

$$p_2^{A,nb} = v_0 + \frac{\varphi^A(1 - \delta)}{2(N + 2)(1 - \Psi)}U \quad (25)$$

$$p_2^{A,b} = v_0 + \frac{\varphi^A(1 - \delta)}{2(N + M + 2)(1 - \Psi)}U \quad (26)$$

where

$$\Psi = \frac{\pi}{(N + 2)^2} + \frac{1 - \pi}{(N + M + 2)^2}; 0 < \Psi < \frac{1}{4} \quad (27)$$

Prices in  $t = 0$  adjust immediately to the liquidity shock  $(1 - \delta)U$ . There are no liquidity providers so the price impact is  $\varphi^A(1 - \delta)U$ . Afterwards, in  $t = 1$  and  $t = 2$ , more market makers enter and prices move back towards  $v_0$ . They do not fully converge because the market never becomes fully competitive.

How does this translate into the empirical setup? Amsterdam news returns  $R_{k,t=1}^A$  are a mixture of price changes in periods  $t = 0$  and  $t = 1$ : they either reflect the immediate impact of a liquidity shock or the partial dissipation of a previous shock. To explain the co-movement patterns in the data I interpret them as the latter. In a similar vein, London post-departure returns,  $R_k^L$ , are interpreted as price changes in London in  $t^* = 1$ . Amsterdam no-news returns  $R_{k,t=2}^A$  correspond to period  $t = 2$  if no boat arrives.

It is straightforward to arrive at the following results:

**Corollary 8** (a)  $cov(p_1^A - p_0^A, p_1^L - p_0^L) > 0$  and (b)  $cov(p_2^{A,nb} - p_1^A, p_1^L - p_0^L) > 0$ , while (c)  $cov(p_2^{A,nb} - p_1^A, p_1^A - p_0^A) > 0$ .

In words, this Corollary states that Amsterdam returns in  $t = 1$  are positively correlated with price movements in London in  $t^* = 1$ . This is due to the dissipation of the liquidity shock. The same holds for Amsterdam returns in period  $t = 2$ . Even in the absence of a boat, new capital pours into the market, making liquidity provision more competitive. Prices move closer to  $v_0$ , generating additional co-movement with London. Apart from co-movement, this process also generates drift. Returns in periods  $t = 1$  and  $t = 2$  are positively correlated. This prediction is inconsistent with the empirical evidence (the argument is similar to the discussion in Section 4.3.2).

Similar to the Kyle model, co-movement between London and Amsterdam in  $t = 1$  is decreasing in the probability  $\pi$  that a boat only arrives after  $t = 2$ :

**Corollary 9**  $\delta cov(p_1^A - p_0^A, p_1^L - p_0^L) / \delta \pi < 0$

The intuition for this result comes from the strategic behavior of the liquidity provider in Amsterdam in  $t = 1$ . If he provides more liquidity in  $t = 1$ , his profits from  $t = 2$  will fall. This endogenously constrains the amount of liquidity he is willing to provide in the first period. However, if a boat arrives and more liquidity providers enter in  $t = 2$ , he will get a smaller fraction of the total profits in that period. If this is more likely to happen, it is optimal to provide more liquidity in period  $t = 1$ . As a result, the Amsterdam price reverts to  $v_0$  faster, and co-movement with London is stronger.

Apart from drift, the model holds another prediction that is inconsistent with the data. The co-movement results are based on a liquidity shock that originates in London and has immediate price impact in both markets. As this shock dissipates, subsequent Amsterdam returns will be negatively correlated with the initial price change in London. In terms of the model:

**Corollary 10** (a)  $cov(p_0^L - v_0, p_1^A - p_0^A) < 0$  and (b)  $cov(p_0^L - v_0, p_2^{A,nb} - p_1^A) < 0$

We can test this by projecting Amsterdam price movements,  $p_{k+T}^A - p_{k,t=1}^A$ , on past returns in London,  $R_{k-1}^L$ . The price change in Amsterdam is calculated over  $T$  days after a boat arrival, where  $T$  varies between 2 days and 4 weeks. Note that  $p_{k,t=1}^A$  incorporates any new public information that is contained in  $R_{k-1}^L$ . The regressions therefore do **not** pick up the response to public news. If the model is correct, returns should be negatively correlated. Estimates are in Table 9. There is no evidence for such return reversals across markets. This is inconsistent with a model of slow moving capital.

[TABLE 9 ABOUT HERE]

There is one final test of this model. Since Dutch investors held between 20 and 30% of outstanding securities, it is unlikely that liquidity shocks solely originated in London. If co-movement reflects slow moving capital, we would therefore expect to observe similar return correlations when we switch London and Amsterdam in the regression analysis. Table 4 shows that there is hardly any evidence for co-movement in this specification. Furthermore, Amsterdam was an important source of capital for the London market (Wilson 1941; Spooner 1981). We would therefore expect that co-movement increased when the next boat from Amsterdam was expected to arrive shortly. Table D.3 in Appendix D shows that this is not the case. In sum, a model of slow moving capital can explain the co-movement results, but also has implications that are inconsistent with the empirical evidence. Table 10 summarizes and compares the empirical fit of the Kyle model with the different alternative explanations.

[TABLE 10 ABOUT HERE]

## 5 Conclusion

This paper studies the effect of privately informed trading on security prices, using unique hand-collected data from the Amsterdam and London markets for English securities in the 1770s and 1780s. Anecdotal evidence suggests that London insiders traded in both markets to benefit from their privileged information. They used official mail boats to communicate with their agents in Amsterdam. These boats only sailed twice a week, and in adverse weather could not sail at all. As a result, Amsterdam was frequently cut off from London news. The paper exploits these periods of exogenous market segmentation to identify the impact of private information.

The results suggest that the classical Kyle (1985) model of strategic informed trading provides an accurate description of the incorporation of private signals into prices. The empirical discussion is guided by a two period model in which an informed agent trades strategically. Prices follow a martingale and slowly reveal the insider's information. The rate at which private information is incorporated in prices depends on when the agent expects the next boat from London to arrive and his informational advantage to (partially) expire. The empirical evidence supports the model's predictions. The importance of private information is underlined by the London market's response to news from Amsterdam. Conditional on its own price discovery, London reacted to observed price changes in Amsterdam. If, due to adverse weather conditions, it took longer for a private signal to "bounce back", the price change in Amsterdam became relatively less informative, and the response in London was weaker.

A number of robustness tests suggest that co-movement between Amsterdam and London was not driven by news arriving through other channels than the official packet boats. The paper also explores a number of alternative explanations for the empirical findings: specifically the slow

incorporation of information due to search frictions, and the price impact of liquidity shocks due to slow moving capital. These models can match (some of) the co-movement results, but, unlike the Kyle model, generally predict drift or return continuation. This is inconsistent with the data.

The estimates indicate that private information was economically important. On the positive side, informed trading contributed significantly to the market's ability to aggregate information. Private information was almost as important for overall price movements as public news. Contemporaries readily acknowledged this and saw no fault in it. On the negative side, the strategic use of private information caused informational asymmetries to be persistent. Results suggest that it took almost two weeks for a private signal to be fully incorporated into prices. This increased overall trading costs and reduced liquidity. As a case in point, evidence suggests that Amsterdam market participants preferred not to trade right after the arrival of a boat, when informational asymmetries were arguably the most severe.

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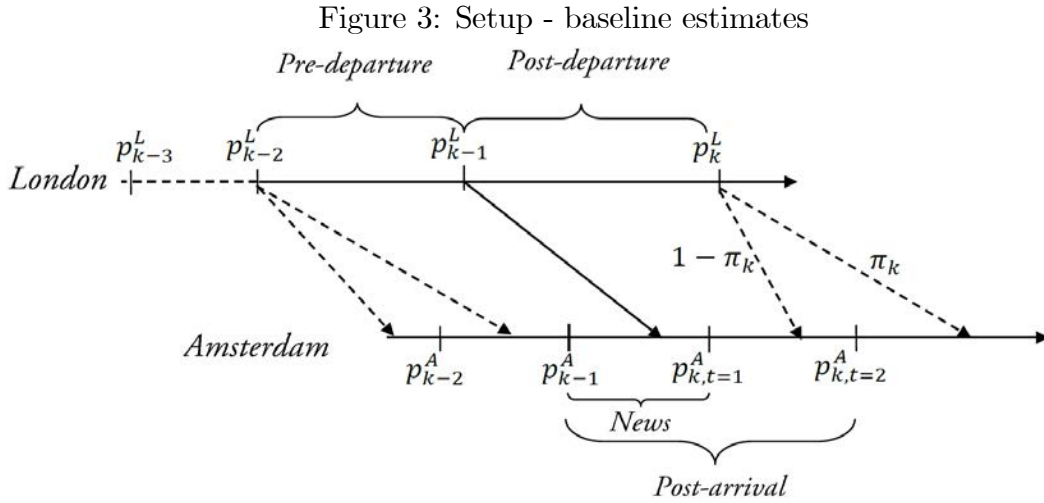
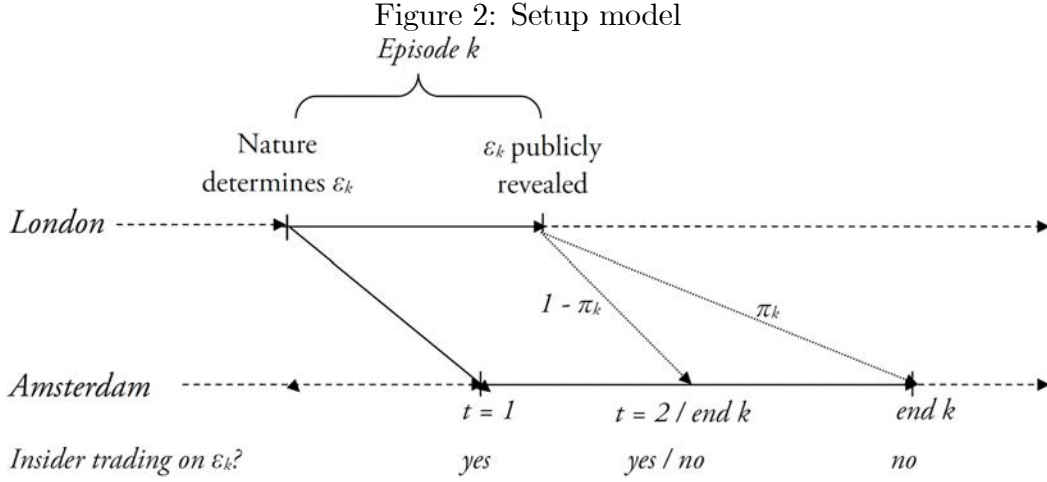
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## Figures and Tables

Figure 1: Map North Sea Area



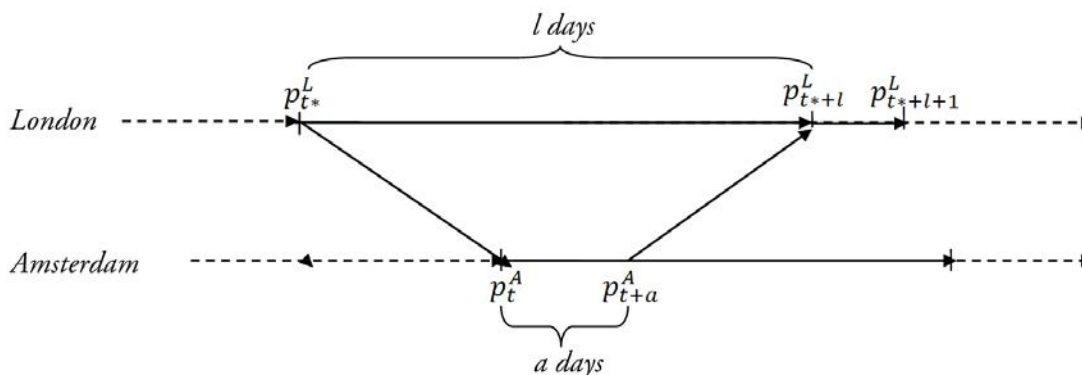


This diagram clarifies the timing of the empirical analysis and defines the different returns that are used. A given boat transmits a private signal from London to Amsterdam. With probability  $\pi$  the next boat arrives quickly and the informed agent has one period to trade on his information (period  $t = 1$  of the theoretical model); we only observe a “news return”. With probability  $1 - \pi$  the next boat is delayed. Now there are additional opportunities to trade (period  $t = 2$  in the theoretical model) and we also observe a “no-news return”.

Returns are defined as follows:

Amsterdam post-arrival news returns ( $t = 1$ ):	$R_{k,t=1}^A = p_{k,t=1}^A - p_{k-1}^A$
Amsterdam post-arrival non-news returns ( $t = 2$ ):	$R_{k,t=2}^A = p_{k,t=2}^A - p_{k,t=1}^A$
London post-departure returns:	$R_k^L = p_k^L - p_{k-1}^L$
London pre-departure returns:	$R_{k-1}^L = p_{k-1}^L - p_{k-2}^L$
Previous London pre-departure returns:	$R_{k-2}^L = p_{k-2}^L - p_{k-3}^L$
Past Amsterdam returns	$R_{k-1}^A = p_{k-1}^A - p_{k-2}^A$

Figure 4: Setup - feedback

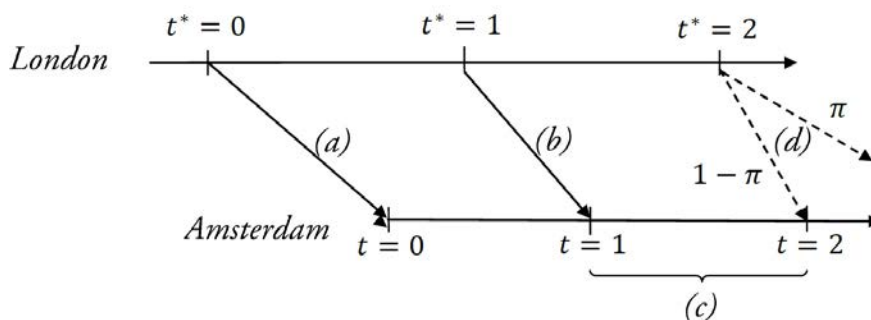


This diagram illustrates the feedback effect from Amsterdam back to London. A certain private signal leaves London at time  $t^*$  and arrives in Amsterdam at time  $t$ . There are  $a$  days between the arrival of this signal in Amsterdam and the departure of the next boat to London. Once this boat finally arrives in London,  $l$  days have been passed since the signal was originally sent. Variation in  $a$  and  $l$  is determined by weather conditions at sea.

The relevant returns are given by:

$$\begin{aligned}
 \text{Amsterdam news returns:} & \quad p_{t+a}^A - p_t^A \\
 \text{London pre-news returns:} & \quad p_{t^*+l}^L - p_{t^*}^L \\
 \text{London news returns:} & \quad p_{t^*+l+1}^L - p_{t^*+l}^L \\
 \text{Earlier news from London:} & \quad p_{t^*}^L - p_t^A
 \end{aligned}$$

Figure 5: Setup - model with slow moving capital



This diagram describes the setup of the model with slow market maker capital.

- (a) Transmission of liquidity shock  $(1 - \theta)U$
- (b) Transmission of market making capital: enabling one market maker in Amsterdam
- (c) Arrival of capital in Amsterdam from elsewhere: enabling  $N$  additional market makers
- (d) Possible transmission of new capital: additional  $M$  additional market makers (with prob.  $1 - \pi$ )

Table 1: Co-movement - baseline

Panel (A): Dep. variable: Amsterdam post-arrival <i>news</i> returns, $R_{k,t=1}^A$						
	EIC		BoE		3% Annuities	
	(1)	(2)	(3)	(4)	(5)	(6)
London post-departure returns, $R_k^L$	0.287 (0.059)***	0.291 (0.048)***	0.193 (0.077)**	0.238 (0.053)***	0.226 (0.102)**	0.242 (0.072)***
London pre-departure returns, $R_{k-1}^L$		0.395 (0.048)***		0.501 (0.065)***		0.605 (0.066)***
Lagged London pre-departure returns, $R_{k-2}^L$		-0.028 (0.044)		0.059 (0.055)		0.081 (0.054)
Lagged Amsterdam returns, $R_{k-1}^A$		-0.149 (0.080)*		-0.328 (0.058)***		-0.386 (0.063)***
Constant	0.069 (0.033)**	0.052 (0.027)*	0.038 (0.020)*	0.028 (0.018)	0.052 (0.024)**	0.015 (0.019)
Obs.	585	570	558	544	663	646
Adj. $R^2$	0.104	0.323	0.033	0.342	0.035	0.412
Panel (B): Dep. variable: Amsterdam post-arrival <i>no-news</i> returns, $R_{k,t=2}^A$						
London post-departure returns, $R_k^L$	0.216 (0.057)***	0.251 (0.056)***	0.255 (0.066)***	0.301 (0.068)***	0.265 (0.083)***	0.310 (0.085)***
London pre-departure returns, $R_{k-1}^L$		0.146 (0.053)***		0.100 (0.071)		0.199 (0.075)***
Lagged Amsterdam returns, $R_{k,t=1}^A$		-0.142 (0.069)***		-0.212 (0.073)***		-0.190 (0.070)***
Constant	-0.024 (0.032)	-0.026 (0.032)	0.016 (0.024)	0.020 (0.024)	0.014 (0.026)	0.019 (0.026)
Obs.	310	306	282	277	374	368
Adj. $R^2$	0.094	0.136	0.078	0.127	0.058	0.115
$\chi^2$ test	0.68	0.26	0.30	0.50	0.08	0.36
(p-value)	0.411	0.608	0.584	0.480	0.781	0.547

Estimates of co-movement between London post-departure and Amsterdam post-arrival returns.

Figure 3 gives the exact definitions of returns. London post-departure returns are calculated

over the three days after a boat departure. A  $\chi^2$  test is performed on the equality of the  $R_k^L$

coefficients in panels A and B. \*\*\*, \*\*, and \* denote statistical significance at the 1, 5, and 10%

level. Robust, bootstrapped standard errors are reported in parentheses.

Table 2: Co-movement - different expectations next boat

Dep. variable: Amsterdam post-arrival news returns, $R_{k,t=1}^A$	EIC		BoE		3% Annuities	
	(1)	(2)	(3)	(4)	(5)	(6)
London post-departure returns, $R_k^L$	0.224 (0.069)***	0.201 (0.048)***	0.145 (0.068)**	0.139 (0.061)**	0.214 (0.101)**	0.183 (0.097)**
* $E[A simple] < 3.5$ days	0.151 (0.092)*		0.250 (0.106)**		0.063 (0.141)	
* $E[A extended] < 3.5$ days		0.211 (0.090)**		0.301 (0.099)***		0.171 (0.136)
$E[A simple] < 3.5$ days	0.016 (0.058)		-0.049 (0.035)		-0.064 (0.040)	
$E[A extended] < 3.5$ days		-0.007 (0.057)		-0.040 (0.033)		-0.105 (0.037)***
London pre-departure returns, $R_{k-1}^L$	0.400 (0.044)***	0.400 (0.042)***	0.499 (0.064)***	0.500 (0.067)***	0.606 (0.066)***	0.610 (0.062)***
Lagged London pre-departure returns, $R_{k-2}^L$	-0.026 (0.044)	-0.026 (0.044)	0.048 (0.054)	0.056 (0.055)	0.080 (0.054)	0.084 (0.055)
Lagged Amsterdam returns, $R_{k-1}^A$	-0.159 (0.078)***	-0.157 (0.077)**	-0.318 (0.059)***	-0.314 (0.060)***	-0.389 (0.065)***	-0.383 (0.061)***
Constant	0.046 (0.038)	0.051 (0.036)	0.051 (0.025)**	0.044 (0.024)*	0.042 (0.025)*	0.060 (0.025)**
Obs.	570	570	544	544	646	646
Adj. $R^2$	0.328	0.336	0.355	0.359	0.413	0.421
$\chi^2$ test (p-value)		1.06 (0.303)		0.39 (0.531)		0.69 (0.408)

Estimates of co-movement between London post-departure and Amsterdam post-arrival *news* returns.  $E[A]$  stands for the expected number of days until the next boat arrival.  $E[A|simple]$  is calculated by adding the median sailing time to the departure date of the next boat. For  $E[A|extended]$ , the median sailing time is replaced by a conditionally expected sailing time which is estimated in a duration model using a Gamma distribution, including a number of weather variables and month dummies (see main text). The reported  $\chi^2$  statistics refer to a test on the equality of the coefficients on  $R_k^L * E[A|simple] < 3.5$  days and  $R_k^L * E[A|extended] < 3.5$  days in cols 1 vs 2; 3 vs 4; and 5 vs 6. Exact definitions of returns are in Figure 3. London post-departure returns are calculated over three days after a boat departure. \*\*\*, \*\*, and \* denote statistical significance at the 1, 5, and 10% level. Robust, bootstrapped standard errors are reported in parentheses.

Table 3: Feedback effects

Dep. variable: London returns between $t^* + l$ and $t^* + l + 1$ ( $p_{t^*+l+1}^L - p_{t^*+l}^L$ )						
	EIC		BoE		3% Ann.	
	(1)	(2)	(3)	(4)	(5)	(6)
Amsterdam news return	0.082	0.122	0.084	0.096	0.058	0.062
$(p_{t+a}^A - p_t^A)$	(0.042)**	(0.050)**	(0.056)	(0.059)	(0.041)	(0.042)
* Amsterdam period $a$		0.092		0.033		0.053
		(0.037)**		(0.032)		(0.026)**
* London period $l$		-0.056		-0.022		-0.035
		(0.022)***		(0.021)		(0.017)**
Lagged London return		-0.070		-0.048		-0.042
$(p_{t^*+l}^L - p_{t^*}^L)$		(0.044)		(0.048)		(0.038)
Amsterdam period $a$		-0.032		-0.003		-0.016
		(0.034)		(0.021)		(0.018)
London period $l$		0.007		-0.009		-0.000
		(0.019)		(0.015)		(0.012)
Past London news	-0.054	-0.087	-0.035	-0.046	0.012	0.007
return $(p_{t^*}^L - p_t^A)$	(0.043)	(0.044)**	(0.052)	(0.051)	(0.034)	(0.034)
Constant	0.053	0.046	0.018	0.018	0.008	0.005
	(0.037)	(0.037)	(0.019)	(0.020)	(0.019)	(0.019)
Obs.	694	693	681	681	842	842
Adj. $R^2$	0.00	0.03	0.01	0.01	0.01	0.02
$\chi^2$ test		2.85		0.819		0.738
(p-value)		(0.091)*		(0.366)		(0.390)

This table provides estimates of the feedback effect of Amsterdam returns on London prices. Definitions of the returns and the exact timing are in Figure 4.  $a$  measures the number of days between the arrival of a signal in Amsterdam and the departure of the next boat to London.  $l$  measures the number of days it takes for the private signal to “bounce off” from Amsterdam. Variation in  $a$  and  $l$  is driven by weather conditions. In columns 2, 4, and 6, the baseline effect of  $p_{t+a}^A - p_t^A$  is estimated at median values of  $l$  (10 days) and  $a$  (2 days).  $\chi^2$  statistics refer to a test on the equality of the coefficients on  $p_{t+a}^A - p_t^A$  in cols 1 vs 2; 3 vs 4; and 5 vs 6. \*\*\*, \*\*, and \* denote significance at the 1, 5, and 10% level. Robust, bootstrapped standard errors are reported in parentheses.

Table 4: Co-movement - Amsterdam as source of information

Dep. variable:	London post-arrival news returns, $R_{k,t=1}^L$			London post-arrival no-news returns, $R_{k,t=2}^L$		
	EIC (1)	BoE (2)	3% Ann. (3)	EIC (4)	BoE (5)	3% Ann. (6)
Amsterdam post-departure returns, $R_k^A$	0.066 (0.052)	0.077 (0.050)	0.049 (0.040)	0.012 (0.058)	-0.006 (0.061)	0.017 (0.044)
Amsterdam pre-departure returns, $R_{k-1}^A$	0.047 (0.045)	0.132 (0.057)**	0.108 (0.037)***	-0.018 (0.053)	-0.010 (0.051)	0.066 (0.040)
Lagged Amsterdam pre- departure returns, $R_{k-2}^A$	0.000 (0.046)	0.042 (0.051)	0.053 (0.042)			
Lagged London returns, $R_{k-1}^L$ or $R_{k,t=1}^L$	-0.089 (0.089)	-0.053 (0.083)	-0.097 (0.058)*	0.030 (0.059)	-0.037 (0.077)	0.022 (0.069)
Constant	0.048 (0.039)	0.018 (0.021)	0.005 (0.020)	0.018 (0.042)	0.066 (0.023)**	0.031 (0.024)
Obs.	593	589	824	286	341	425
Adj. $R^2$	0.00	0.02	0.03	0.00	0.00	0.00
$\chi^2$ test (p-value)	13.5 (0.00)	6.67 (0.01)	6.92 (0.01)	9.65 (0.00)	12.3 (0.00)	9.96 (0.00)

Baselines estimates where the identities of the two cities are switched around, i.e. Amsterdam is assumed the source of relevant information. The (permuted) definitions of returns are in Figure 3. Amsterdam post-departure returns are calculated over three or four days. A  $\chi^2$  test is reported on the equality of the coefficients on  $R_k^A$  in this table and the coefficients on  $R_k^L$  in Table 1, cols 2, 4, 6. \*\*\*, \*\*, and \* denote statistical significance at the 1, 5, and 10% level. Robust, bootstrapped standard errors are reported in parentheses.

Table 5: Co-movement - favorable winds and winter

Dep. variable: Amsterdam post-arrival no-news returns, $R_{k,t=2}^A$	EIC		BoE		3% Annuities	
	(1)	(2)	(3)	(4)	(5)	(6)
London post-departure returns, $R_k^L$	0.242 (0.128)*	0.404 (0.125)***	0.397 (0.182)**	0.354 (0.155)**	0.290 (0.162)*	0.352 (0.144)**
*favorable (A)	0.004 (0.141)		-0.119 (0.195)		0.029 (0.198)	
*non – winter favorable (A)	-0.144 (0.109)	-0.225 (0.141)	0.046 (0.072)	-0.085 (0.161)	-0.033 (0.084)	-0.090 (0.181)
non – winter		-0.036 (0.064)		-0.047 (0.055)		-0.041 (0.052)
London pre-departure returns, $R_{k-1}^L$	0.138 (0.055)**	0.142 (0.053)***	0.101 (0.071)	0.093 (0.072)***	0.197 (0.078)**	0.193 (0.079)**
Lagged Amsterdam returns, $R_{k,t=1}^A$	-0.137 (0.075)*	-0.143 (0.071)**	-0.218 (0.077)***	-0.210 (0.078)***	-0.188 (0.072)***	-0.191 (0.074)***
Constant	0.094 (0.103)	-0.013 (0.053)	-0.017 (0.068)	0.050 (0.048)	0.046 (0.080)	0.045 (0.046)
Obs.	306	306	277	277	368	368
Adj. $R^2$	0.138	0.154	0.125	0.126	0.110	0.113
Obs. with non-favorable	53		50		66	
Obs. with winter		113		97		136

Estimates of co-movement between London post-departure and Amsterdam post-arrival *no-news* returns. Co-movement is made conditional on (1) having favorable winds or not (“favorable”) or (2) observations taking place during the winter or the rest of the year (“non-winter”). The baseline coefficients measure co-movement during the winter or during periods with non-favorable winds. The interaction term captures any additional co-movement outside the winter or during periods with favorable winds. The table uses definition A for non-favorable winds (see main text for details). The table lists the number of observations during the winter or under non-favorable wind conditions. The baseline coefficients are based on this (limited) number of observations. Exact definitions of returns are in Figure 3. London post-departure returns are calculated over three days after a boat departure. \*\*\*, \*\*, and \* denote statistical significance at the 1, 5, and 10% level. Robust, bootstrapped standard errors are reported in parentheses.



Table 6: Co-movement - excluding potential impact Dover-Calais

Dep. variable:	Amsterdam post-arrival news returns, $R_{k,t=1}^A$			Amsterdam post-arrival no-news returns, $R_{k,t=2}^A$		
	EIC (1)	BoE (2)	3% Ann. (3)	EIC (4)	BoE (5)	3% Ann. (6)
London post-departure returns, $R_k^L$	0.274 (0.046)***	0.233 (0.056)***	0.261 (0.073)***	0.411 (0.085)***	0.332 (0.097)***	0.474 (0.171)***
London pre-departure returns, $R_{k-1}^L$	0.401 (0.048)***	0.524 (0.065)***	0.620 (0.069)***	0.436 (0.106)***	0.271 (0.152)*	0.459 (0.129)***
Lagged London pre- departure returns, $R_{k-2}^L$	-0.016 (0.046)	0.066 (0.055)	0.118 (0.051)			
Lagged Amsterdam returns, $R_{k-1}^A$ or $R_{k,t=1}^A$	-0.160 (0.083)*	-0.343 (0.057)***	-0.411 (0.062)***	-0.363 (0.100)***	-0.316 (0.122)***	-0.358 (0.127)***
Constant	0.046 (0.029)	0.027 (0.017)	0.011 (0.019)	-0.037 (0.055)	0.013 (0.039)	0.026 (0.039)
Obs.	538	518	607	157	143	191
Adj. $R^2$	0.33	0.37	0.44	0.31	0.17	0.22
$\chi^2$ test (p-value)				2.05 0.152	0.82 0.366	1.43 0.231

Replication of table 1 (conditional estimates only), omitting all Amsterdam price information that could be affected by news arriving via Dover-Calais (see text for details). London post-departure returns are estimated over three day periods after a boat departure. A  $\chi^2$  test is performed on the equality of the coefficients on  $R_k^L$ : cols 1 vs 4; cols 2 vs 5; and columns 3 vs 6. \*\*\*, \*\*, and \* denotes statistical significance at the 1, 5, 10% level. Robust, bootstrapped standard errors are reported in parentheses.

Table 7: Co-movement - zero returns in London

Dep. variable:	Amsterdam post-arrival news			Amsterdam post-arrival no-news		
	returns, $R_{k,t=1}^A$			returns, $R_{k,t=2}^A$		
	EIC	BoE	3% Ann.	EIC	BoE	3% Ann.
	(1)	(2)	(3)	(4)	(5)	(6)
London post-departure	0.288	0.234	0.249	0.255	0.319	0.304
returns, $R_k^L$	(0.057)***	(0.063)***	(0.076)***	(0.065)***	(0.073)***	(0.086)***
$*I(R_{k-1}^L = 0)$	0.020	0.037	-0.098	0.001	-0.171	0.044
	(0.094)	(0.115)	(0.136)	(0.131)	(0.158)	(0.285)
$I(R_{k-1}^L = 0)$	0.138	0.031	0.082	0.138	0.007	-0.068
	(0.074)*	(0.036)	(0.040)**	(0.075)*	(0.040)	(0.059)
London pre-departure	0.397	0.502	0.607	0.147	0.101	0.198
returns, $R_{k-1}^L$	(0.044)***	(0.068)***	(0.064)***	(0.054)***	(0.072)	(0.077)**
Lagged London pre-	-0.027	0.058	0.083			
departure returns, $R_{k-2}^L$	(0.044)	(0.056)	(0.054)			
Lagged Amsterdam	-0.151	-0.329	-0.388	-0.144	-0.211	-0.189
returns, $R_{k-1}^A$ or $R_{k,t=1}^A$	(0.080)*	(0.061)***	(0.063)***	(0.070)**	(0.077)***	(0.071)***
Constant	0.029	0.023	0.001	-0.050	0.016	0.032
	(0.030)	(0.020)	(0.022)	(0.036)	(0.027)	(0.028)
Obs.	570	544	646	306	277	368
Adj. $R^2$	0.325	0.341	0.413	0.137	0.124	0.112
Obs. with $R_{k-1}^L = 0$	94	96	123	53	40	68

This table presents co-movement estimates that are conditional on whether the London pre-departure return is zero or not:  $I(R_{k-1}^L = 0)$ . The interaction term measures whether there is additional co-movement if  $R_{k-1}^L = 0$ . London pre and post-departure returns are calculated over three day periods. The table reports the number of observations associated with zero returns in London.

\*\*\*, \*\*, and \* denote statistical significance at the 1, 5, and 10% level. Robust, bootstrapped standard errors are reported in parentheses.

Table 8: Expectation next boat and general weather conditions

	$E[A extended]$		t-statistic	Obs.
	< 3.5 days	> 3.5 days		
Average daily temperature ( $^{\circ}C$ )	9.84	9.80	-0.09	898
Fraction of days with average $T < 3^{\circ}C$	0.18	0.16	-0.69	898
Fraction of days with icy frost	0.03	0.03	0.23	898
Fraction of days with snow	0.03	0.03	-0.03	898
Fraction of days with hail	0.02	0.03	1.06	898
Fraction of days with rain	0.26	0.35	2.78***	898
Average daily rainfall (mm)	1.19	1.62	1.97**	898
Fraction of days with rain throughout the day (2 out of 2 or 3 daily obs.)	0.08	0.11	1.60	898
Fraction of days with total daily rainfall > 90 <sup>th</sup> percentile	0.09	0.11	1.17	898
Average max. daily wind speed (Beaufort)	3.04	3.19	1.72*	898
Fraction of days with wind speed > 7 Beaufort	0.00	0.00	0.23	898
Fraction of days with rain and wind speed > 5 Beaufort	0.04	0.05	1.08	898
Fraction of days with snow or hail and wind speed > 5 Beaufort	0.01	0.01	-0.29	898
Fraction of days with thunder	0.02	0.01	-1.08	898

This table presents information about weather conditions on the days London news arrived in Amsterdam. Days are differentiated by whether the next packet boat is expected to arrive in short order or not ( $E[A] \leq 3.5$  days). Information comes from the observatory of Zwanenburg (close to Amsterdam) and is based on 3 observations a day (between sunrise and sunset). The table reports the average temperature during the day (in degrees Celcius) and indicates when at least one observation reports icy frost, snow, hail or rain. Total daily rainfall is determined by adding up the rainfall reported for each observation (this excludes rainfall at nighttime). The table also reports the maximum wind speed across all three observations. Wind speed is measured in Beaufort (0-12). A wind speed in excess of 7 (gales or stronger) can seriously impede pedestrians. A wind speed in excess of 5 (strong breeze or stronger) makes it difficult to use an umbrella. Days with thunder generally feature heavy rainfall. \*\*\*, \*\*, and \* denote statistical significance at the 1, 5, and 10% level. Source: Royal Dutch Meteorological Institute, *KNMI*.

Table 9: Reversals across markets

Dep. variable: Amsterdam return over period $T$ after episode $k$ ( $p_{k+T}^A - p_{k,t=1}^A$ )							
	$T =$	2/3 days	4/5 days	1 week	2 weeks	3 weeks	4 weeks
EIC							
London return ( $R_{k-1}^L$ )	0.043	0.028	0.077	0.077	0.087	0.195	
	(0.043)	(0.060)	(0.060)	(0.077)	(0.104)	(0.115)*	
Constant	-0.007	0.011	0.068	0.131	0.159	0.214	
	(0.028)	(0.038)	(0.048)	(0.067)*	(0.087)	(0.102)	
N	734	733	731	726	719	717	
Adj. $R^2$	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BoE							
London return ( $R_{k-1}^L$ )	0.072	0.142	0.108	0.281	0.325	0.470	
	(0.043)*	(0.069)**	(0.074)	(0.096)***	(0.124)***	(0.150)***	
Constant	0.026	0.054	0.078	0.144	0.247	0.306	
	(0.016)*	(0.022)**	(0.026)***	(0.038)***	(0.050)***	(0.058)***	
N	705	705	702	695	688	685	
Adj. $R^2$	0.01	0.02	0.00	0.02	0.02	0.03	
3% Annuities							
London return ( $R_{k-1}^L$ )	0.081	0.155	0.129	0.255	0.317	0.497	
	(0.052)	(0.061)**	(0.083)	(0.094)***	(0.117)***	(0.131)***	
Constant	0.010	0.045	0.073	0.144	0.241	0.307	
	(0.019)	(0.025)*	(0.029)**	(0.039)***	(0.050)***	(0.058)***	
Obs.	863	862	857	848	838	834	
Adj. $R^2$	0.01	0.02	0.01	0.02	0.02	0.04	

Estimates of regressions predicting future Amsterdam returns based on London returns. The London return is defined as the London pre-departure return ( $R_{k-1}^L$ , defined in Figure 3). The Amsterdam return  $p_{k+T}^A - p_{k,t=1}^A$  is calculated over  $T$  days after the arrival of a boat ( $k, t = 1$ ) where  $T$  varies between 2-3 days and 4 weeks. \*\*\*, \*\*, and \* denote statistical significance at the 1, 5, and 10% level. Robust, bootstrapped standard errors are reported in parentheses.

Table 10: Empirical fit Kyle model and alternative explanations

	Empirical evidence	Kyle model	Inattention / het. beliefs	public news	Search frictions private signals	Slow moving capital
Co-movement	Yes	Yes	Yes	Yes	Yes	Yes
Stronger initial co-movement if next boat expected shortly	Yes	Yes	No	No	No	Yes <sup>1</sup>
Feedback effects in London	Yes	Yes	No	?	?	?
Return continuation	No	No	Yes	No	Yes	Yes
Co-movement in the reverse direction (cities switched)	No	No <sup>2</sup>	No	No	No	Yes <sup>1,3</sup>
_____initially stronger if next boat expected shortly	No	No <sup>2</sup>	No	No	No	Yes <sup>1,3</sup>
Stronger co-movement after zero returns	No	No	No	Yes	No	No
Stronger initial co-movement during good weather	No	No	No	Yes <sup>4</sup>	Yes <sup>4</sup>	No
Return reversals <i>across</i> markets	No	No	No	No	No	Yes

This table summarizes the empirical fit of the Kyle model and a number of alternative explanations. The rows include a number of salient features of the data. “?”: prediction of the model is unclear without further assumptions. <sup>1</sup>Assuming that packet boats brought in capital and improved liquidity in Amsterdam/London. <sup>2</sup>Under the assumption that Amsterdam was *not* an independent source of private information. <sup>3</sup>Assuming that liquidity shocks originated in Amsterdam as well.

<sup>4</sup>Under the assumption that search frictions were related to bad weather. See Sections 4.2 - 4.4 for a detailed discussion.