Board gender-balancing and insider trading performance*

B. Espen Eckbo† Bernt Arne Ødegaard‡

May 16, 2023

Abstract

Using modern holdings-based performance measures, we test whether the dramatic female-director network expansion caused by Norway's board gender-balancing law has improved the information content and performance of trades by male versus female primary insiders. The potential for a network effect arises because industry peers share firm characteristics. We also examine gender-based insider purchase activity following the exogenous price-shocks during the financial crisis to draw inferences about potential differences in risk aversion. We identify a positive network-spurred information effect but no gender-based difference in either holdings-based performance or crisis-induced purchase activity.

JEL classification: G14, M14

Keywords: Board gender-balancing, director network, insider holdings, trading performance, risk aversion

*We are grateful for the comments of Tristan Fitzgerald (discussant), Caleb Houston (discussant), Olga Kuzmina (discussant), Anete Pajuste (discussant), and Karin Thorburn, as well as seminar participants at the Norwegian School of Economics (NHH) and Stockholm University. The paper has been presented at the following academic conferences: the European Finance Association meetings, the Financial Management Association meetings, the FIBE Conference at the Norwegian School of Economics, the Nordic Corporate Governance Conference, the Paris Corporate Finance meetings, the Conference on board diversity quotas at the Stockholm Business School, and the World Finance & Banking Symposium. The research assistance of Helena Fjeldberg, Arne Tobias Malkenes Ødegaard and Dag Thomas Michalsen is also gratefully acknowledged. This research received partial financial support from Tuck's Lindenauer Forum for Governance Research (Eckbo).

†Tuck School of Business at Dartmouth College, b.espen.eckbo@dartmouth.edu

‡University of Stavanger, bernt.a.odegaard@uis.no

1 Introduction

By definition, industry peers share fundamental demand and supply characteristics that drive firm value. With this in mind, we hypothesize that gaining access to a network of peer-company insiders enhances each individual insider's assessment of the value of the insider's own private information. We provide a first test of this network-spurred information hypothesis by exploiting the dramatic shock to the size of the female director network caused by Norway's pioneering board gender-balancing law. Over the two-year period 1/2006–12/2007, this law led to an increase in the fraction of female directors of firms listed on the Oslo Stock Exchange (OSE) from an average of 15% to a legally mandated 40%. Our main objective is to test whether this significant expansion of the female director network has enhanced both the information content and the relative performance of female primary insider trades.[1] We use a standard, fixed-window event-study analysis to detect changes in the information content of insider trades, and modern holdings-based performance tests, which control for the insiders actual holding periods, to identify insiders' abnormal trading performance.

Moreover, we extend our gender-based performance analysis to trades following a second exogenous shock: the financial crisis of 2008. At that point in time, the director networks were gender-balanced and the crisis-induced price declines were, of course, independent of insiders' private information. Hence, possible motivations for insider purchases in the wake of the dramatic price declines ranges from portfolio rebalancing to contrarian investments *without* inside information. While we do not have data on directors' individual holdings outside of the firms in which they are insiders, purchasing additional shares—regardless of the underlying motivation—involves taking on additional (priced or idiosyncratic) risk. Hence, classifying crisis-induced insider purchases by gender allows us to draw new and interesting inferences about relative risk aversion of male and female directors, which so far has been limited to the results of survey data (Croson and Gneezy, 2009).[2]

Our total sample period begins in January 1997—the year of Norway's adoption of the European Union (EU) requirement that insiders report their trades within one day—and ends in December of 2016.

[1] The validity of the exclusion restriction underlying the experimental setting is also supported by the fact that the identity of the director network is publicly available information, and that the quota law did not itself affect the market value of OSE-listed firms (Eckbo, Nygaard, and Thorburn, 2022a,b).

[2] Adams and Funk (2012) suggest that, to be considered a candidate for a board seat in a male-dominated public corporation, females may have to develop core values and risk attitudes that are similar to male directors:"If women must be more like men to break the glass ceiling, we might expect gender differences to disappear among directors." (abstract). After surveying directors in Swedish listed companies in year 2005, they conclude that female executives and directors are, if anything, somewhat *less* risk averse than their male counterparts.

Director networks are measured using the concept of network centrality or pagerank (Page, Brin, Motwani, and Winograd, 1999). The performance analysis is carried out in three distinct steps. The first step tests whether the market perceives the information content of female insider purchase announcements to be greater following the director network shock (i.e., after year 2007). For this particular test, we follow Cohen, Malloy, and Pomorski (2012) and eliminate routine trades, which are unlikely to be viewed by the market as being motivated by inside information. Moreover, as is the case for the standard event-study methodology (Thompson, 1985; Seyhun, 1986; MacKinlay, 1997), the market reaction to insider trading announcements is measured using a fixed event window around the trade date—essentially measuring the abnormal performance of the *firm* itself—not of the insiders whose actual holding periods differ from the fixed event window.

The event-study analysis shows that, prior to the mandatory gender balancing, the market reacts significantly more favorably to primary insider purchase announcements by male directors than by females (the latter is insignificantly different from zero). This result is qualitatively similar to the conclusion of Inci, Narayanan, and Seyhun (2017) on insider trades in the U.S. over the period 1975–2012, a period where the U.S. female director network remains relatively small and stable throughout. However, we then show that the market reaction to female insider purchases switches from insignificant to positive and significant following the mandatory gender-balancing—with a magnitude similar to the average market reaction to male purchases. Cross-sectional regressions further confirm that the market reaction to both male and female director purchases is increasing in firm-level insider-network power. In sum, the female director network expansion has led to an increase in the market's perception of the information content of purchase announcements by female insiders. Since, as we show below, the expansion of the female network occurs without concentrating directorships among a few females (the number of seats remain close to one per female), we infer that the positive information effect is caused by the network expansion itself.

In the second step of our analysis, we test whether mandatory board gender-balancing has affected female primary insiders' trading performance. Here, we implement holdings-based performance tests, which explicitly account for the insiders' actual holding periods. Moreover, to add test power, we exploit the cross-sectional variation in insiders' ability to "buy low and sell high"—measured using the covariance between holdings and future returns. In the U.S., holdings-based covariance tests have so far been

applied to mutual funds only—typically at the quarterly or monthly frequency.[3] However, Eckbo and Smith (1998), who also use insider holdings data, present the first conditional version of Grinblatt and Titman (1993)'s covariance measure (estimated using generalized method of moments–GMM). In this paper, we further contribute by exploring the effect of expanding the time horizon within which private inside information becomes public from one month to three and six months after the insider trade itself. Our overall conclusion is that insiders do not earn statistically significant abnormal returns regardless of gender and whether before or after Norway's board gender-balancing. In other words, when we account for insiders actual holding periods, the significant information content of insider trades generated by the expanded female director network has *not* mapped into abnormal trading performance by either male or female primary insiders.

In the third step of our analysis, we contrast the impact of the financial crisis on the buy-intensity of male and female insiders over the period 10/2008–12/2010. Since Norway's gender-balancing was already in place by 2008, male and female directors had access to equal-sized director networks during this crisis period. Hence, there is no reason to expect male and female directors of the same firm to differ in their interpretation of the exogenous price shock. With this in mind, we present two interesting empirical findings: First, during the crisis period, there is a substantial increase in purchase intensity by *both* male and female primary insiders. Second, as expected given the exogenous nature of the crisis-driven price drop, we verify that the purchase-increase does not generate subsequent holdings-based abnormal performance. Our finding that the increase in purchase intensity is as high for female as for male directors, suggests that female directors are no more risk averse than their male counterparts. This conclusion, which is novel in that it follows from actual trading behavior, is consistent with Adams and Funk (2012), who draw a similar inference based on director surveys.

2 Institutional setting and insider population data

This section summarizes the nature of the board gender balancing that was mandated at the end of 2005, the insider trading regulations in effect during our total sample period, 1997–2016, and our population data on insider trades and holdings.

[3]See, e.g., Cornell (1979), Copeland and Mayers (1982), Grinblatt and Titman (1989, 1993), Ferson and Khang (2002) and, most recently, by Ferson and Wang (2021). Ferson (2010) and Wermers (2011) provide comprehensive reviews of various econometric measures used in studies of mutual fund performance.

2.1 The mandatory board gender-balancing

Under Norway's codetermination law, shareholders elect the majority of directors while the company's employees elect and fill an additional one-third of the board seats. In December of 2005, Norway required public limited companies (ASA)—about half of which are typically OSE-listed—to gender-balance their shareholder-elected directors within two years or face liquidation. The gender quota applies to shareholder-elected directors only, who are nominated by an independent committee and typically appointed for a term of two years, and it does not apply to the much bigger population of private limited companies (AS). Since our empirical analysis includes all primary insiders, it also covers the insider trading activity of non-shareholder-elected directors.

The board gender quota mandates that, in a board with three shareholder-elected directors, at least one must be female and at least one male. Moreover, there must be at least two women for boards with four to five members, three women for six to eight-member boards, and four women for a nine-member board. For a board with ten or more members, the fraction of female (and male) directors must be at least 40%. Several other European countries have since followed Norway's lead by adopting their own mandatory board gender quotas (Belgium, France, Germany, Iceland, Italy, the Netherlands, Portugal, and Spain). These countries typically impose substantially lower penalties for non-compliance than Norway's threat of forced liquidation.

Norway's forced gender-balancing was truly exogenous to the private sector as it was driven by gender politics unrelated to firm performance (explained in the government white paper, *Odelstingsproposisjon* 97 2002–2003). Moreover, it imposed no restriction on companies beyond director gender-balancing. These two points strengthens our use of the gender-balancing as a valid quasi-experimental setting for examining director-network-induced changes in insider trading. It contrasts with more complex corporate governance regulations, such as the 2002 U.S. Sarbanes Oxley Act (SOX), which not only responded to performance scandals (such as Enron) but also mandates complex governance changes ranging from costly new internal control systems to enhanced director fiduciaries (Chhaochharia and Grinstein, 2007; Duchin, Matsusaka, and Ozbas, 2010).

Also relevant for our experimental setting, the comprehensive empirical evidence in Eckbo, Nygaard, and Thorburn (2022a,b) is consistent with a value-neutral impact of teh introduction of Norway's gender-quota. By excluding a direct valuation channel of the forced gender balancing on insider trading, their evi-

dence makes it likely that observed changes in insider trades (if any) are caused by a network-information effect, which forms the basis for our test strategy. The evidence of a value-neutral impact is further supported by descriptive evidence on the professional background of directors and executives (Ahern and Dittmar, 2012; Bertrand, Black, Jensen, and Lleras-Muney, 2019), all of which points to a deep pool of highly qualified potential female directors in Norway.

We collect firm-level data on board size, board composition and director gender from the Brønnøysund Register Centre (1998–2016) via the Norwegian School of Economics (Berner, Mjøs, and Olving, 2013). Panel A of Figure 1 shows the evolution of board size and the number and percentage of females on the boards of OSE-listed Norwegian firms over the 1998–2016 period. The percentage female directors was less than 10% in 1998 and increased to 15% prior to the mandatory gender balancing, which began in January of 2006. Over the following two years the percentage females rose to the mandated 40%—a more than doubling of the number of female directors.

Panel A of Figure 1 also shows that, during our sample period, the average board size has remained stable at five shareholder-elected members, which means that shareholders typically chose to replace male directors with females rather than expanding board size to meet the quota requirement. An alternative shareholder strategy could have been to retain all five male directors and fill the quota by hiring three additional female directors—expanding board size to eight members. However, not a single ASA made this expansion (Eckbo, Nygaard, and Thorburn, 2022a,b). This evidence further suggests that shareholders perceived the cost of the gender quota to be relatively low—with the cost of expanding board size to eight directors as an expected upper bound on this cost.

Panel B of Figure 1 also confirms that, regardless of gender, the board gender-balancing did not lead to an increase in the number of board seats per director in OSE-listed firms. Rather, in both year 2002 and 2008, only a small fraction of all directors hold more than one seat, with single-seat female directors replacing single-seat male directors to satisfy the gender-balancing requirement. For example, in 2008, 86% of all directors hold a single board seat only, with an additional 10% holding two seats only. The lack of concentration of board seats among a few female directors in 2008 confirms that shareholders were able to fulfill the gender quota from a deep supply of qualified female directors.

2.2 Quantifying the board network at the OSE

To further characterize the interconnectedness of OSE boards we formally construct the network of board connections. For two OSE boards to be connected, at least one of the directors must sit on both boards. In the terminology of network analysis, and as illustrated in Figure 2, a company (board) is a single node in the network, while the connection between nodes (directors on both boards)—so-called edges or lines—goes both ways. The figure shows the change in the network from year 2002 (the year before the first public discussion of a possible gender quota) to year 2008 (the first year of full quota compliance). Solid (red) dots are companies with at least one female on the board, while grey (blue) dots represent all-male boards.[4]

Figure 2 illustrates the effect of gender-balancing. In year 2008, the few remaining all-male boards (blue nodes) are foreign firms listed on the OSE, which are not regulated by the quota law. More important, the figure shows an increase in the number of director linkages in 2008 relative to 2002. In other words, while gender-balancing has led to a dramatic increase in the female director network, the overall board network has also become somewhat more connected. For this to have happened, some of the incoming female directors most likely have replaced male directors that were less connected. In our empirical hypotheses below, it is this dramatic increase in the female director network that drives the potential for female insider trading performance and the market reaction to female trades.

2.3 Insider trading regulations

Our sample period starts in January 1997 when Norway began implementing a new generation insider trading legislation ("Lov om Verdipapirhandel") adopted by the European Union. Norway is under treaty obligation to adopts EU regulations, including EU restrictions on insider trades, and there has only been minor adjustments to EU's and Norway's insider trading regulations between 1997 and the end of our sample period (December, 2016).[5] The law defines inside information as reasonably precise price-sensitive information that is not yet publicly available. In principle, all use of such inside information for trading is illegal, no matter who trades on it.

Companies are also obligated to maintain on an ongoing basis an internal list of individuals with

[4] In the Internet Appendix we reproduce Figure 2 using the board-network of all public and private ASA.

[5] For a summary of Norway's insider trading regulations, see sections 6 (Issuer's obligations) and 7 (primary insider's obligations) of NOU 2017:4.

access to important price-sensitive information. This list must be turned over to the OSE and the financial regulator *Finanstilsynet* upon request. Such requests, which tend to follow significant corporate events, enhance the law's oversight function as individual insiders end up on the financial regulator's radar screen even if they themselves did not actively trade around those events. Moreover, the law assigns an enhanced responsibility for *primary insiders*—board members and top management including the chief executive officer (CEO) and chief financial officer—to report their trades to the market. While our empirical analysis includes data on all insider holdings and trades, our main empirical tests focus on primary insiders.

Also important, under the 1996 legislation, insiders must publicly report their trades within one day, which typically happens prior to next day's stock-market opening. The law also specifies certain insider trade blackout periods, including prior to corporate earnings announcements. As is typical in the literature on insider trading, we study *all* trades based on public reporting—not just the trades that were judged to be illegal *ex post* (Meulbroek, 1992; Bhattacharya, 2014). What is clear *ex ante* is that insiders do from time to time possess price-sensitive information, and that the likelihood that they trade on this information depends on the expected financial and reputational cost of doing so.

A quick search identifies a total of 22 court cases where the defendant is charged with criminal insider trading over the period 1998–2018. In general, a conviction leads to both jail time and a fine equal to the estimated trading profit. This enforcement likely deters blatantly illegal trades, but leaves room for smaller information-based trades that are hard to classify as illegal *ex post*. The performance tests reported below therefore examine whether insiders on average are able to include, undetected, such smaller information-based trades among their more routine trades.

2.4 Population data on insider trades and holdings

We collect population data on insider trades and holdings over the period 1997–2016 from OSE electronic records (`https://newsweb.oslobors.no/`). To be included, the trade announcement must contain the name and formal company-position of the insider, the trade date, and the number of shares bought or sold. The report typically also include the insider's share holding after the reported trade. If the holding is not reported, we reconstruct the holding by adding or subtracting the purchase or sale to the previously observed holding. In addition to insider trading data, we obtain stock prices, accounting information and corporate events from the OSE data service and Datastream, interest rates from Norges

Bank (The Norwegian Central Bank), and other macroeconomic information from the Norwegian Bureau of Statistics (SSB).

As shown in Panel A of Table 1, the total number of trades over the 1997–2016 period is 24,217. This total includes trades in different firms by the same insider, which as it turns out occur only rarely. Moreover, we succeed in classifying 21,406 of these transactions by gender—a classification success rate of 88%. We identify the insider's gender from his or her given name, which in Norway nearly always identifies the gender. For insiders with foreign names, we include only those where the gender is unambiguous from the given name. Of the gender-identified insider trades, 74.8% (16,003) are executed by primary insiders (management and board members).

In their study of insider trades in the U.S., Cohen, Malloy, and Pomorski (2012) filter out routine (repeat) trades, which may be considered non-informative. Specifically, an insider trade in month t is labeled as routine if the same insider traded in the same calendar month in each of the three years preceding the trade in month t. Interestingly, while Cohen, Malloy, and Pomorski (2012) report that 50% of their U.S. insider trades are classified as non-informative, repeat trades by insiders in our study constitutes only 12% of the total (Panel A of Table 1). One reason for this difference is the low frequency of stock- and option-based executive compensation plans among OSE companies.[6] While we include all trades when computing insider holdings, as indicated below, we eliminate routine trades in some of the trade-performance analysis.

Panel B of Table 1 provides information on insider transactions in terms of purchases, sales and trade size, classified by gender and primary insider. 15% of the 6,179 distinct primary insiders are female, and the total transaction value is NOK 14.1 billion for purchases and 6.6 billion for sales (measured in 2016 constant kroner). Of the purchase transactions, which are the main focus of our insider trading analysis, female primary insiders undertake 11.5%. While not tabulated, this percentage increases from 7.1% before 2008 to 15.3% afterwards. In terms of value, the median purchase-size of primary female insiders is about half that of the median-sized male insider purchase.

In Panel C of Table 1, we follow Inci, Narayanan, and Seyhun (2017) and report, for each insider, the average annual number and value of his/her trades per year over the insiders' tenure period. This measure is not affected by the low fraction of female insiders early in our sample period, and therefore provides

[6]Prior to 1999, stock options as a form of managerial compensation was extremely tax disadvantaged: the exercise value was taxed as regular income in the year of the option grant.

a more direct comparison of the trading intensities of male and female insiders. In this calculation, the first year of an insider's tenure period is the year of the first reported trade in our data, while the ending year is the year of the last reported trade. Thus, an insider with just one reported trade—or several trades within one year—are recorded as having a tenure period of just one year. The results in Panel C show that male insiders tend to trade more in total NOK. However, trading *intensity*—the number of transactions per year over the insider's tenure period—is actually similar across male and female insiders.

Figure 3 shows the average percent insider ownership (Panel A) and fraction of primary-insider trades by females (Panel B). In Panel A, the average percent insider ownership is calculated by, for each company, summing the holdings of all reporting insiders on a daily basis. We then aggregate each firm's daily insider ownership series up to a quarterly level, and plot the average quarterly insider holdings for each quarter. This average is shown on the left axis, while the right axis shows the total market value of all OSE-listed stocks in billion NOK.

Panel B of Figure 3 shows the annual percent of all primary insider trades performed by female executives and directors. Throughout the sample period, female executives trade substantially more than female directors. For both categories of primary female insiders, the percentage of all trades jumps noticeably following the 2005 board quota law (which gave firms until 2008 to fully comply). As expected, this increase is greater for female directors than for female executives.

3 Market reaction to non-routine insider purchases

In this section, we begin our network information analysis by examining the market reaction to public announcements of insider trades, which during our sample period occur the day following the trade at the latest. Our empirical hypothesis is summarized in Proposition 1:

Proposition 1 (market reaction): *The increase in the female director network caused by Norway's mandatory board gender-balancing enhances the market's perception of the value of a female director's information when she trades.*

The economic reason for the potential existence of a network-driven information effect is that firms operating in related industries and using related supply chains face similar production technologies. Hence, within-network communications has the potential for enhancing each individual director's basic

understanding and assessment of the value of the inside information.

3.1 Event-study specification

We estimate the short-term market reaction in event time around dates of insider purchases. We focus on insider purchases because the extant literature tends to conclude that stocks perform abnormally well following insider purchases, with negligible abnormal performance following insider sales (Cohen, Malloy, and Pomorski, 2012). Moreover, for this analysis, we screen out the routine trades (explained in Section 2.4 above), as these are unlikely to be based on inside information. Also, since insiders during our sample period are required to report their trades within 24 hours, the analysis is performed using daily stock returns.

We estimate the conditional abnormal return parameter γ_i in the following one-factor return-generating process for firm i:

$$r^e_{it} = a_i + b^m_i(r_{mt} - r_{ft}) + \gamma_i D_{it} + \varepsilon_{it}, \quad t = t_{i1}, \ldots, t_{i2}, \tag{1}$$

where r_{it}, r_{mt}, and r_{ft} are the one-day returns to firm i, the equal-weighted market portfolio of OSE stocks, and the risk-free rate (the Norwegian Interbank Offered Rate or NIBOR). The start-date of the estimation, t_{i1}, is 1/1/1997 or, if later, the date firm i is first listed on the OSE. The end-date, t_{i2}, is the earlier of delisting and 12/31/2016. The estimation is done for the two periods 1997–2007 and 2008–2016, respectively.

D_{it} is a dummy variable that takes a value of one inside an event window centered on the day of the insider purchase (day 0 in event time) and zero otherwise, while ε_{it} is a mean-zero error term. We employ four alternative event windows (from day τ_1 to day τ_2): days $(-1, 1)$, $(-1, 5)$, $(-1, 25)$, and $(-1, 50)$. By construction, the event parameter γ_i measures the average daily abnormal return across all event windows experienced by firm i between t_{i1} and t_{i2}. The joint estimation of all firm-i events using Eq (1) avoids the double-counting of overlapping event periods in calendar time that may otherwise occur when a series of events by the same firm are treated as independent.[7]

Ignoring for simplicity the firm-subscript i in Eq. (1), the cumulative abnormal return over firm i's

[7]We have also verified that using the more standard residual-return approach (here with a fixed 250-day estimation period prior to the event and the exclusion of days with prior events in the estimation period) does not materially change our main conclusions. See, e.g., MacKinlay (1997) for a description of the standard residual-based approach to estimating event-induced abnormal returns, which treats multiple events by the same firm as independent. Thompson (1985) provides a general comparison of the conditional event-parameter estimation (such as in Eq. (1) above), while Kothari and Warner (2007) and Kolari and Pynnönnen (2010) discuss power issues in event studies.

k'th purchase event is:

$$CAR_k(\tau_1, \tau_2) = \tau_k \gamma_k, \tag{2}$$

where τ_k is the number of trading days in the k'th event window. Moreover, the t-statistic of CAR_k is $t_k = \tau_k \gamma_k / \sigma_{\tau\gamma} = \gamma_k / \sigma_\gamma$ where the standard deviation σ_γ is provided by the regression Eq. (1). If two event windows overlap in calendar time, we adjust (shorten) the second window so that they do not overlap, and adjust τ_k accordingly.

The literature estimating cumulative abnormal stock returns around reported insider trades, of which our CAR_k is one example, goes back to Jaffe (1974) and Seyhun (1986) on U.S. data.[8] A typical finding in this literature is a positive market reaction to insider buys with no statistically significant market reaction to insider sales. Moreover, in the extant literature, Inci, Narayanan, and Seyhun (2017) also condition the market reaction to insider trades on gender. However, unlike this study, they do not have access to a quasi-experimental setting that shocks the pool of female insiders.

3.2 Event-study test results

Table 2 shows the results of the event study estimation for each of the two sub-periods.[9] The estimates provide significant support for the positive information effect of the female director network expansion hypothesized in Proposition 1. Specifically, the table shows a statistically significant increase in the average $CAR(-1, 1)$ and $CAR(-1, 5)$ for female insiders from essentially zero in the pre-quota period (1997–2007) to a significant 0.15% and 0.14% in the post-quota period (2008–2016), respectively. For males, in both periods, the average CAR is significantly positive in the two shortest windows, $(-1, 1)$ and $(-1, 5)$. We infer from this evidence that insider purchases convey positive firm-specific information to the market, and more so for female trades after the quota-law was implemented.

The increase in the CAR based on female purchases possibly reflects a combination of two effects, both driven by the board reform. First, the female network expansion may have given female insiders better access to valuable inside information, on which they trade occasionally. Second, the network expansion itself may have increased the stock market's confidence in the information conveyed by female insider

[8] For more recent examples, also on U.S. data, see, e.g., Chang and Suk (1998), Lakonishok and Lee (2001), Jeng, Metrick, and Zeckhauser (2003), Betzer, Gider, Metzger, and Theissen (2015), and Inci, Narayanan, and Seyhun (2017). Fidrmuc, Goergen, and Renneboog (2006) compare insider trades in the U.K. and the U.S., Cziraki, Goeij, and Rennebog (2014) use data from the Netherlands, while Berkman, Koch, and Westerholm (2023) perform their analysis on data from Finland.

[9] For completeness, we also report the event-study estimation results for the entire sample period, 1996–2016, in an Internet Appendix.

trades. The evidence that the *CAR* of male insiders has not materially changed with the quota also supports the notion that you need a network increase to signal an increase in the information content of the trades. As Table 2 also shows, the board reform, which create two and largely equal-sized male and female director networks, appear to have resulted in the average *CAR* of female insiders to become not only statistically significant but also of a magnitude that is indistinguishable from the average *CAR* of male insiders.

In Table 3, we further quantify the impact of a board's network centrality on the market reaction to the firm's primary insider purchases. Our measure of centrality is the pagerank network centrality score (Page, Brin, Motwani, and Winograd, 1999).[10] To estimate the impact of this network centrality score, we estimate the following cross-sectional regressions with abnormal returns as dependent variable:

$$CAR_i(\tau_1, \tau_2) = \alpha_i + \beta_1 MktCap_i + \beta_2 TradeSize_i + \beta_3 Centrality_i + \varepsilon_i, \tag{3}$$

where τ_1 and τ_2 defines the days in the event window. The regressors consist of the (log) market capitalization of the firm (*Market Cap*), the (log) size of the insider trade (*Trade Size*), and the board's PageRank score (*Centrality*). Table 3 shows that *Centrality* receives a positive coefficient in all four columns, with the coefficient estimate being highly significant with $CAR(-1, 1)$ as dependent variable in Column (1). This evidence supports the notion that the market views insider purchases as having greater (positive) information content when the insider sits on a board with relatively high centrality score.

In sum, following the dramatic increase in the female director network expansion caused by Norway's mandatory board gender-balancing, the short-term performance of female purchases has increased significantly, from zero to an average of 0.15% over the seven-day window following purchases. Also consistent with our Proposition 1, the results of the cross-sectional regressions with pagerank as a director network centrality score further indicate that the market assigns greater information content to purchases by directors who sit on highly connected boards.

Our finding of a positive coefficient on the network centrality parameter is consistent with the results

[10] In using the pagerank score, we follow the network literature (Newman, 2018, pg 167). The pagerank network centrality score is the basic algorithm underlying Google's search engine. Intuitively, with a total of N individual directors across firms, one measure of network centrality is simply the number of direct connections to the other $N-1$ directors. Pagerank expands this definition by using eigenvector centrality, which modifies the sum of network connections by giving greater weight to directors who themselves have important connections. Moreover, pagerank adds a small positive weight to otherwise isolated directors (who receive a zero weight in the simple count). The pagerank computation is carried out with the R library `igraph` (Csardi and Nepusz, 2006).

in Akbas, Meschke, and Wintoki (2016), Marc, Renneboog, and Zhao (2019), and El-Khatib, Jandik, and Jandik (2021) who infer that trades of relatively well-connected directors are also more profitable. Moreover, our results are consistent with Clacher, Osma, Scarlat, and Shields (2021) who look at gender differences in CEO networks (absent a network shock).

We next turn to the question of whether the increased information content of purchases by female primary insiders have also allowed these insiders to realize a positive holdings-based abnormal performance—a systematic ability to buy low and sell high. This question cannot be answered by the cross-sectionally constant (and therefore counterfactual) holding periods underlying the event-study technique but must instead use the actual holding periods of firm i's insiders.

4 Insider performance evaluation

In this section, we link the director-network shock caused by Norway's forced gender-balancing to the actual portfolio performance of primary insiders:

Proposition 2 (insider performance): *The increase in the female director network caused by Norway's mandatory board gender-balancing enhances the value of female primary-insider information which, if exploited, translates into improved holdings-based abnormal insider performance.*

While Proposition 1 above focuses on the market's perception of the information content of insider purchases, Proposition 2 holds that the increased information content documented empirically in Section 3 maps into enhanced insider performance. The basic idea is that the increase in the female director network caused by the mandatory board gender balancing has improved informal network communications with industry peers, which in turn improves individual insiders' understanding of the market's assessment of their own-firm values.

4.1 Holdings-based performance measurement

4.1.1 The holdings-based performance measure

Let ω_{it} denote the weight of insider holdings in firm i at time t, and $r_{i,t+\tau}$ the firm's τ-period future stock return. For an insider to show positive τ-period performance, the covariance between ω_{it} and $r_{i,t+\tau}$ must

be positive:

$$cov(\omega_{it}; r_{i,t+1}) = E(\omega_{it}(r_{i,t+1} - E[r_{i,t+1}])) = E[(\omega_{it} - E[\omega_{it}])r_{i,t+1}] > 0. \tag{4}$$

This covariance-definition shows that a holdings-based covariance measure of performance requires demeaning the portfolio weight or the stock return—or both, which is the general approach behind our holdings-based covariance measure, here denoted *HCM*:

$$HCM = \frac{1}{T-2}\sum_{t=1}^{T}\frac{1}{N_t}\left(\sum_{t=1}^{N_t} cov\left(\omega_{it} - E[\omega_{i,t-1}]; r_{i,t+\tau} - E[r_{i,t+\tau}]\right)\right). \tag{5}$$

N_t is the number of OSE-listed firms at time t and T is the length of the estimation period. Thus, computing *HCM* requires specifying (i) the length of time $t+\tau$ that it may take before the insider's private information reaches the market, (ii) the insider's stockholding ω_{it} and its change $\Delta\omega_{it} \equiv \omega_{it} - E[\omega_{i,t-1}]$, and (iii) the stock's risk-adjusted τ-period future expected stock return $E[r_{i,t+\tau}]$.

To compute *HCM*, we adopt the following four specifications. First, to allow for potentially long-lived inside information, we report results for each of the following three alternative return horizons: horizons $(t+\tau)$:

$$\tau \equiv \begin{cases} \text{1 month} & \text{short-lived insider information} \\ \text{3 months} & \text{intermediate-lived insider information} \\ \text{6 months} & \text{long-lived insider information} \end{cases} \tag{6}$$

While the return horizon τ is treated as a constant across insiders, it introduces a novel perspective on the potential for longer-lived inside information.

Second, we measure ω_{it} in two different ways:

$$\omega_{it} \equiv \begin{cases} \omega_{it}^{ow} = s_{it}/S_{it} & \text{insider ownership weight} \\ \omega_{it}^{vw} = p_{it}s_{it}/\sum_{i=1}^{N_t} p_{it}s_{it} & \text{insider value weight} \end{cases} \tag{7}$$

Here, S_{it} denotes firm i's total number of shares outstanding at time t, of which insiders hold s_{it} number of shares. This insider holding is worth $s_{it}p_{it}$, where p_{it} is firm i's stock price. In other words, ω_{it}^{ow} measures the fraction of firm i's total shares outstanding that are held by the firm's insiders, while ω_{it}^{vw} measures the fraction of the value of all insiders' shareholdings across the N listed firms that is invested in firm i at time t. While ω_{it}^{ow} gives greater weight to firms in which insiders hold a larger ownership

fraction of the firm's outstanding shares, ω_{it}^{vw} gives greater weight to firms where this shareholding also represents a relatively large share of the total investments across all insiders.

Third, as to the weight-change $\Delta\omega_{it}$, we employ two alternative measures:

$$\Delta\omega_{it} \equiv \begin{cases} \omega_{it} - \omega_{i,t-1} & \text{insider weight change} \\ \omega_{it} - \omega_{i,t-1}^{m} & \text{market-adjusted insider weight change} \end{cases} \tag{8}$$

where $\omega_{i,t-1}^{m}$ is firm i's value-weight in the OSE market portfolio at time $t-1$. We explore both definitions of a weight change because ω_{it} is impacted by changes in the market value of OSE stocks even if the insider does not actively trade. The weight change $\omega_{it} - \omega_{i,t-1}^{m}$ corrects for such "buy-and-hold" changes in the market-based weights.

Fourth, $E[r_{i,t+\tau}]$ is computed as the predicted return from the following four-factor model (Fama and French, 1993; Carhart, 1997):

$$r_{it}^{e} = \alpha_{it}^{4f} + \beta_{i}^{m}\left(r_{mt} - r_{ft}\right) + b_{i}^{smb} SMB_{t} + b_{i}^{hml} HML_{t} + b_{i}^{mom} MOM_{t} + \epsilon_{it}^{e}, \tag{9}$$

Here, $r_{it}^{e} = r_{it} - r_{ft}$ is the return to firm i in month t in excess of the risk-free rate (the monthly NIBOR). SMB_t is a size factor (a portfolio of Small-Minus-Big stocks), HML_t a value factor (a portfolio of High-Minus-Low book-to-market stocks), and MOM_t is a momentum factor (a long-short portfolio of stocks that is long in above-mean return and short in below-mean return over the past twelve months). All factors are generated within the OSE cross-section of stocks (Næs, Skjeltorp, and Ødegaard, 2008). Specifically, at date $t-1$, we estimate the four-factor model in Eq. (9) using five years of monthly return data. This yields a rolling (time varying) vector of OLS-estimated coefficients $\left\{\hat{\alpha}_{i,t-1}, \hat{\beta}_{i,t-1}^{m}, \hat{b}_{i,t-1}^{smb}, \hat{b}_{i,t-1}^{hml}, \hat{b}_{i,t-1}^{mom}\right\}$, which are then used to generate an estimate of the expected return $E[r_{i,t+\tau}]$.

In terms of the extant literature, beginning with Grinblatt and Titman (1993), studies of mutual fund performance have employed variations of *HCM* as holdings-based covariance performance measures applied to quarterly holdings data (Ferson and Khang, 2002; Ferson and Wang, 2021). In the literature on insider performance evaluation, the only other study employing this type performance measure is Eckbo and Smith (1998), who replace the bracketed expression in our Eq. (5) with the following:

$$\sum_{i=1}^{N_p} cov(\omega_{it}, r_{i,t+1} | Z_t^*) = \sum_{i=1}^{N_p} E[\omega_{it}(r_{i,t+1} - E[r_{i,t+1}|Z_t^*])|Z_t^*]. \tag{10}$$

This differs from *HCM* in that it does not demean the weight ω_{it}. Also, Eckbo and Smith (1998) use a set Z_t^* of public information available at time t to generate the conditional expected return $E[r_{i,t+1}|Z_t^*]$. We instead use the rolling estimation of Eq. (9) to account for possibly time-varying expected returns.[11]

Finally, a note on three methodological issues that has also been raised in the extant literature on insider trading. First, Akbas, Jiang, and Koch (2020) and Biggerstaff, Cicero, and Wintoki (2020) suggest that the trading by long term investors is more informative than short-term investors. While, as shown above, the return horizon $(t+\tau)$ is cross-sectionally constant in our analysis, our returns-based portfolio analysis below, which is based on insiders' actual portfolio weights, does capture the insiders' actual holding periods. Second, as pointed out by Eckbo and Smith (1998), Marin and Olivier (2008), and Gao, Ma, Ng, and Wu (2022), it is important to also account for the effect of decisions by insiders *not* to trade. Our weight-based portfolio analysis captures the effect of insider non-trading: a constant (non-changed) weight is still related to a subsequent stock return. Third, since our covariance-based analysis (HCM) uses weights that are increasing in the size of the insiders' investment in the firm, we also capture the effect, if any, of the relative magnitude of trades, which Cziraki and Gider (2021) instead examine using the dollar profit of insider trades.

4.1.2 Holdings-based performance results

Data necessary to construct ω_{it} are from the insider holdings (number of shares) contained in the insider reports to the OSE, which starts in 1997. To correctly measure insider holdings, we use *all* trade and holding information for all insider trades. That is, contrary to the event-study analysis in Section 3 above, we do not exclude routine trades. If a firm with positive insider holdings delists from the stock exchange, we assume that the insider's holding is brought to zero (sold) at the end-of-month price prevailing just prior to the month of delisting. As for the initial and final share-holdings of individuals (added and subtracted on the dates when they became or ceased to be insiders according to our records), we follow the convention in the extant literature of not treating these as *bona fide* information-based purchases or sales.

Columns (1)–(6) of Table 4 show the result of the estimation of *HCM*, classified by gender, for the

[11] Eckbo and Smith (1998) perform their insider trading analysis during the period 1985–1992, which covers Norway's first generation insider trading regulations. During their sample period, insiders were required to report their trades within one month, which contrasts with the 24-hour reporting requirement introduced in 1997 (Section 2.3 above). While not tabulated, we have verified that using our *HCM* statistics on data from the period 1985–1992 confirms the main conclusion of Eckbo and Smith (1998).

two periods 1997–2007 and 2008-2016.[12] Columns (3) and (6) show p-values for tests of equality of HCM for male and female insiders, respectively. The main conclusion is that we cannot reject the hypothesis of zero abnormal performance either before or after the forced board gender-balancing. All of the values of HCM in columns (1)–(6) indicate that insiders' abnormal performance is statistically insignificant at conventional levels. The results in Table 4 therefore fail to support Proposition 2. That is, we cannot conclude that the significant female-director network expansion caused by Norway's mandatory board gender balancing has improved the performance of female primary insiders' stock holdings.

4.2 Returns-based performance measurement

In the analysis above, we test the performance of primary insider trades using the holdings-based covariance measure HMC estimated cross-sectionally for our OSE-listed firms. Exploiting this cross-sectional variation enhances the precision of the test results. In this section, however, we instead calculate the returns of our insider portfolio (formed using the weights ω_{it}) and use the more standard time-series estimate of Jensen's alpha (Jensen, 1968) to identify abnormal portfolio performance for portfolio p, α_p. As illustrated in particularly simple terms by Ferson and Wang (2021),[13] Jensen's alpha for a portfolio can itself be decomposed as $\alpha_p = TSA + AAR$, where TSA is the time-series predictive ability averaged across the stocks in the portfolio. TSA, which we approximate with our covariance measure HCM above, reflects both factor timing and short-term security selection information. The second term, AAR, is the portfolio's abnormal return based on its average weights over the estimation period (hence interpreted as a long-run measure of performance). The larger the AAR, the more the portfolio weights on average overweighs the high-alpha stocks and underweighs the low-alpha stocks in the portfolio.[14]

4.2.1 Returns-based performance measure

We estimate α_p for our two insider portfolios with holdings-based portfolio weights ω_{it}^{ow} and ω_{it}^{vw}. For each gender-based portfolio, we also form a zero-investment portfolio that is long in the male insider and short in the female insider portfolios, respectively. Let $r_{pt}^e = r_{pt} - r_{ft} = \sum_{i=1}^{N_t} \omega_{it}(r_{it} - r_{ft})$ denote the

[12] For completeness, and as a check on whether using the longer sample period 1997–2016 leads to a different conclusion, In the Internet Appendix we show estimates based on the total sample period. The results based on the total sample period are consistent with those reported in Table 4.

[13] For further conceptual reviews, see also Ferson (2010) and Wermers (2011).

[14] "If the AAR component of performance reflects the long-term policy of the fund, it is not likely to be related to active management." (Ferson and Wang, 2021, p.4).

monthly stock return to an insider portfolio with weights ω_{it} in excess of the risk-free rate. Our two returns-based performance measures represent variations of α_{pt}, where

$$\alpha_{pt} \equiv \begin{cases} \alpha_{pt}^{4f} = r_{pt}^{e} - [\widehat{\beta}_{p}^{m}\left(r_{mt} - r_{ft}\right) + \widehat{b}_{p}^{SMB} SMB_{t} + \widehat{b}_{p}^{HML} HML_{t} + \widehat{b}_{p}^{MOM} MOM_{t}] \\ \alpha_{pt}^{rb} = r_{pt}^{e} - [\widehat{\beta}_{p,t-1}^{rb}\left(r_{mt} - r_{ft}\right)] \end{cases} \tag{11}$$

Here, the first performance metric is the constant term α_{p}^{4f} in the four-factor return model also used to form our covariance measure in Section 4.1 above.

The second metric, α_{pt}^{rb}, is an estimate of the constant term in the rolling-beta estimation of the one-factor capital asset pricing model (CAPM), which allows for time variation in the portfolio's (lagged) market risk factor exposure $\beta_{p,t-1}^{rb}$. We report the average of these constant terms, $\alpha_{p}^{rb} = \frac{1}{T}\sum_{t=1}^{T}\alpha_{pt}^{rb}$. The estimate of the portfolio beta ($\widehat{\beta}_{p,t-1}^{rb}$) is calculated as a weighted average of beta estimates for the stocks in the portfolio: $\widehat{\beta}_{p,t-1}^{rb} = \sum_{i=1}^{N_t}\omega_{it}\widehat{\beta}_{i,t-1}$. For each firm i, the beta $\widehat{\beta}_{i,t-1}$ is estimated using three years of daily returns prior to the current month and the Scholes and Williams (1977) lead-lag beta adjustment for non-synchronous trading.

4.2.2 Returns-based test results

Table 5 summarizes the returns-based performance estimates for the portfolios of primary insiders for each of the two subperiods before and after the gender-quota introduction, respectively.[15] In each table, the first panel shows portfolio return descriptives, including average raw return, average excess return, and portfolio Sharpe Ratios calculated as $\text{mean}(r_p - r_f)/\text{sd}(r_p - r_f)$. For the long-short portfolios, the Sharpe ratio is $\text{mean}(r_p)/\text{sd}(r_p)$. In both periods the Sharpe Ratio of the female insider portfolio with ownership weights (Column 4) is higher than for the male portfolio (Column 5). For the portfolio with insider value-weights, however, the Sharpe Ratio is higher for males in the first period, but this switches to a higher value in the second period (columns 7 and 8).

Turning to the four-factor performance estimate in panels A.2 and B.2, notice first that the market exposures of the female portfolios tend to be slightly lower those of the male portfolios. As expected for broad based portfolios, the market betas are all statistically significant and close to one. As to the four-factor alphas in the first row, α_{p}^{4f} is only marginally significant (at the 10% level) in one case, a

[15] For completeness, we also show, in the Internet Appendix, the results of estimating returns-based abnormal performance over the full sample period, 1996–2016. This does not change our statistical inferences.

positive 0.7% alpha for the insider-ownership portfolio. Most important, the significance of the alphas of the long-short portfolios is even weaker.

The lack of significance, and the consistently negative sign of the alphas of the long-short portfolios, clearly rejects the hypothesis that insider trades by males have better performance than those of females. This inference also holds when using the average rolling-beta estimation in panels A.3 and B.3 of Table 5. Again, none of these recursive CAPM-alpha estimates, which allow for time variation in the estimated portfolio beta, are significant at the 5% level or better, nor are the alpha estimates of the long-short portfolios.

4.3 Additional performance issues

4.3.1 Portfolio formation using equal-weighting

To better link our findings to the extant literature on insider trading performance, which absent data on actual insider holding periods use equal-weighted portfolios, Table 6 reports tests based on an equal-weighted "buy signal" portfolio with the following weights:

$$\omega_{it}^{ew} = \begin{cases} 1/n_{t-1} & \text{if stock } i \text{ has insider buys in period } t-1 \\ 0 & \text{otherwise} \end{cases} \tag{12}$$

where n_{t-1} is the number of stocks with insider buys in period $t-1$. We report results with equal-weights for comparison purposes only, as this approach fails to give greater weight to firms and periods when insider holdings are in fact high (measured by ω_{it}^{ow} or ω_{it}^{vw}). Assuming equal-weights when actual weighs tend to be high due to price-sensitive inside information biases the estimated abnormal performance towards zero. However, regardless of gender, Table 6 again shows statistically insignificant alpha estimates also for the equally-weighted buy-signal portfolios.

4.3.2 A specialized insider portfolio

A failure to reject the hypothesis of zero insider abnormal performance does not rule out the possibility that some small subgroup may be able to profit from their trades. While not tabulated, we address this issue by examine a small and specialized insider portfolio—labelled *Innsideporteføljen*—generated by Norway's daily financial newspaper *Finansavisen*. Beginning in 1995, *Finansavisen* publishes each

Saturday the names of a few (typically five) prominent insiders—typically drawn from large shareholders and top executives and directors—who report insider purchases sometime during the week.

Finansavisen's reporting carry some weight since it has survived for more than 25 years. During this period, the newspaper has spent resources identifying these insiders and placed at some risk its reputation as a source of timely financial information. The newspaper's idea is that outsiders might benefit from purchasing *Innsideporteføljen*—under the presumption that the insiders' private information is long-lived. *Innsideporteføljen* presents an interesting test asset for our purposes since it helps address whether there is evidence that a prominent (gender-neutral) subgroup of insider realize abnormal trading performance. It also helps that our weight-based test statistic HCM explicitly allows for long-lived private information, if any. However, when we apply HCM to *Innsideporteføljen*, we cannot reject the hypothesis of zero holdings-based abnormal performance also for this specialized portfolio.[16]

5 Insider trading during the financial crisis

In this section we examine gender-based insider trading during the financial crisis period, defined here as from October 2008 through December 2010. A a consequence of the mandatory board gender-balancing law, the male and female director networks were of similar magnitudes during this period. With similar-sized director networks, male and female insiders also have similar access to network-based information. With this in mind, we make the following proposition:

Proposition 3 (crisis-induced insider trading): *Suppose insiders respond to the crisis-induced price decline by purchasing additional shares in the firm. Absent inside information that the shares have become underpriced, these purchases increase insiders' investment-risk exposures. Hence, gender-based differences in this purchase activity provide information on gender-based differences in risk aversion.*

To address Proposition 3, we proceed in two steps: We first test whether male and female insiders differ in their purchase intensities during the financial crisis period. Second, we then test whether the crisis-induced purchase activity generates holdings-based abnormal performance, which is necessary to rule out that the trades are based on valuable inside information—the central assumption behind the

[16]Some descriptives: The number of firms in *Innsideporteføljen* changes between 21 and 23 times of the 52 weeks in a year. Moreover, it is not uncommon for a single stock to remain in the portfolio for two-to-four weeks while *Finansavisen* adds new stocks—resulting in 40 stocks as the maximum number of firms in the portfolio in any given week. On average, a firms stays in the portfolio for 59 days (eight weeks).

proposition. Absent abnormal performance, we use gender-based differences (if any) in purchase activity to infer gender-based differences in director risk aversion.

5.1 Crisis-period insider trading intensity

Figure 4 plots, at the firm level, the average fraction of female directors that trade in a given year, 1998–2016. Panel A shows female buy trades. The increase in 2006 and 2007 is likely driven by the incentives generated by the gender-quota law for newly appointed female directors to hold stocks in the firms they just joined as directors. This particular purchase effect expired by the end of 2007, when all OSE-listed firms were in full compliance with the 40% quota (Figure 1). Interestingly, Panels A and B of Figure 4 show that the purchase propensities of both female and male directors peaks in 2009—in the midst of the financial crisis. Moreover, this peak trading pattern is most dramatic for female directors. This is evidenced not only by the rate of increase in buy transactions in Panels A and B but also by the near-disappearance of sell orders in Panel C of Figure 1, which is unique to female directors.

In Table 7, we use firm-quarters over the period 1998–2016 to estimate the effect of the financial crisis on primary insiders' trading propensity, as follows:

$$Y_{jt} = \alpha + \beta_1 Crisis_t + \boldsymbol{\beta_2'} \mathbf{Control}_{jt} + \epsilon_{jt}, \tag{13}$$

where the latent dependent variable Y_{jt} takes a value of one if there is at least one trade by primary insiders in quarter t and zero otherwise. $Crisis_t$—the main variable of interest—is a dummy that takes a value of one during the 27-month crisis period 2008:10–2010:12. The vector $\mathbf{Control}_{jt}$ contains other firm characteristics that may also affect the trading likelihood. These characteristics include *Market Cap* (the natural log of the firm's market capitalization), *Volatility* (the firm's quarterly stock return volatility) *Liquidity* (last quarter's average daily stock quoted bid/ask spread), and *Beta* (stock beta estimated over the past 36 months). These controls capture the notion that it may be more difficult to trade based on price-sensitive information in larger, less opaque and more liquid stocks. Finally, *Industry FE* capture industry fixed effects for the 10 Global Industry Classification Standard (GICS) codes.

The signs of the non-crisis determinants reported in Table 7 are intuitive: Larger firms (which have more insiders), more volatile firms (where the scope for insider opinion is larger), and more liquid com-

panies (low trading cost) stocks are all significantly more likely to see insider buying.[17] The results for primary insider sells are less clear, but also here there is significantly more activity in large firms and more liquid firms. Turning to the key variable of interest, $Crisis$, Table 7 shows that insider purchases increases significantly for all types of insiders during the financial crisis period. That is, regardless of gender, the market decline caused by the financial crisis prompted primary insiders to significantly step up their purchase activities. For male primary insiders, there is also a significant reduction in selling activity.

We next restrict the dependent variable in Eq. (13) to the level of individual directors only, which allows us to more closely address our Proposition 3. Because we know firms' board sizes, we also know the exact fraction of a firm's directors who do not trade in any period, which is not the case for the broader category of primary insiders used in Table 7.[18] In Table 8, $Y_{jt} = 1$ is given directly by our information on trades, while we now calculate the number of directors on each board that do not trade in the quarter ($Y_{jt} = 0$) as the difference between total (annual) board size and the number of trading directors. For example, if one director of a five-director board trades in quarter t, we add another four panel observations where $Y_{kt} = 0$ for that firm in quarter t, $k = 1, \ldots, 4$. Since we focus on possible gender differences in the trading likelihood, this way of constructing the data panel requires the assumption that the ratio of female to male board members is constant throughout the calendar year—an assumption that is easily defended as directors in Norway are elected for two-year terms only.

Table 8 shows the coefficient estimates for Eq. (13) regressed separately for female and male director trades. As expected, trading activity (both buys and sales) is again higher for insiders in firms with higher liquidity (lower spreads) and volatility. This effect is more significant for male than for female insiders—likely due to the greater sample size. It suggests that insiders of both gender tend to concentrate their trades in less opaque firms. Turning to the key variable of interest, the coefficients on $Crisis$ is large and statistically significant at the 1% level or better for purchases, and small and statistically insignificant for sales. Both male and female directors increased their purchase propensities significantly during crisis period, with almost identical $Crisis$ coefficient estimates of 0.229 and 0.227, respectively.

[17] Since liquidity is measured using the bid/ask spread, it is the lowest for the most liquid stocks where trading is cheaper.

[18] While Norway's insider trading regulations require all directors and top executives to report all trades, lower level executives need only report trades that they deem to reflect price-sensitive information (e.g., when participating in merger discussions). Hence, an increase in the number of trades by executives may in part reflect an increase in the number of people obligated to report. During the crisis, the scope for what was deemed price-sensitive may have increased, increasing the number of executives obligated to report.

In sum, Figure 4 and Table 8 show that female directors not only substantially increased their purchases during the financial crisis, but that they were also as likely as their male counterparts to purchase stocks. Below, we return to the significance of this finding after first testing whether the increased purchase propensity may have been motivated by inside information.[19]

5.2 Crisis-period trading performance and risk aversion

To measure the performance of insider trades during the crisis, we repeat the holdings-based performance analysis of Section 4. Table 9 shows estimates of our holdings-based performance measure *HCM* estimated over the crisis period 2008:10–2010:12. The table focuses on the two most relevant portfolios—the insider-ownership and insider-value portfolios—neither of which yield abnormal performance. Equally important, there is no evidence of a difference between the male and female portfolios in terms of this performance. In other words, Table 9 rejects the proposition that the significant and equal spikes in male and female director purchase intensities during the financial crisis period were driven by inside information about a potential market underpricing. From Proposition 3, and recalling that male and female directors during the financial crisis had access to fully gender-balanced director networks, this suggests that both genders took on additional risk. Since a decision to take on additional risk depends on the degree of risk aversion, this evidence also provides an opportunity to draw inferences about relative risk aversion of male and female directors.

As surveyed by Croson and Gneezy (2009), the literature on gender differences suggests that there are systematic dispositional differences between males and females. For example, data from laboratory settings, where the participants are typically students or workers, tend to indicate that females are more risk-averse than males (Eckel and Grossman, 2008; Sapienza, Zingales, and Maestripieri, 2009). Adams and Funk (2012) argue that this type of evidence may not carry over to the more select group of individuals in corporate leadership, who are rarely available for such experiments. Also, to be considered a candidate for a board seat in a male-dominated public corporation, females may have to develop core values and risk attitudes that are similar to male directors.[20] After surveying directors in Swedish listed companies in year 2005, Adams and Funk conclude that female executives and directors are, if anything, somewhat *less* risk averse than their male counterparts.

[19] In the Internet Appendix, we present two other measures of the direction of insider trades during the financial crisis.

[20] "If women must be more like men to break the glass ceiling, we might expect gender differences to disappear among directors." (Adams and Funk, 2012, abstract).

Our evidence on gender-based insider trading and performance during the financial crisis adds to the above debate. In summary: (1) board gender-balancing tends to equalize the access of male and female directors to inside information about firm value; (2) the exogenous price declines caused by the financial crisis caused both male and female directors to increase their stock purchase intensities in almost equal measures; and (3) there is no evidence that these director purchases were driven by inside information. Following Proposition 3, these three results suggest that the spike in insider purchases during the financial crisis period is associated with greater risk taking by the insiders. Hence, our finding that male and female directors both increase their purchase intensities in an almost equal fashion is consistent with the suggestion of Adams and Funk that female directors are no more risk averse than their male counterparts.

6 Conclusion

Since industry peers share fundamental demand and supply characteristics driving firm value, gaining access to an extended network of peer-company insiders enhances the value of each individual insider's own firm-specific information. We examine this network-information effect using two quasi-experimental settings and three decades of trading by the population of primary insiders on the Oslo Stock Exchange. The first setting is the dramatic increase in the female director network caused by Norway's pioneering board gender-balancing law, which raised the fraction of female directors from an average of 15% to the legally mandated 40%. In our second quasi-experimental setting, we measure the effect of the price decline caused by the financial crisis on insider trading by male and female directors at a time with equal access to the extended director network.

Consistent with our network information hypothesis, following board gender-balancing, we show that the short-term market reaction to non-routine trades by female primary insiders has indeed become significantly positive on average—and similar in magnitude to that of males. Also consistent with this hypothesis, controlling for measures of stock liquidity, the market reaction is greater in response to trades by directors who sit on boards where directors are themselves more highly connected with other boards (measured using the board's pagerank network centrality score).

However, regardless of gender, and accounting for insiders' *actual* holding periods, the positive network-driven information effect does not map into positive abnormal trading performance. This conclusion is robust not only to alternative definitions of insider portfolio weights but also to alternative

assumptions about how long-lived the inside information is (before becoming known to outsiders). Overall, notwithstanding the quota-driven increase in the market's perception of the information content of female insider purchases, the covariance between changes in insider stock holdings and subsequent abnormal stock returns rejects the notion that insiders—male or female—succeed in "buying low and selling high."

Finally, we provide robust evidence that, following the board gender-balancing, both male and female primary insiders significantly increased their stock purchases during the 27-month financial crisis period 2008:10–2010:12. Also important, we show that this increased purchase activity did *not* produce significant holdings-based abnormal performance. In other words, these purchases were not driven by inside information indicating that the stocks had become significantly underpriced. This lack of abnormal performance suggests that the purchases constitutes bets against the market or portfolio rebalancing (restoring optimal asset allocation)—a form of risk taking that depends on the individuals' degree or risk aversion. Since we also find that the crisis-induced marginal increase in purchase activity is indistinguishable across male and female directors, our evidence suggests that female directors are no more risk averse than their male counterparts. While this conclusion is consistent with the extant literature based on surveys, our trade-based inference is uniquely powerful in that it reflects individual investment decisions.

References

Adams, Renée B., and Patricia Funk, 2012, Beyond the glass ceiling: Does gender matter?, *Management Science* 58, 219–235.

Ahern, Kenneth R, and Amy K Dittmar, 2012, The changing of the boards: The impact on firm valuation of mandated female board representation, *The Quarterly Journal of Economics* 127, 137.

Akbas, Ferhat, Chao Jiang, and Paul D. Koch, 2020, Insider investment horizon, *Journal of Finance* 75, 1579–1627.

Akbas, Ferhat, Felix Meschke, and M. Babajide Wintoki, 2016, Director networks and informed traders, *Journal of Accounting and Economics* 62, 1–23.

Anginer, Deniz, Anil Donmez, Nejat Seyhun, and Ray Zhang, 2020, Global economic impact of covid-19: Evidence from insider trades, Working paper, Simon Fraser University.

Berkman, Henk, Paul Koch, and P Joakim Westerholm, 2023, The other insiders: Personal trading by brokers, analysts, and fund managers, *The Review of Asset Pricing Studies* https://doi.org/10.1093/rapstu/raad002.

Berner, Endre, Aksel Mjøs, and Marius Olving, 2013, Norwegian corporate accounts, Working paper 42/13, Center for Applied Research at NHH.

Bertrand, Marianne, Sandra E Black, Sissel Jensen, and Adriana Lleras-Muney, 2019, Breaking the glass ceiling? The effect of board quotas on female labour market outcomes in Norway, *The Review of Economic Studies* 86, 191–239.

Betzer, André, Jasmin Gider, Daniel Metzger, and Erik Theissen, 2015, Stealth trading and trade reporting by corporate insiders, *Review of Finance* 19, 865–905.

Bhattacharya, Utpal, 2014, Insider trading controversies: A literature review, *Annual Review of Financial Economics* 6, 385–403.

Biggerstaff, Lee, David Cicero, and M. Babajide Wintoki, 2020, Insider trading patterns, *Journal of Corporate Finance* 64, 101654.

Carhart, Mark M, 1997, On persistence in mutual fund performance, *Journal of Finance* 52, 57–82.

Chang, Saeyoung, and David Suk, 1998, Stock prices and secondary dissemination of information: The Wall Stree Journal's 'Iinside Spotlight' column, *Financial Review* 33, 115–128.

Chhaochharia, Vidhi, and Yaniv Grinstein, 2007, Corporate governance and firm value: The impact of the 2002 governance rules, *Journal of Finance* 63, 1789–1825.

Clacher, Iain, Beatriz Garcia Osma, Elvira Scarlat, and Karin Shields, 2021, Do commonalities facilitate private information channels? evidence from common gender and insider trading, *Journal of Corporate Finance* 70, 102062.

Cohen, Lauren, Christopther Malloy, and Lukasz Pomorski, 2012, Decoding inside information, *Journal of Finance* 67, 1009–1043.

Copeland, Thomas, and David Mayers, 1982, The value line enigma (1965–1978). A case study of performance evaluation issues, *Journal of Financial Economics* 10, 289–321.

Cornell, Bradford, 1979, Asymmetric information and portfolio performance measurement, *Journal of Financial Economics* 7, 381–390.

Croson, Rachel, and Uri Gneezy, 2009, Gender differences in preferences, *Journal of Economic Literature* 47, 448–474.

Csardi, Gabor, and Tamas Nepusz, 2006, The igraph software package for complex network research, *InterJournal* Complex Systems, 1695.

Cziraki, Peter, and Jasmin Gider, 2021, The dollar profits to insider trading, *Review of Finance* 25, 1547–1580.

Cziraki, Peter, Peter De Goeij, and Luc Rennebog, 2014, Corporate governance rules and insider trading profits, *Review of Finance* 18, 67–108.

Duchin, Ran, John Matsusaka, and Oguzhan Ozbas, 2010, When are outside directors effective?, *Journal of Financial Economics* 96, 195–214.

Eckbo, B. Espen, Knut Nygaard, and Karin S. Thorburn, 2022a, Does mandatory board gender-balancing reduce firm value?, *Harvard Business Law Review* 12, 407–437.

——— , 2022b, Valuation effects of Norway's board gender-quota law revisited, *Management Science* 68, 4112–4134.

Eckbo, B Espen, and David C Smith, 1998, The conditional performance of insider trades, *Journal of Finance* 53, 467–498.

Eckel, Catherine C, and Philip J Grossman, 2008, Men, women and risk aversion: Experimental evidence, *Handbook of experimental economics results* 1, 1061–1073.

El-Khatib, Rwan, Dobrina Jandik, and Tomas Jandik, 2021, Network centrality, connections, and social capital: Evidence from CEO insider trading gains, *Financial Review* 56, 433–457.

Fama, Eugene F, and Kenneth R French, 1993, Common risk factors in the returns on stocks and bonds, *Journal of Financial Economics* 33, 3–56.

Ferson, Wayne, 2010, Investment performance evaluation, in Andy Lo, and Robert Merton, ed.: *Annual Review of Financial Economics*, vol. 2 of *Annual Reviews* . pp. 207–34 (Annual Reviews).

——— , and Kenneth Khang, 2002, Conditional performance measurement using portfolio weights: Evidence for pension funds, *Journal of Financial Economics* 65, 249–282.

Ferson, Wayne, and Junbo L Wang, 2021, A panel regression approach to holdings-based fund performance measures, *The Review of Asset Pricing Studies* Forthcoming.

Fidrmuc, Jana, Marc Goergen, and Luc Renneboog, 2006, Insider trading, news releases and ownership concentration, *Journal of Finance* 61, 2931–2974.

Finansdepartementet, 2017, NOU 2017:14 Nye regler om markedsmisbruk – sanksjoner og straff, .

Gao, George P, Qingzhong Ma, David T Ng, and Ying Wu, 2022, The sound of silence: What do we know when insiders do not trade?, *Management Science* 68, 4835–4857.

Grinblatt, Mark, and Sheridan Titman, 1989, Portfolio performance evaluation. Old issues and new insights, *Review of Financial Studies* 2, 393–421.

——— , 1993, Performance measurement without benchmarks, *Journal of Business* 66, 47–68.

Inci, A Can, M P Narayanan, and H Nejat Seyhun, 2017, Gender differences in executives' access to information, *Journal of Financial and Quantitative Analysis* 52, 991–1016.

Jaffe, Jeffery F., 1974, Special information and insider trading, *Journal of Business* 47, 410–428.

Jeng, Leslie A, Adrew Metrick, and Richard Zeckhauser, 2003, Estimating the returns to insider trading: A performance-evaluation perspective, *Review of Economics and Statistics* 85, 453–471.

Jensen, Michael C, 1968, The performance of mutual funds in the period 1945-1964, *Journal of Finance* 23, 389–416.

Kolari, James W, and Seppo Pynnönnen, 2010, Event-study testing with cross-sectional correlation of abnormal stock returns, *Review of Financial Eonomics* 23, 3998–4025.

Kothari, S P, and Warner, 2007, Econometrics of event studies, in *Handbook of Corporate Finance: Empirical Corporate Finance*, vol. 2 . pp. 3–36 (North-Holland).

Lakonishok, Josef, and Inmoo Lee, 2001, Are insider trades informative?, *Review of Financial Studies* 14, 79–111.

MacKinlay, A Craig, 1997, Event studies in economics and finance, *Journal of Economic Literature* 35, 13–39.

Marc, Goergen., Luc Renneboog, and Yang Zhao, 2019, Insider trading and networked directors, *Journal of Corporate Finance* 56, 152–175.

Marin, Jose M, and Jacques P Olivier, 2008, The dog that did not bark: Insider trading and chrashes, *Journal of Finance* LXIII, 2429–2476.

Meulbroek, Lisa K., 1992, An empirical analysis of illegal insider trading, *Journal of Finance* 47, 1661–1699.

Næs, Randi, Johannes Skjeltorp, and Bernt Arne Ødegaard, 2008, Hvilke faktorer driver kursutviklingen på Oslo Børs?, *Norsk Økonomisk Tidskrift* 122, 36–81.

Newman, Mark, 2018, *Networks* (Oxford) Second edn.

Page, Lawrence, Sergey Brin, Rajeev Motwani, and Terry Winograd, 1999, The PageRank citation ranking: Bringing order to the Web, Working Paper, Stanford University.

Sapienza, Paola, Luigi Zingales, and Dario Maestripieri, 2009, Gender differences in financial risk aversion and career choices are affected by testosterone, *Proceedings of the National Academy of Sciences* 106, 15268–15273.

Scholes, M, and J Williams, 1977, Estimating betas from nonsynchroneous data, *Journal of Financial Economics* 5, 309–327.

Seyhun, H Nejat, 1986, Insiders profits, costs of trading, and market efficiency, *Journal of Financial Economics* 16, 189–212.

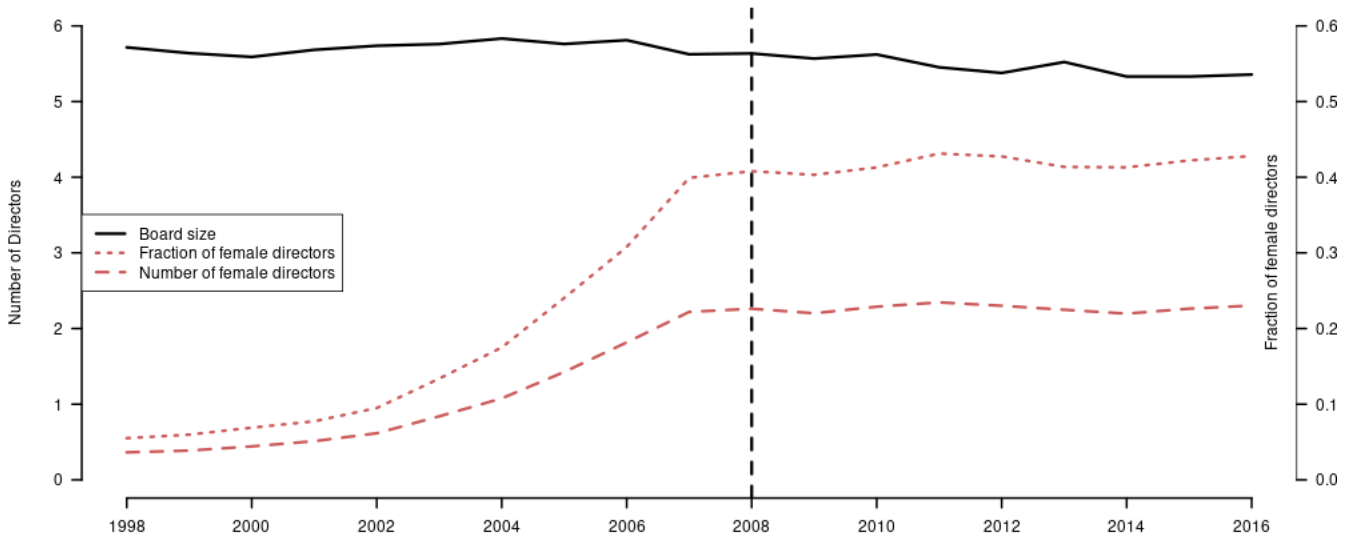
Thompson, R, 1985, Conditioning the return-generating process on firm–specific events: A discussion of event–study methods, *Journal of Financial and Quantitative Analysis* 20.

Wermers, Russ, 2011, Performance measurement of mutual funds, hedge funds, and institutional accounts, in Andy Lo, and Robert Merton, ed.: *Annual Review of Financial Economics*, vol. 3 of *Annual Reviews* . pp. 537–74 (Annual Reviews).

Figure 1: Board size and fraction female directors

Panel A shows the average board size (left axis), defined as the number of shareholder-elected directors, and the number (left axis) and fraction (right axis) of female directors. The sample is all OSE-listed stocks. Year 2008 (indicated with a vertical line) is the first year in which all Norwegian-domiciled ASA are in full compliance with Norway's board gender-balancing law, which took effect in December of 2005. Panel B shows the distribution of the number of directorships in listed companies held by individual male and female directors in years 2002 and 2008, respectively. Board data are from the national *Brønnøysund Registry Centre*, 1998-2016.

Panel A: Board size and fraction female directors, OSE listed firms



Panel B: Number of board seats held by male and female directors in 2002 and 2008

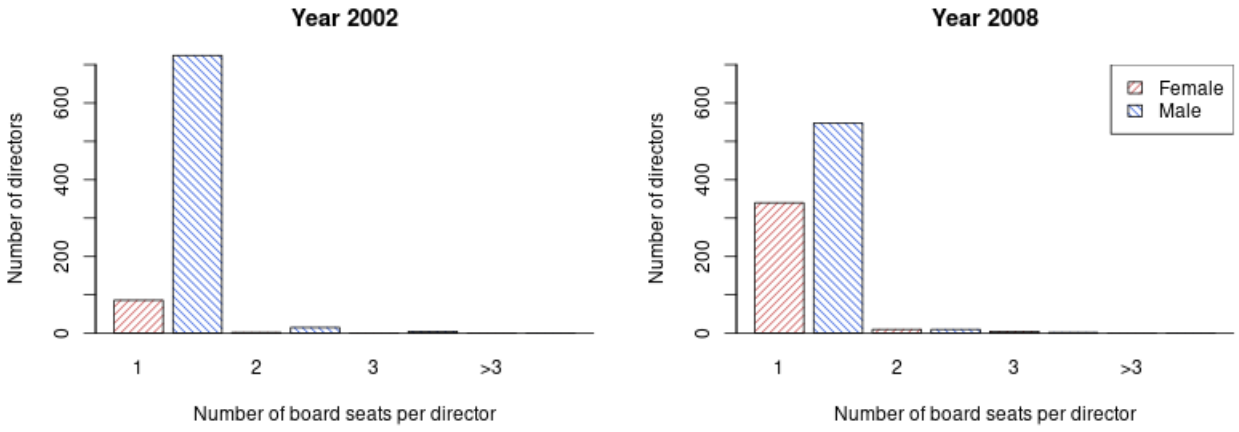
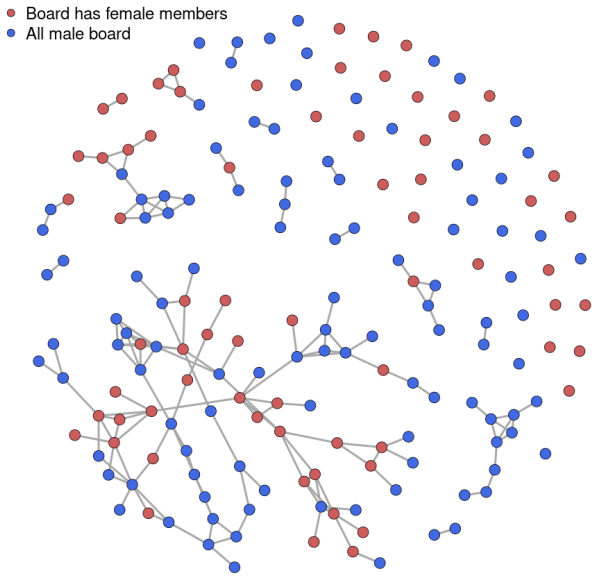


Figure 2: Evolution of board network links and gender composition

The figure illustrates the network structure of the boards of Norwegian listed companies. Each node is a company board. A link (line) between two boards indicates that at least one director sits on both boards. Solid (red) dots are companies with at least one female on the board, while grey (blue) dots represent all-male boards. Plot produced using the `R` library `igraph` (Csardi and Nepusz, 2006). Board data are from the national *Brønnøysund Registry Centre*, 1998-2016.

Year 2002



Year 2008

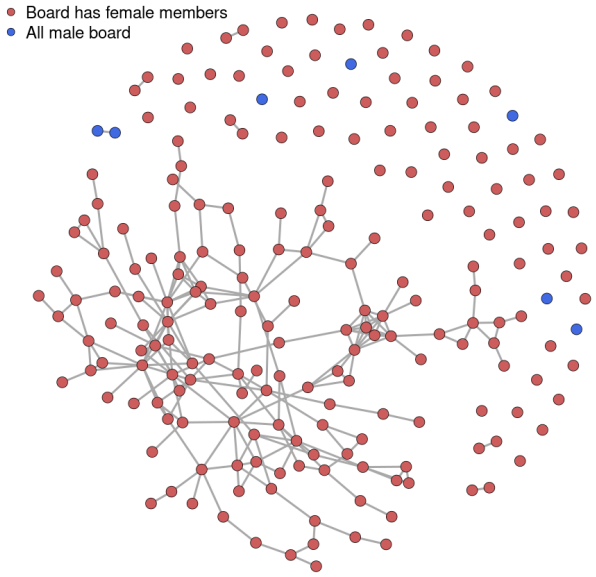
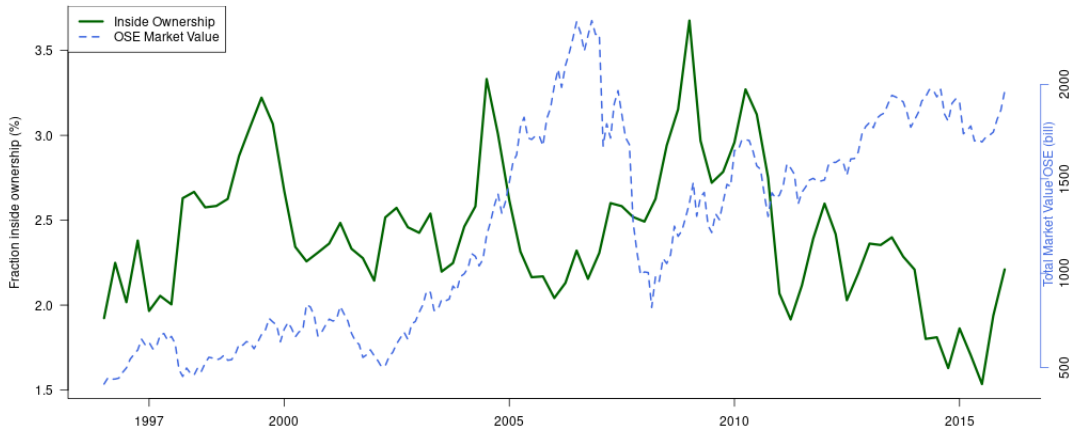


Figure 3: Average insider ownership and fraction of primary-insider trades by females

Panel A shows the average percent insider ownership across OSE-listed companies (left axis), and the total market value of all OSE-listed stocks (right axis, in billion NOK), 1997–2016. The former is calculated by, for each company, summing the holdings of all reporting insiders on a daily basis. We then aggregate each firm's daily insider ownership series up to a quarterly level, and plot the average quarterly insider holdings for each quarter. Panel B plots the number of female primary insider trades in percent of all primary insider trades. Population data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

Panel A: Percent insider ownership and total OSE market value



Panel B: Percent of primary insider trades executed by females

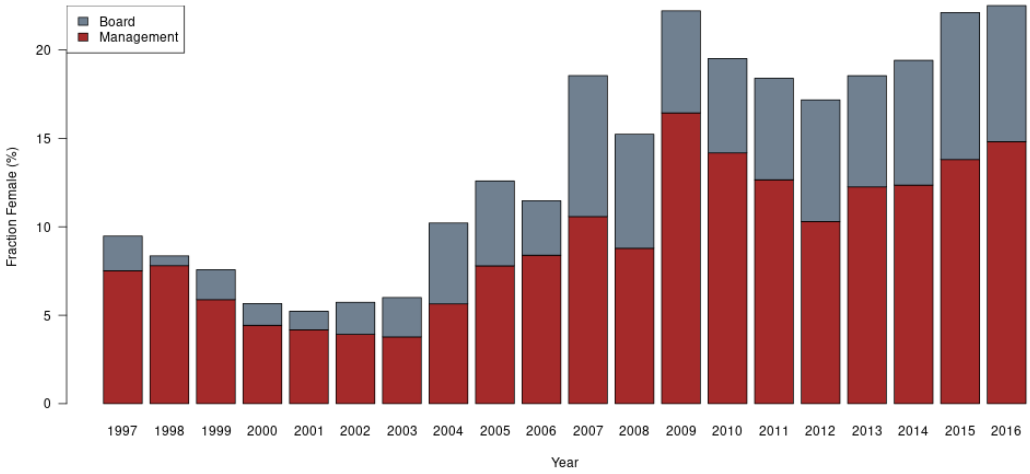
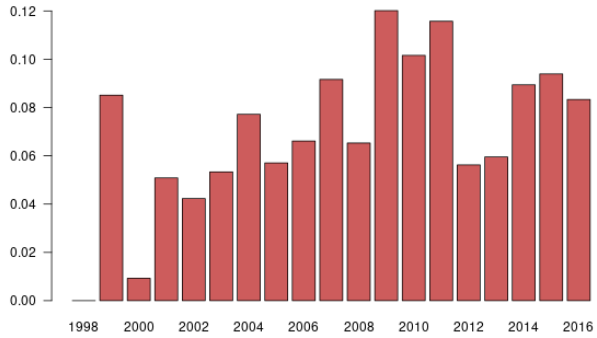


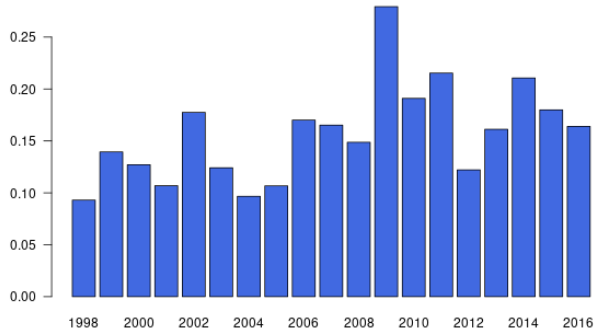
Figure 4: Fraction of male and female directors that trade

The figure reports the annual average fraction of a board's directors, classified by gender, that report an insider purchase (panels A and B) or sale (panels C and D). Sample period: 1998–2016. Population data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`). Board data are from the national *Brønnøysund Registry Centre*.

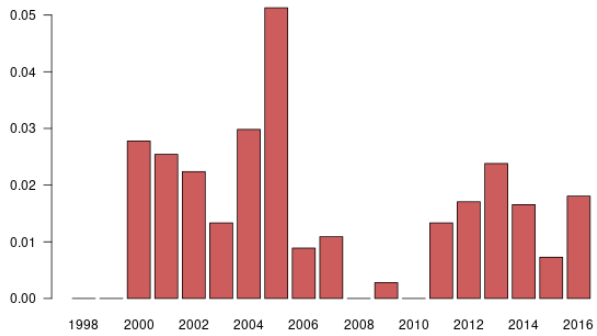
Panel A: Female buy trades



Panel B: Male buy trades



Panel C: Female sell trades



Panel D: Male sell trades

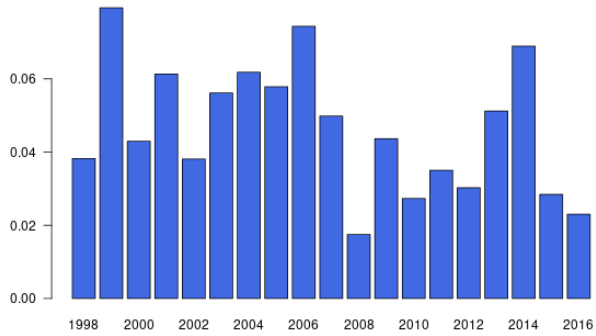


Table 1: Insider trading by gender: Sample descriptives, 1997–2016

Primary insiders are directors and executives. Routine (repeated) trades are identified using the methodology of Cohen, Malloy, and Pomorski (2012), in which an insider trader in month t is classified as a "repeat performer" if the same insider traded in the same calendar month in each of the three years preceding the trade in month t. In Panel B, the number of distinct insiders is the number of individuals with insider transactions (excluding insiders who never transact). Panel C characterizes insider trading on an individual trader basis, using the insiders' trading history. The trading history begins with the first reported trade and ends with the last reported trade. We first compute the annual number of trades and trade values for each insider, and then form the sample period average for each insider (including years without trades). Panel B then reports the averages of these per insider averages. All value are in constant 2016 NOK using the consumer price index supplied by the Norwegian Bureau of Statistics (SSB).

A: Total sample of insider trades

Total transaction records	24217
Records with gender identified	21406
of which primary	16003
of which non-routine	14624

B: Transaction totals and averages

	All insiders				Primary Insiders			
	Total	Male	Female	Female(%)	Total	Male	Female	Female(%)
Number of firms	535	530	340	63.6	511	508	277	54.2
Number of distinct insiders	9077	7534	1554	17.1	6179	5261	928	15.0
Total transaction value (mill.)								
Buys	140678	139827	851	0.6	55225	54491	734	1.3
Sells	66498	65109	1389	2.1	60414	59230	1185	2.0
Number of transactions								
Buys	16389	14206	2183	13.3	12623	11177	1446	11.5
Sells	5017	4476	541	10.8	3380	3122	258	7.6
Average transaction (1,000)								
Buys	8584	9843	390		4375	4875	508	
Sells	13255	14546	2568		17874	18972	4592	
Median transaction (1,000)								
Buys	108	120	48		132	146	70	
Sells	456	534	131		663	729	189	

C: Individual insiders' trading intensity

	All insiders			Primary insiders		
	All	Female	Male	All	Female	Male
Number of trades in year						
Buys	1.21	1.13	1.23	1.25	1.15	1.27
Sells	1.15	1.10	1.15	1.14	1.09	1.15
Annual transaction value (1,000)						
Buys	5194	477	6170	2965	641	3380
Sells	16049	2411	18145	22319	4301	24248

Table 2: Market reaction to non-routine primary insider purchases classified by gender

The table reports the cumulative abnormal abnormal stock return $CAR \equiv \tau\gamma$, where γ is the average daily abnormal return over τ days in event time centered on the day of insider purchases (day 0) and estimated using the following one-factor return-generating process for firm i:

$$r^e_{it} = a_i + b_i r^e_{mt} + \gamma_i D_{it} + \varepsilon_{it},$$

where r^e_{mt} is the return on the market portfolio in excess of the risk-free rate on day t, and D_{it} is a dummy variable that takes a value of one inside the event window and zero otherwise. There are four alternative event windows around day 0: days $(-1, 1)$, $(-1, 5)$, $(-1, 25)$, and $(-1, 50)$, with corresponding τ-values of 3, 7, 27, and 52 days. The estimation is done for the two periods 1997–2007 and 2008–2016, respectively. The estimation in panels A and C (panels B and D) uses trades of primary female (male) insiders only. In the estimation we remove routine trades as in Cohen, Malloy, and Pomorski (2012). Standard errors in brackets. Statistical significance is indicated by: *=p<0.1, **=p<0.05, ***=p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

	Event windows for the cumulative abnormal return			
	$CAR(-1,1)$	$CAR(-1,5)$	$CAR(-1,25)$	$CAR(-1,50)$
Pre-quota years, 1997–2007				
A: Female Insiders 1997–2007				
CAR	0.0026	0.0069	−0.0041	−0.0108
	(0.002)	(0.001)	(0.001)	(0.0004)
Observations	209,427	209,427	209,427	209,427
$\overline{R}^2$	0.038	0.038	0.038	0.038
B: Male Insiders 1997–2007				
CAR	0.014***	0.014***	0.0064	−0.001
	(0.001)	(0.001)	(0.0003)	(0.0003)
Observations	507,385	507,385	507,385	507,385
$\overline{R}^2$	0.021	0.021	0.021	0.021
Post-quota years, 2008–2016				
C: Female Insiders 2008-2016				
CAR	0.0155***	0.0147***	0.0139	0.01126
	(0.001)	(0.001)	(0.001)	(0.0004)
Observations	309,470	309,470	309,470	309,470
$\overline{R}^2$	0.027	0.027	0.027	0.027
D: Male Insiders 2008-2016				
CAR	0.014**	0.013	−0.0022	−0.0205
	(0.002)	(0.002)	(0.001)	(0.001)
Observations	470,032	470,032	470,032	470,032
$\overline{R}^2$	0.003	0.003	0.003	0.003

Table 3: Determinants of the market reaction to director purchases

The table reports results of regressions

$$CAR_i(\tau_1, \tau_2) = \alpha_i + \beta_1 MktCap_i + \beta_2 TradeSize_i + \beta_3 Centrality_i + \varepsilon_i,$$

where $CAR_i(\tau_1, \tau_2)$ is the cumulated abnormal return associated with director trade i from event day τ_1 to event day τ_2, $MktCap_i$ is the log market capitalization, $TradeSize_i$ is the log trading volume, and $Centrality_i$ is firm i's board network centrality measured using pagerank (Page, Brin, Motwani, and Winograd, 1999). CAR_i is estimated using the CAPM as the model of expected return with the CAPM beta estimated using five years of prior returns relative to the event date. The estimation is done for all reported trades by directors in the period 1998–2016. In the estimation we remove routine trades as in Cohen, Malloy, and Pomorski (2012). Standard errors in brackets. Statistical significance is indicated by: *=p<0.1, **=p<0.05, ***=p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`). Board data are from the national *Brønnøysund Registry Centre.*

	Cumulative abnormal return (τ_1, τ_2)			
	$CAR(-1,1)$	$CAR(-1,5)$	$CAR(-1,20)$	$CAR(-1,50)$
	(1)	(2)	(3)	(4)
Constant	0.072***	0.157***	0.257***	0.516***
	(0.014)	(0.026)	(0.042)	(0.074)
MktCap	−0.004***	−0.007***	−0.012***	−0.023***
	(0.001)	(0.001)	(0.002)	(0.003)
TradeSize	−0.0002	−0.001	−0.0004	−0.002
	(0.001)	(0.001)	(0.002)	(0.003)
Centrality	2.147***	1.614*	3.144**	0.276
	(0.482)	(0.886)	(1.462)	(2.565)
Observations	2,679	2,679	2,679	2,679
Adjusted R^2	0.015	0.013	0.016	0.018

Table 4: Holdings-based primary insider performance

Performance estimates using holdings-based performance evaluation. The two sets of portfolio weights are defined in Eq. (8) in the text. The Insider-ownership-weight of firm i (columns 1-3) is the insiders' percentage ownership of firm i divided by the sum of the percentage insider holdings across all OSE firms. The Insider-value-weight (columns 4-6) of firm i is the value of insider holdings in i divided by the value of all insider holdings in all OSE firms. The holdings-based estimates are based on covariances between monthly changes in insider holdings (weights) and subsequent returns, as follows:

$$HCM = \frac{1}{T-2}\sum_{t=2}^{T}\frac{1}{N_t}\left(\sum_{t=1}^{N_t} cov\left(\Delta w_{it},\ r_{i,t+\tau} - E[r_{i,t+\tau}]\right)\right)$$

where Δw_{it} is the change in the weight of stock i in the insider portfolio from month $t-1$ to t, and $r_{i,t+\tau} - E[r_{i,t+\tau}]$ is the abnormal returns over the subsequent τ months ($\tau = 1, 3, 6$). Δw_{it} is the monthly change in insider holdings, $w_{it}^{ins} - w_{i,t-1}^{ins}$. $E[r_{i,t+\tau}]$ is the predicted return using the Fama-French-Carhart risk factors estimated using five years of monthly data prior to time t. The estimation is done for the two periods 1997–2007 and 2008–2016. The columns labelled p(diff) report the p-value for the test of difference between the male and female portfolio performance metrics. The p-values are calculated using standard errors robust to autocorrelation. Statistical significance is indicated as: *=p<0.1, **=p<0.05, ***= p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

Table 4: (Continued)

Panel A: Pre-quota period, 1997–2007

	Insider-ownership portfolio weights			Insider-value portfolio weights		
	Female	Male	p(diff)	Female	Male	p(diff)
	(1)	(2)	(3)	(4)	(5)	(6)
A.1: Short-lived insider information: one-month horizon ($\tau = 1$)						
Δw_{it}*: lagged insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\ r_{i,t+1} - E[r_{i,t+1}])$	0.0007	−0.0003	0.46	0.0006	0.0020	0.54
Δw_{it}*: market-adjusted insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\ r_{i,t+1} - E[r_{i,t+1}])$	0.0006	−0.0018	0.66	−0.0034	−0.0064**	0.61
A.2; Intermediate-lived inside information: three-month horizon ($\tau = 3$)						
Δw_{it}*: lagged insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\ r_{i,t+3} - E[r_{i,t+3}])$	0.0031	−0.0000	0.31	0.0025	0.0017	0.84
Δw_{it}*: market-adjusted insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\ r_{i,t+3} - E[r_{i,t+3}])$	−0.0001	−0.0066	0.69	−0.0147	−0.0226**	0.72
A.3: Long-lived insider information: six-month horizon ($\tau = 6$)						
Δw_{it}*: lagged insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\ r_{i,t+6} - E[r_{i,t+6}])$	0.0007	−0.0005	0.63	−0.0012	0.0039	0.43
Δw_{it}*: market-adjusted insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\ r_{i,t+6} - E[r_{i,t+6}])$	−0.0154	−0.0082	0.79	−0.0438	−0.0423**	0.97

Table 4: (Continued)

Panel B: Post-quota period, 2008–2016

	Insider-ownership portfolio weights			Insider-value portfolio weights		
	Female (1)	Male (2)	p(diff) (3)	Female (4)	Male (5)	p(diff) (6)
B.1: Short-lived insider information: one-month horizon ($\tau = 1$)						
Δw_{it}: *lagged insider portfolio weights* $cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\ r_{i,t+1} - E[r_{i,t+1}])$	0.0014	0.0004	0.70	0.0008	−0.0006	0.28
Δw_{it}: *market-adjusted insider portfolio weights* $cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\ r_{i,t+1} - E[r_{i,t+1}])$	0.0033	−0.0041	0.39	0.0008	0.0014	0.88
B.2; Intermediate-lived inside information: three-month horizon ($\tau = 3$)						
Δw_{it}: *lagged insider portfolio weights* $cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\ r_{i,t+3} - E[r_{i,t+3}])$	0.0018	0.0007	0.72	0.0009	−0.0024	0.06
Δw_{it}: *market-adjusted insider portfolio weights* $cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\ r_{i,t+3} - E[r_{i,t+3}])$	0.0069	−0.0048	0.53	0.0004	0.0070	0.41
B.3: Long-lived insider information: six-month horizon ($\tau = 6$)						
Δw_{it}: *lagged insider portfolio weights* $cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\ r_{i,t+6} - E[r_{i,t+6}])$	0.0011	0.0012	1.00	0.0016	−0.0041	0.09
Δw_{it}: *market-adjusted insider portfolio weights* $cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\ r_{i,t+6} - E[r_{i,t+6}])$	0.0168	−0.0006	0.51	0.0058	0.0208	0.24

Table 5: Returns-based primary insider portfolio performance.

The performance estimates reported in this table are based on monthly portfolio returns and rebalancing. The three sets of portfolio weights are defined in Eqns. (8) and (12) in the text. The Insider-ownership-weight of firm i (columns 1-3) is the insiders' percentage ownership of firm i divided by the sum of the percentage insider holdings across all OSE firms. The Insider-value-weight (columns 4-6) of firm i is the value of insider holdings in i divided by the value of all insider holdings in all OSE firms. The equally weighted "buy signal" portfolio contains stocks with insider buys in a previous period. The Male–female portfolio is long in male and short in female insider weights, respectively. The estimation is done for the two periods 1997–2007 and 2008–2016, respectively. In Panel **1**, Sharpe Ratio is $\text{mean}(r_p - r_f)/\text{sd}(r_p - r_f)$ for the long portfolios and, for the long-short portfolio, $\text{mean}(r_p)/\text{sd}(r_p)$. The two performance metrics, α_p^{4f} in Panel **2** and α_p^{rb} in Panel **3**, are defined in Eq. (11) in the text. The first is the constant term in a four-factor Fama-French-Carhart regression, while the second is the average constant term in a rolling-beta CAPM regression. Standard errors in brackets. Statistical significance indicated as *=p<0.1, **=p<0.05, ***= p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

Table 5: (Continued)

Panel A: Pre-quota period, 1997–2007

	Insider-ownership portfolio weights			Insider-value portfolio weights		
	Female (1)	Male (2)	Male− Female (3)	Female (4)	Male (5)	Male− Female (6)
A.1: Average raw returns and Sharpe Ratio						
$(1/N)\sum r_{pt}$	0.0146	0.0131	−0.0015	0.0097	0.0162	0.0066
$(1/N)\sum r^e_{pt}$	0.0106	0.0090		0.0056	0.0122	
Sharpe Ratio	0.1456	0.1310	−0.0193	0.0661	0.1471	0.0939
A.2: Four-factor alpha estimate						
α_p^{4f}	0.008	0.007*	−0.008	−0.0002	−0.006*	−0.009
	(0.011)	(0.004)	(0.012)	(0.006)	(0.003)	(0.007)
β_p^m	1.182***	1.314***	0.132	0.676***	1.116***	0.449***
	(0.233)	(0.079)	(0.246)	(0.119)	(0.064)	(0.131)
b_p^{SMB}	0.302	0.217**	−0.124	0.324**	0.179**	−0.146
	(0.297)	(0.106)	(0.314)	(0.161)	(0.087)	(0.176)
b_p^{HML}	−0.468*	−0.161*	0.316	0.261*	−0.089	−0.347**
	(0.258)	(0.087)	(0.272)	(0.133)	(0.071)	(0.145)
b_p^{UMD}	0.321*	−0.208***	−0.500**	0.044	−0.084*	−0.121
	(0.193)	(0.062)	(0.204)	(0.094)	(0.051)	(0.103)
Observations	99	132	99	132	132	132
$\overline{R}^2$	0.310	0.733	0.039	0.178	0.736	0.157
A.3: Average rolling-beta CAPM estimate of alpha						
α_p^{rb}	0.0017	−0.0036	−0.0093	−0.0037	−0.0124	−0.0127
	(0.0058)	(0.003)	(0.0065)	(0.0063)	(0.004)	(0.0068)
$\overline{\beta}_p^{rb}$	0.5790	1.0017	0.4226	1.0820	1.5022	

Table 5: (Continued)

Panel B: Post-quota period, 2008–2016

	Insider-ownership portfolio weights			Insider-value portfolio weights		
	Female (1)	Male (2)	Male− Female (3)	Female (4)	Male (5)	Male− Female (6)
B.1: Average raw returns and Sharpe Ratio						
$(1/N)\sum r_{pt}$	0.0080	0.0048	−0.0032	0.0102	0.0065	−0.0037
$(1/N)\sum r^e_{pt}$	0.0061	0.0029		0.0083	0.0046	
Sharpe Ratio	0.0603	0.0440	−0.0325	0.1376	0.0651	−0.0720
B.2: Four-factor alpha estimate						
α_p^{4f}	0.027	0.004	−0.023	−0.003	−0.005	−0.005
	(0.027)	(0.007)	(0.023)	(0.010)	(0.004)	(0.010)
β_p^m	1.487**	1.695***	0.207	0.952***	1.150***	0.216
	(0.647)	(0.166)	(0.541)	(0.234)	(0.105)	(0.241)
b_p^{SMB}	0.337	0.224	−0.112	0.125	−0.020	−0.136
	(0.635)	(0.163)	(0.530)	(0.230)	(0.103)	(0.237)
b_p^{HML}	−0.812	0.049	0.889**	0.330*	0.018	−0.314
	(0.516)	(0.132)	(0.432)	(0.186)	(0.083)	(0.191)
b_p^{UMD}	−0.249	0.058	0.289	0.191	−0.046	−0.234
	(0.521)	(0.133)	(0.435)	(0.187)	(0.084)	(0.193)
Observations	106	108	106	108	108	108
$\overline{R}^2$	0.050	0.515	0.011	0.136	0.590	0.030
B.3: Average rolling-beta CAPM estimate of alpha						
α_p^{rb}	−0.0004	−0.0040	−0.0055	−0.0034	−0.0061	−0.0046
	(0.0091)	(0.0041)	(0.0092)	(0.0093)	(0.0048)	(0.0093)
$\overline{\beta}_p^{rb}$	0.6654	0.9792	0.3138	1.2444	1.3994	0.1550

Table 6: Returns-based performance of equally weighted (buy signal) portfolio

The performance estimates reported in this table are based on monthly equally weigted (buy signal) portfolio returns, as defined in equation (12). The equally weighted "buy signal" portfolio contains stocks with insider buys in a previous period. The Male–female portfolio is long in male and short in female insider weights, respectively. The estimation is done for the two periods 1997–2007 and 2008–2016, respectively. In Panel **A**, Sharpe Ratio is $\text{mean}(r_p - r_f)/\text{sd}(r_p - r_f)$ for the long portfolios and, for the long-short portfolio, $\text{mean}(r_p)/\text{sd}(r_p)$. The two performance metrics, α_p^{4f} in Panel **B** and α_p^{rb} in Panel **C**, are defined in Eq. (11) in the text. The first is the constant term in a four-factor Fama-French-Carhart regression, while the second is the average constant term in a rolling-beta CAPM regression. Standard errors in brackets. Statistical significance indicated as *=p<0.1, **=p<0.05, ***= p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

Table 6: (Continued)

	Equal weighted portfolio weights					
	1997–2007			2008-2016		
	Female	Male	Male− Female	Female	Male	Male− Female
	(1)	(2)	(3)	(4)	(5)	(6)
A: Average raw returns and Sharpe Ratio						
$(1/N)\sum r_{pt}$	0.0239	0.0269	−0.0086	0.0434	0.0208	−0.0209
$(1/N)\sum r^e_{pt}$	0.0199	0.0229		0.0414	0.0189	
Sharpe Ratio	0.1532	0.2735	−0.0739	0.1569	0.1982	−0.0965
B: Four-factor alpha estimate						
α_p^{4f}	−0.009	−0.004	0.001	−0.001	−0.004	−0.005
	(0.006)	(0.004)	(0.006)	(0.004)	(0.004)	(0.005)
β_p^m	1.071***	1.313***	0.251**	1.104***	1.169***	0.083
	(0.117)	(0.077)	(0.125)	(0.089)	(0.102)	(0.127)
b_p^{SMB}	0.117	−0.080	−0.197	−0.142	−0.401***	−0.251**
	(0.157)	(0.104)	(0.169)	(0.087)	(0.100)	(0.125)
b_p^{HML}	−0.093	−0.154*	−0.058	−0.163**	−0.150*	0.011
	(0.129)	(0.086)	(0.139)	(0.070)	(0.081)	(0.101)
b_p^{UMD}	−0.030	−0.080	−0.043	0.153**	0.151*	0.001
	(0.091)	(0.060)	(0.098)	(0.071)	(0.082)	(0.102)
Observations	132	132	132	108	108	108
$\overline{R}^2$	0.432	0.739	0.029	0.654	0.663	0.024
C: Average rolling-beta CAPM estimate of alpha						
α_p^{rb}	0.0105	0.0083	−0.0088	0.0346	0.0114*	−0.0235
	(0.0104)	(0.0041)	(0.0109)	(0.0252)	(0.0065)	(0.0214)
$\overline{\beta}_p^{rb}$	1.1078	1.0925	−0.0075	1.1078	1.0925	−0.0075

Table 7: The likelihood of trades by primary insiders during the financial crisis

The table reports coefficient estimates in probit regressions of the likelihood of observing at least one insider trade in a given company. Estimated separately for gender using firm-quarter observations. In a given firm-quarter, the left-hand-side variable takes a value of one if there is an insider trade and zero otherwise. The explanatory variables include the indicator variable *Crisis*, which takes a value of one during the financial crisis period 2008:10–2010:12. The firm-level explanatory variables include the log of the *Market Capitalization* of the firm, stock *Volatility* (the quarterly volatility of the firm's stock return), stock *Liquidity* (last quarter's average daily quoted stock bid/ask spread), and stock *Beta* (estimated over the past 36 months). The regressions include industry fixed effects for the 10 GICS industry codes. The estimation period is 1998-2016. Statistical significance is indicated by p-values as follows: *=p<0.1, **=p<0.05, ***=p<0.01.

	Primary Females		**Primary males**	
	Buys	Sells	Buys	Sells
	(1)	(2)	(3)	(4)
Constant	-3.616^{***}	-4.265^{***}	-1.536^{***}	-2.212^{***}
	(0.295)	(0.516)	(0.187)	(0.240)
Crisis	0.403^{***}	-0.026	0.145^{***}	-0.156^{***}
	(0.047)	(0.100)	(0.034)	(0.049)
Market Cap	0.092^{***}	0.097^{***}	0.035^{***}	0.038^{***}
	(0.013)	(0.022)	(0.008)	(0.011)
Volatility	0.806^{**}	0.707	0.948^{***}	0.887^{***}
	(0.403)	(0.591)	(0.322)	(0.333)
Liquidity	-3.171^{***}	-5.102^{***}	-2.753^{***}	-3.494^{***}
	(0.820)	(1.791)	(0.468)	(0.634)
Beta	-0.098^{***}	-0.154^{**}	-0.041^{**}	0.005
	(0.033)	(0.060)	(0.020)	(0.025)
Industry FE	Yes	Yes	Yes	Yes
Observations	14,837	14,837	14,837	14,837

Table 8: The likelihood of trades by directors during the financial crisis

The table reports coefficient estimates of a probit model for the likelihood of an insider trade by an individual director (board member) in a given quarter, 1998–2016. The variable *Female* is a indicator variable equal to one if the director is female. The indicator variable *Crisis* takes a value of one during the financial crisis period 2008:10–2010:12 and zero otherwise. The firm-level explanatory variables include *Market Cap* (the natural log of the firm's market capitalization), *Volatility* (the quarterly volatility of the firm's stock return), *Liquidity* (last quarter's average daily stock quoted bid/ask spread), and *Beta* (stock beta estimated over the past 36 months). The regressions include industry fixed effects for the 10 GICS industry codes. Standard errors in brackets. Statistical significance is indicated as follows: *=p<0.1, **=p<0.05, ***=p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`). Board data are from the national *Brønnøysund Registry Centre.*

	Female Directors		**Male Directors**	
	Purchases	Sales	Purchases	Sales
	(1)	(2)	(3)	(4)
Constant	−2.544 * **	−3.591 * **	−2.080 * **	−2.516 * **
	(0.366)	(0.849)	(0.178)	(0.270)
Crisis	0.227 * **	−0.628 * *	0.229 * **	−0.144 * *
	(0.055)	(0.274)	(0.033)	(0.064)
Market Cap	0.019	0.026	0.013*	0.014
	(0.016)	(0.036)	(0.008)	(0.012)
Volatility	1.537 * *	1.716*	1.040 * **	0.966 * **
	(0.603)	(0.920)	(0.217)	(0.282)
Liquidity	−2.908 * **	−6.533*	−2.967 * **	−3.264 * **
	(1.064)	(3.560)	(0.459)	(0.748)
Beta	−0.022	0.007	0.011	0.035
	(0.043)	(0.095)	(0.020)	(0.029)
Industry FE	Yes	Yes	Yes	Yes
Observations	17,255	17,242	43,846	43,819

Table 9: Holdings-based primary insider performance during the crisis period

Performance estimates using holdings-based performance evalulation. The two sets of portfolio weights are defined in Eq. (8) in the text. The Insider-ownership-weight of firm i (columns 1-3) is the insiders' percentage ownership of firm i divided by the sum of the percentage insider holdings across all OSE firms. The Insider-value-weight (columns 4-6) of firm i is the value of insider holdings in i divided by the value of all insider holdings in all OSE firms. The holdings-based estimates are based on covariances between monthly changes in insider holdings (weights) and subsequent returns, as follows:

$$HCM = \frac{1}{T-2}\sum_{t=2}^{T}\frac{1}{N_t}\left(\sum_{t=1}^{N_t} cov\left(\Delta w_{it},\ r_{i,t+\tau} - E[r_{i,t+\tau}]\right)\right)$$

where Δw_{it} is the change in the weight of stock i in the insider portfolio from month $t-1$ to t, and $r_{i,t+\tau} - E[r_{i,t+\tau}]$ is the abnormal returns over the subsequent τ months ($\tau = 1, 3, 6$). Δw_{it} is the monthly change in insider holdings, $w_{it}^{ins} - w_{i,t-1}^{ins}$. $E[r_{i,t+\tau}]$ is the predicted return using the Fama-French-Carhart risk factors estimated using five years of monthly data prior to time t. The estimation is done for the two periods 1997–2007 and 2008–2016. The columns labelled p(diff) report the p-value for the test of difference between the male and female portfolio performance metrics. The p-values are calculated using standard errors robust to autocorrelation. Statistical significance is indicated as: *=p<0.1, **=p<0.05, ***= p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

Table 9: (Continued)

	Insider-ownership portfolio weights			Insider-value portfolio weights		
	Female	Male	p(diff)	Female	Male	p(diff)
	(1)	(2)	(3)	(4)	(5)	(6)
A: Short-lived insider information: one-month horizon ($\tau = 1$)						
Δw_{it}*: lagged insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\ r_{i,t+1} - E[r_{i,t+1}])$	−0.0070	−0.0013	0.36	−0.0046	−0.0013	0.61
Δw_{it}*: market-adjusted insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\ r_{i,t+1} - E[r_{i,t+1}])$	−0.0104	0.0062	0.09	−0.0164	−0.0031	0.24
B; Intermediate-lived inside information: three-month horizon ($\tau = 3$)						
Δw_{it}*: lagged insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\ r_{i,t+3} - E[r_{i,t+3}])$	−0.0031	−0.0018	0.82	−0.0004	−0.0025	0.78
Δw_{it}*: market-adjusted insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\ r_{i,t+3} - E[r_{i,t+3}])$	0.0029	0.0353*	0.24	−0.0123	−0.0110	0.96
C: Long-lived insider information: six-month horizon ($\tau = 6$)						
Δw_{it}*: lagged insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\ r_{i,t+6} - E[r_{i,t+6}])$	−0.0047	−0.0015	0.56	0.0014	−0.0061	0.42
Δw_{it}*: market-adjusted insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\ r_{i,t+6} - E[r_{i,t+6}])$	0.0067	0.0477**	0.14	−0.0242*	−0.0267	0.93

Board gender-balancing and insider trading performance

Internet Appendix

B. Espen Eckbo and Bernt Arne Ødegaard

May 16, 2023

Addendum to Section 2: Institutional setting and insider population data

Figures IA.1 and IA.2 complement Figure 1 and 2 by constructing the board network using all public limited liability (ASA) companies (not OSE-listed ASA only).

Table IA.1 complements Table 1 by providing subperiod descriptives: 1997–2007 and 2008–2016.

Tables IA.2 and IA.3 provides descriptives by year over the sample period.

Addendum to Section 3: Market reaction to non-routine insider purchases

Table IA.4 complements Table 2 by providing event-study results for the entire sample period 1997-2016.

Addendum to Section 4: Insider performance evaluation

Table IA.5 complements Table 4 by estimating the holdings-based abnormal performance over the entire sample period 1997–2016.

Table IA.6 complements Table 5 by estimating the returns-based abnormal performance over the entire sample period 1997–2016.

Table IA.7 complements Table 6 by estimating abnormal performance using the equally-weighted (buy signal) portfolio for the entire sample period 1997–2016.

Addendum to Section 5: Insider trading during the financial crisis

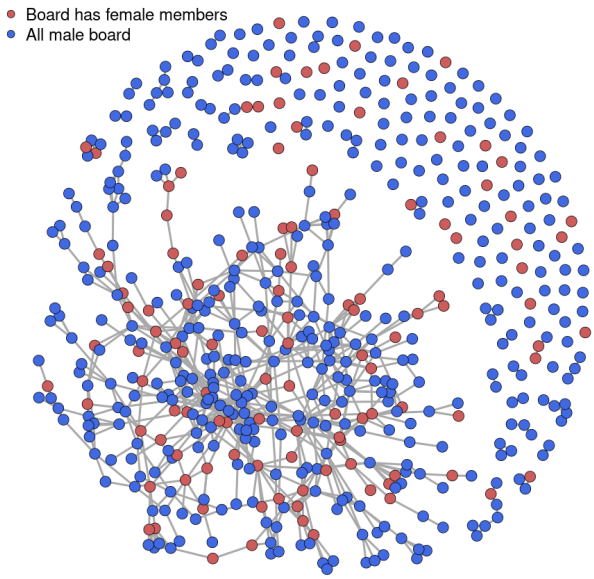
Table IA.8 complements Table 7 by repeating the probit estimation separately for executive and director insiders (instead of pooling all primary insiders).

Figure IA.3 and Table IA.9 complement the crisis analysis by introducing alternative measures of the propensity of insiders to trade and their behaviour during the financial crisis.

Figure IA.1: Evolution of board network links and gender composition - ASA firms

The figure illustrates the network structure of the boards of Norwegian public (ASA) companies. Each node is a company board. A link (line) between two boards indicates that at least one director sits on both boards. Solid (red) dots are companies with at least one female on the board, while grey (blue) dots represent all-male boards. Plot produced using the `R` library `igraph` (Csardi and Nepusz, 2006). Board data are from the national *Brønnøysund Registry Centre*, 1998-2016.

Year 2002



Year 2008

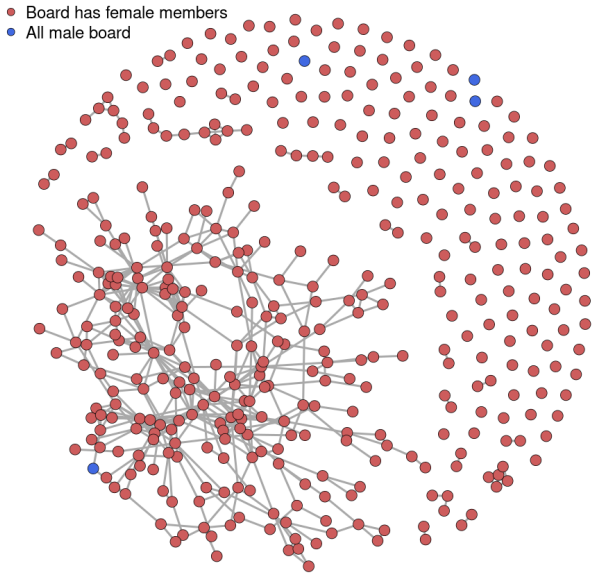


Figure IA.2: Number of board seats held by male and female directors in 2002 and 2008 - ASA firms

The distribution of the number of directorships in public (ASA) companies held by individual male and female directors in years 2002 and 2008, respectively. Board data are from the national *Brønnøysund Registry Centre*, 1998-2016.

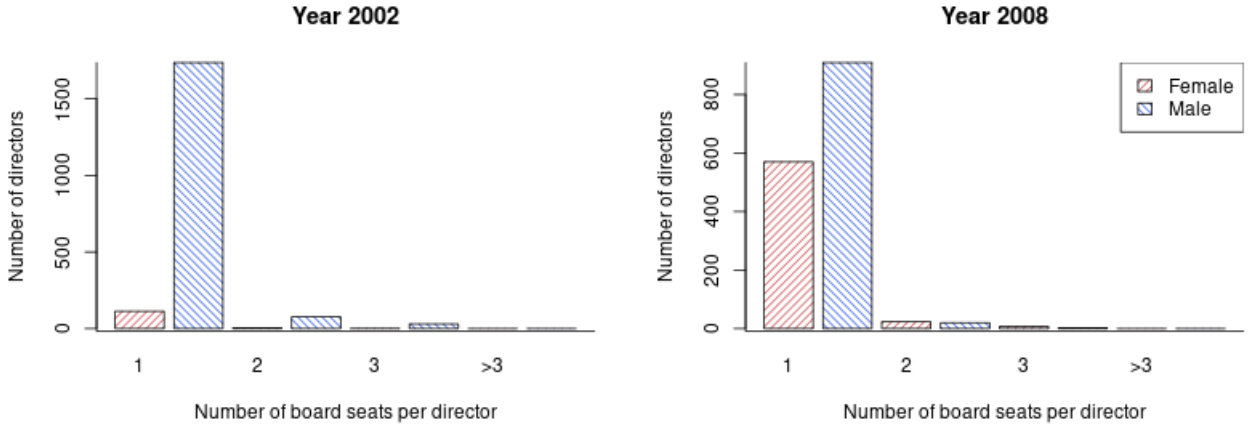


Table IA.1: Insider trades before and after quota compliance (1997–2007 v. 2008–2016)

The tables providede descriptives for the insider sample for the two periods 1997–2007 and 2008–2016. In Panel A, the number of distinct insiders is the number of primary insiders with transactions (excluding insiders who never transact). Panel B characterizes insider trading on an individual trader basis, using the insiders' trading history. The trading history begins with the first reported trade and ends with the last reported trade. We first compute the annual number of trades and trade values for each insider, and then form the sample period average for each insider (including years without trades). Panel B then reports the averages of these per insider averages. All value as in constant 2016 kroner (NOK) using the consumer price index supplied by the Norwegian Bureau of Statistics (SSB). Data only for primary insiders.

A: Transaction totals and averages

	Primary Insiders							
	1997–2007				2008–2016			
	Total	Male	Female	Female(%)	Total	Male	Female	Female(%)
Number of distinct insiders	3394	3059	335	9.9	2913	2612	640	22.0
Total transaction value (million)								
Buys	45438	45229	208	0.5	9787	9261	526	5.4
Sells	54892	54235	657	1.2	5522	4995	528	9.6
Number of transactions								
Buys	5935	5512	423	7.1	6688	5665	1023	15.3
Sells	2397	2265	132	5.5	983	857	126	12.8
Average transaction (1,000)								
Buys	7656	8206	493		1463	1635	514	
Sells	22900	23945	4978		5618	5828	4187	
Median transaction (1,000)								
Buys	138	147	56		127	144	82	
Sells	742	793	168		505	611	195	

B: Individual insiders' trading frequency and intensity

	Primary insiders					
	1997–2007			2008–2016		
	All	Female	Male	All	Female	Male
Number of trades in year						
Buys	1.29	1.23	1.29	1.27	1.16	1.30
Sells	1.16	1.08	1.17	1.15	1.09	1.16
Annual transaction value (thousands)						
Buys	7529	698	8273	1725	613	1995
Sells	29795	6266	31652	5704	2107	6298

Table IA.2: Annual primary insider trades by gender and value, OSE 1997-2016

This table shows the annual distribution of the primary insider trades. Primary insiders are directors and executives. 100K means NOK 100.000. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

	Primary Insider Purchases					**Primary Insider Sales**				
	Number of Transactions				% Female	Number of Transactions				% Female
Year	<100K	>100K	Female	Male	by value	<100K	>100K	Female	Male	by value
1997	353	488	60	781	0.43	281	111	20	372	0.20
1998	187	230	21	398	0.05	87	28	7	108	0.10
1999	477	554	60	977	0.78	270	105	18	357	0.28
2000	277	270	20	529	0.15	218	34	13	239	14.24
2001	227	221	18	431	3.25	154	54	6	202	2.22
2002	261	286	24	523	0.12	69	43	3	109	0.01
2003	159	196	18	338	1.38	120	63	6	177	0.05
2004	149	168	25	294	0.26	123	38	15	146	0.59
2005	163	143	32	278	2.49	156	32	16	174	0.10
2006	306	156	41	424	0.32	223	26	15	235	0.69
2007	429	213	104	539	0.37	145	13	13	146	2.49
2008	345	275	84	538	7.31	61	15	3	73	0.04
2009	520	643	205	971	6.49	104	33	17	120	0.35
2010	487	531	162	866	14.50	98	31	14	115	3.00
2011	508	425	139	797	4.76	65	26	10	81	21.79
2012	314	191	66	440	1.45	80	24	17	87	14.17
2013	349	198	68	479	1.46	97	32	19	110	14.79
2014	402	247	91	559	2.77	96	35	20	111	25.61
2015	338	284	102	521	10.35	53	26	13	66	4.23
2016	295	302	106	494	10.37	69	38	13	94	2.39
All	6546	6021	1446	11177	1.47	2569	807	258	3122	2.09

Table IA.3: Annual primary insider trades by gender and position, OSE 1997-2016

This table shows the annual distribution of the primary insider trades. Primary insiders are directors and executives. 100K means NOK 100.000. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

	Primary Insider Purchases				**Primary Insider Sales**			
	Female		Male		Female		Male	
Year	Mgmt	Board	Mgmt	Board	Mgmt	Board	Mgmt	Board
1997	42	18	523	258	13	7	228	144
1998	20	1	244	154	7	0	70	38
1999	40	20	618	359	14	4	241	116
2000	16	4	329	200	7	6	159	80
2001	13	5	261	170	4	2	123	79
2002	14	10	307	216	1	2	61	48
2003	7	11	195	143	5	1	111	66
2004	10	15	213	81	8	7	87	59
2005	16	16	171	107	8	8	113	61
2006	23	18	226	198	11	4	145	90
2007	45	59	348	191	8	5	99	47
2008	40	44	382	156	2	1	54	19
2009	136	69	662	309	10	7	79	41
2010	102	60	607	259	12	2	78	37
2011	84	55	557	240	6	4	63	18
2012	33	33	289	151	8	9	67	20
2013	39	29	253	226	5	14	61	49
2014	44	47	331	228	11	9	56	55
2015	49	53	310	211	7	6	41	25
2016	55	51	306	188	9	4	57	37
All	828	618	7132	4045	156	102	1993	1129

Table IA.4: Market reaction to insider purchases, 1997–2016

The table reports the cumulative abnormal abnormal stock return $CAR \equiv \tau\gamma$, where γ is the average daily abnormal return over τ days in event time centered on the day of insider purchases (day 0) and estimated using the following one-factor return-generating process for firm i:

$$r^e_{it} = a_i + b_i r^e_{mt} + \gamma_i D_{it} + \varepsilon_{it},$$

where r^e_{mt} is the return on the market portfolio in excess of the risk-free rate on day t, and D_{it} is a dummy variable that takes a value of one inside the event window and zero otherwise. There are four alternative event windows around day 0: days $(-1, 1)$, $(-1, 5)$, $(-1, 25)$, and $(-1, 50)$. The estimation in Panel A (Panel B) uses trades of primary female (male) insiders only. We remove routine trades as in Cohen, Malloy, and Pomorski (2012). Standard errors in brackets. Statistical significance is indicated by: *=p<0.1, **=p<0.05, ***=p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

	Event windows for the cumulative abnormal return			
	$CAR(-1,1)$	$CAR(-1,5)$	$CAR(-1,25)$	$CAR(-1,50)$
A: Female Insiders				
CAR	0.012***	0.012***	0.007	0.003
	(0.001)	(0.0008)	(0.0004)	(0.0003)
Observations	643,261	643,261	643,261	643,261
$\overline{R}^2$	0.030	0.030	0.030	0.030
B: Male Insiders				
CAR	0.014***	0.014***	0.003	−0.009
	(0.001)	(0.001)	(0.001)	(0.0004)
Observations	1,013,513	1,013,513	1,013,513	1,013,513
$\overline{R}^2$	0.005	0.005	0.005	0.005

Table IA.5: Holdings-based primary insider performance, 1997–2016

Performance estimates using holdings-based performance evalulation. The three sets of portfolio weights are defined in Eqns. (**XX**) and (**XY**) in the text. The Insider-ownership-weight of firm i (columns 1-3) is the insiders' percentage ownership of firm i divided by the sum of the percentage insider holdings across all OSE firms. The Insider-value-weight (columns 4-6) of firm i is the value of insider holdings in i divided by the value of all insider holdings in all OSE firms. The holdings-based estimates are based on covariances between monthly changes in insider holdings (weights) and subsequent returns, as follows:

$$HCM = \frac{1}{T-2}\sum_{t=2}^{T}\frac{1}{N_t}\left(\sum_{t=1}^{N_t} cov\left(\Delta w_{it},\ r_{i,t+T} - E[r_{i,t+T}]\right)\right)$$

where Δw_{it} is the change in the weight of stock i in the insider portfolio from month $t-1$ to t, and $r_{i,t+T} - E[r_{i,t+T}]$ is the abnormal returns over the subsequent T months ($T = 1, 3, 6$). Δw_{it} is either the monthly change in insider holdings, $w_{it}^{ins} - w_{i,t-1}^{ins}$, or the monthly change in insider holdings relative to the firm's weight in the OSE market portfolio (a CAPM "buy and hold" weight). $E[r_{i,t+T}]$ is the predicted return using the Fama-French-Carhart risk factors estimated using five years of monthly data prior to time t. The columns labelled p(diff) report the p-value for the test of difference between the male and female portfolio performance metrics. The p-values are calculated using standard errors that are robust to autocorrelation. Standard errors are in brackets, with p-values indicated as: *=p<0.1, **=p<0.05, ***= p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

	Insider-ownership portfolio weights			**Insider-value portfolio weights**		
	Female	Male	p(diff)	Female	Male	p(diff)
	(1)	(2)	(3)	(4)	(5)	(6)
A: Short-lived insider information: one-month future return horizon ($T = 1$)						
Δ_{it}: *lagged insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\quad r_{i,t+1} - E[r_{i,t+1}])$	0.0010	0.0000	0.46	0.0007	0.0008	0.93
Δ_{it}: *market portfolio weights*						
$Cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\quad r_{i,t+1} - E[r_{i,t+1}])$	0.0018	−0.0028	0.34	−0.0015	−0.0029	0.72
B; Intermediate-lived inside information: three-month future return horizon ($T = 3$)						
Δ_{it}: *lagged insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\quad r_{i,t+3} - E[r_{i,t+3}])$	0.0025	0.0003	0.31	0.0018	−0.0002	0.40
Δ_{it}: *market portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\quad r_{i,t+3} - E[r_{i,t+3}])$	0.0030	−0.0058	0.48	−0.0079	−0.0092	0.92
C: Long-lived insider information: six-month future return horizon ($T = 6$)						
Δ_{it}: *lagged insider portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{ins}\ ;\quad r_{i,t+6} - E[r_{i,t+6}])$	0.0009	0.0002	0.70	0.0000	0.0003	0.95
Δ_{it}: *market portfolio weights*						
$cov(w_{it}^{ins} - w_{i,t-1}^{m}\ ;\quad r_{i,t+6} - E[r_{i,t+6}])$	−0.0009	−0.0048	0.84	−0.0215	−0.0139	0.73

Table IA.6: Returns-based primary insider portfolio performance, 1997–2016.

The performance estimates reported in this table are based on monthly portfolio returns and rebalancing. The three sets of portfolio weights are defined in Eqns. (**YY**) and (**YX**) in the text. The Insider-ownership-weight of firm i (columns 1-3) is the insiders' percentage ownership of firm i divided by the sum of the percentage insider holdings across all OSE firms. The Insider-value-weight (columns 4-6) of firm i is the value of insider holdings in i divided by the value of all insider holdings in all OSE firms. The equally weighted "buy signal" portfolio contains stocks with insider buys in a previous period. The Male–female portfolio is long in male and short in female insider weights, respectively. In Panel A, Sharpe Ratio is $\text{mean}(r_p - r_f)/\text{sd}(r_p - r_f)$ and, for the long-short portfolio, $\text{mean}(r_p)/\text{sd}(r_p)$. The two performance metrics, α_p^{4f} in Panel B and α_p^{rb} in Panel C, are defined in the text. The first is the constant term in a four-factor Fama-French-Carhart regression, while the second is the average constant term in a rolling-beta CAPM regression. Standard errors are in brackets. Statistical significance indicated as *=p<0.1, **=p<0.05, ***= p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

	Insider-ownership portfolio weights			**Insider-value portfolio weights**		
	Female	Male	Male− Female	Female	Male	Male− Female
	(1)	(2)	(3)	(4)	(5)	(6)
A: Average raw returns and Sharpe Ratio						
$(1/N)\sum r_{pt}$	0.0116	0.0094	−0.0023	0.0099	0.0119	0.0020
$(1/N)\sum r^e_{pt}$	0.0085	0.0063		0.0068	0.0088	
Sharpe Ratio	0.0991	0.0930	−0.0259	0.0912	0.1133	0.0313
B: Four-factor alpha estimate						
α_p^{4f}	−0.001	−0.006**	−0.008	−0.005	−0.004	−0.002
	(0.005)	(0.003)	(0.006)	(0.004)	(0.003)	(0.004)
β_p^m	0.774***	1.142***	0.378***	1.063***	1.258***	0.204**
	(0.113)	(0.055)	(0.119)	(0.076)	(0.060)	(0.087)
b_p^{SMB}	0.217	0.088	−0.126	−0.014	−0.219***	−0.203*
	(0.135)	(0.066)	(0.142)	(0.091)	(0.072)	(0.104)
b_p^{HML}	0.304***	−0.042	−0.346***	−0.134*	−0.163***	−0.029
	(0.110)	(0.053)	(0.116)	(0.074)	(0.059)	(0.085)
b_p^{UMD}	0.081	−0.072	−0.148	0.025	0.002	−0.017
	(0.091)	(0.044)	(0.095)	(0.061)	(0.049)	(0.070)
Observations	240	240	240	240	240	240
$\overline{R}^2$	0.158	0.674	0.098	0.493	0.703	0.039
C: Average rolling-beta CAPM estimate of alpha						
α_p^{rb}	0.0008	−0.0038	−0.0076	−0.0036	−0.0096***	−0.0091
	(0.0052)	(0.0026)	(0.0055)	(0.0054)	(0.0031)	(0.0056)
$\overline{\beta}_p^{rb}$	0.6179	0.9916	0.3737	1.1551	1.4559	0.3009

Table IA.7: Returns-based insider portfolio performance, equal weighted (buy signal) portfolio, 1997–2016.

The performance estimates reported in this table are based on monthly portfolio returns and rebalancing. The equally weighted "buy signal" portfolio contains stocks with insider buys in a previous period. The Male–female portfolio is long in male and short in female insider weights, respectively. In Panel A, Sharpe Ratio is mean$(r_p - r_f)$/sd$(r_p - r_f)$ and, for the long-short portfolio, mean(r_p)/sd(r_p). The two performance metrics, α_p^{4f} in Panel B and α_p^{rb} in Panel C, are defined in the text. The first is the constant term in a four-factor Fama-French-Carhart regression, while the second is the average constant term in a rolling-beta CAPM regression. Standard errors are in brackets. Statistical significance indicated as *=p<0.1, **=p<0.05, ***= p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

	Buy Signal portfolio weights		
	Female	Male	Male− Female
	(1)	(2)	(3)
A: Average raw returns and Sharpe Ratio			
$(1/N)\sum r_{pt}$	0.0381	0.0242	−0.0149
$(1/N)\sum r^e_{pt}$	0.0340	0.0211	
Sharpe Ratio	0.1593	0.2371	−0.0854
B: Four-factor alpha estimate			
α_p^{4f}	0.019	0.006	−0.017
	(0.015)	(0.004)	(0.013)
β_p^m	1.309***	1.450***	0.176
	(0.312)	(0.079)	(0.272)
b_p^{SMB}	0.241	0.223**	−0.035
	(0.358)	(0.094)	(0.313)
b_p^{HML}	−0.662**	−0.033	0.664**
	(0.299)	(0.077)	(0.261)
b_p^{UMD}	0.029	−0.126**	−0.131
	(0.261)	(0.064)	(0.228)
	205	240	205
$\overline{R}^2$	0.108	0.612	0.016
C: Average rolling-beta CAPM estimate of alpha			
α_p^{rb}	0.0230	0.0097***	−0.0164
	(0.014)	(0.0037)	(0.0123)
$\overline{\beta}_p^{rb}$	1.1078	1.0925	−0.0075

Table IA.8: The likelihood of trades by primary insiders during the financial crisis

The table reports coefficient estimates in probit regressions of the likelihood of observing at least one insider trade in a given company. Estimated separately for gender using firm-quarter observations. In a given firm-quarter, the left-hand-side variable takes a value of one if there is an insider trade and zero otherwise. The explanatory variables include the indicator variable *Crisis*, which takes a value of one during the financial crisis period 2008:10–2010:12. The firm-level explanatory variables include the log of the *Market Capitalization* of the firm, stock *Volatility* (the quarterly volatility of the firm's stock return), stock *Liquidity* (last quarter's average daily quoted stock bid/ask spread), and stock *Beta* (estimated over the past 36 months). The regressions include industry fixed effects for the 10 GICS industry codes. The estimation period is 1998-2016. Statistical significance is indicated by p-values as follows: *=p<0.1, **=p<0.05, ***=p<0.01.

Panel A: Directors

Insider trade among	**Female Directors**		**Male Directors**	
	Purchases	**Sales**	**Purchases**	**Sales**
Constant	-3.176^{***}	-5.190^{***}	-1.413^{***}	-2.170^{***}
	(0.368)	(0.705)	(0.220)	(0.308)
Crisis	0.343^{***}	-0.262	0.136^{***}	-0.278^{***}
	(0.057)	(0.174)	(0.040)	(0.069)
Market Cap	0.061^{***}	0.113^{***}	0.007	0.019
	(0.016)	(0.030)	(0.010)	(0.014)
Volatility	0.559	0.765	1.006^{***}	0.823^{**}
	(0.481)	(0.570)	(0.329)	(0.361)
Liquidity	-3.417^{***}	-1.943	-2.085^{***}	-2.550^{***}
	(1.036)	(2.178)	(0.539)	(0.794)
Beta	-0.110^{***}	-0.037	-0.019	0.028
	(0.041)	(0.079)	(0.023)	(0.030)
Industry Fixed Effects	*Y*	*Y*	*Y*	*Y*
Observations	14,837	14,837	14,837	14,837
Note:				*p<0.1; **p<0.05; ***p<0.01

Panale B: Executives

Insider trade among	**Female Directors**		**Male Directors**	
	Purchases	**Sales**	**Purchases**	**Sales**
Constant	-4.248^{***}	-3.397^{***}	-2.038^{***}	-2.630^{***}
	(0.353)	(0.629)	(0.202)	(0.266)
Crisis	0.459^{***}	0.037	0.196^{***}	-0.108^{**}
	(0.054)	(0.113)	(0.036)	(0.053)
Market Cap	0.107^{***}	0.059^{**}	0.050^{***}	0.050^{***}
	(0.015)	(0.027)	(0.009)	(0.012)
Volatility	0.884^{**}	-0.303	0.694^{**}	0.887^{**}
	(0.423)	(2.236)	(0.326)	(0.352)
Liquidity	-2.623^{***}	-7.369^{***}	-2.864^{***}	-4.008^{***}
	(0.984)	(2.597)	(0.516)	(0.728)
Beta	-0.090^{**}	-0.188^{**}	-0.045^{**}	-0.013
	(0.040)	(0.075)	(0.022)	(0.028)
Industry Fixed Effects	*Y*	*Y*	*Y*	*Y*
Observations	14,837	14,837	14,837	14,837
Note:				*p<0.1; **p<0.05; ***p<0.01

Alternative measures of insider trading

For purposes of robustness, we also estimate the effect of the financial crisis on the following two alternative measures of monthly aggregate insider trades, used previously by Lakonishok and Lee (2001) and Anginer, Donmez, Seyhun, and Zhang (2020):

$$Insider\ Direction_{it} = \frac{\sum_j Buy_{ijt} - \sum_j Sell_{ijt}}{\sum_j Buy_{ijt} + \sum_j Sell_{ijt}}, \tag{14}$$

where a Buy (Sell) is an indicator variable that takes a value of one if insider j in firm i has made a purchase (sale) in month t, and

$$Insider\ Shares_{it} = \frac{Shares\ Purchased_{it} - Shares\ Sold_{it}}{Shares\ Purchased_{it} + Shares\ Sold_{it}}, \tag{15}$$

where $Shares\ Purchased\ (Sold)_{it}$ is the total number of shares of company i purchased (sold) by insiders in month t. *Insider Direction* treats each insider trade equally, independent of the trade size, while *Insider Shares* gives more weight to larger trades in terms of the number of shares purchases or sold.

Figure IA.3: Fraction of positive *Insider direction*, 1997–2016

The figure plots the quarterly fractions of OSE-listed firms with positive aggregate *Insider Direction*, where

$$Insider\ Direction_{i,t} = \frac{\sum_j Buy_{ijt} - \sum_j Sell_{ijt}}{\sum_j Buy_{ijt} + \sum_j Sell_{ijt}}.$$

Buy (Sell) is an indicator variable that takes a value of one if insider j in firm i has made a purchase (sale) in quarter t. Population data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

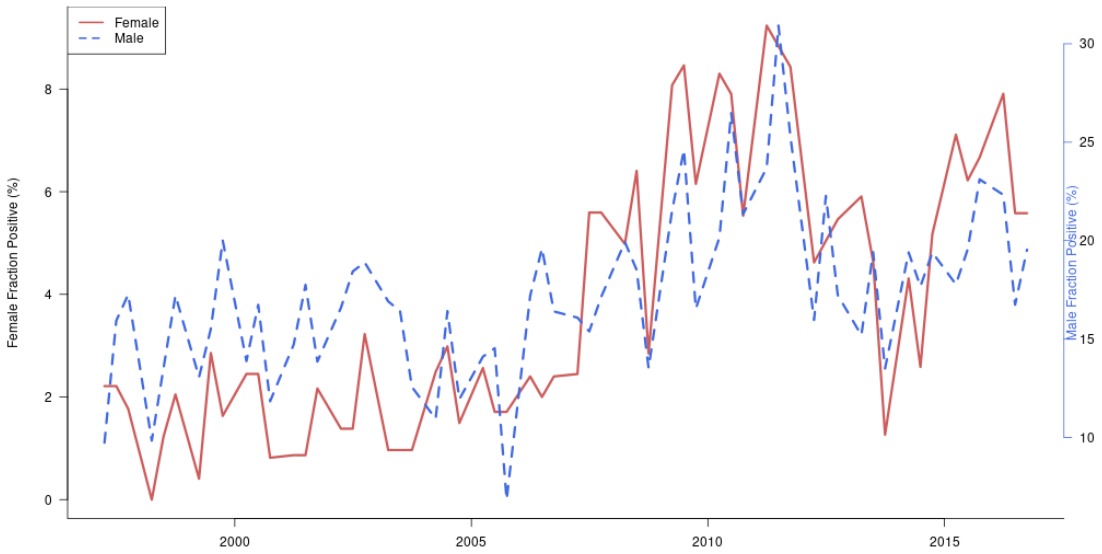


Figure IA.3 plots the fraction of companies at the OSE with positive *Insider Direction*, calculated

separately for the trades of female and male insiders. The number of firms with a positive aggregate direction of inside trading clearly increases at the beginning of the crisis. This effect of the crisis is confirmed in Table IA.9, which reports coefficient estimates from panel regressions with either $Insider\ Direction_{it}$ or $Insider\ Shares_{it}$ as dependent variable. Again, the coefficient estimate for *Crisis* is positive and significant for both female and male insiders. Also as before, independent of gender, the coefficients indicate more insider trading in larger, more volatile, more liquid, and less risky firms.

Table IA.9: Effect of financial crisis on two alternative measures of insider trades

The table reports coefficient in cross-sectional regressions with the following two alternative measures of monthly aggregate insider trade as dependent variable:

$$Insider\ Direction_{it} = \frac{\sum_j Buy_{ijt} - \sum_j Sell_{ijt}}{\sum_j Buy_{ijt} + \sum_j Sell_{ijt}}$$

where Buy (Sell) is an indicator variable that takes a value of one if insider j in firm i has made a purchase (sale) in month t, and

$$Insider\ Shares_{it} = \frac{Shares\ Purchased_{it} - Shares\ Sold_{it}}{Shares\ Purchased_{it} + Shares\ Sold_{it}}$$

where $Shares\ Purchased\ (Sold)_{it}$ is the total number of shares of company i purchased (sold) by insiders in month t. The explanatory variables include the indicator variable *Crisis*, which takes a value of one during the financial crisis period 2008:10–2010:12. The firm-level explanatory variables include the log of the *market capitalization* of the firm, stock *volatility* (the quarterly volatility of the firm's stock return), stock *liquidity* (last quarter's average daily quoted stock bid/ask spread), and stock *beta* (estimated over the past 36 months). The estimation period is 1998-2016. Standard errors in brackets. Statistical significance is indicated by p-values as follows: *=p<0.1, **=p<0.05, ***=p<0.01. Data on insider trades and holdings are from OSE electronic records (`https://newsweb.oslobors.no/`).

	Alternative measures of insider trades			
	Insider Direction		*Insider Shares*	
	Female	Male	Female	Male
	(1)	(2)	(3)	(4)
Constant	−0.059***	0.026	−0.058***	0.032
	(0.016)	(0.031)	(0.016)	(0.031)
Crisis	0.011***	0.012**	0.011***	0.010**
	(0.002)	(0.005)	(0.002)	(0.005)
Market Capitalization	0.004***	0.002	0.003***	0.002
	(0.001)	(0.001)	(0.001)	(0.001)
Volatility	0.067**	0.120**	0.067**	0.120**
	(0.029)	(0.055)	(0.029)	(0.056)
Liquidity	−0.088**	−0.273***	−0.092**	−0.264***
	(0.039)	(0.074)	(0.039)	(0.075)
Beta	−0.002	−0.003	−0.002	−0.003
	(0.002)	(0.003)	(0.002)	(0.003)
Industry Fixed Effects	Yes	Yes	Yes	Yes
Observations	24,143	24,143	24,143	24,143
$\overline{R}^2$	0.005	0.004	0.005	0.004