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Director informativeness following board gender-balancing: Evidence from insider trading

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Abstract

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

JEL Classifications: G14, M14

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"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)

1 Introduction

The international trend towards mandating gender-balanced boards raises difficult but important questions about the impact of board composition on firm value. A central issue is whether female directors elected under a quota will lower the value of the board's strategic advice and oversight, since they often lack chief executive officer (CEO) experience. In addition, it has been suggested that female directors may be too focused on monitoring and exhibit a lower appetite for risk taking than male directors (Croson and Gneezy, 2009; Sila, Gonzales, and Hagendorff, 2016)—unless such gender differences disappear on the way to the top (Adams and Funk, 2012). On the other hand, board effectiveness may increase if the quota leads to a more professional director election process, e.g., by reducing the influence of an "old boys" director network, by favoring more independent females, and by drawing on a broader skill set.[1]

Norway's pioneering quota law, which was implemented over the two-year period 2006–2007, provides a powerful quasi-experimental setting for examining these potentially opposing treatment effects. As summarized in Appendix A, the main conclusion of the existing literature is a statistically insignificant effect on the market value of companies listed on the Oslo Stock Exchange (OSE) (Eckbo, Nygaard, and Thorburn, 2022a). Nevertheless, the debate continues over whether the quota may have caused the introduction of female directors that on average are less effective than their male counterparts. Based solely on demographic characteristics such as age, education, and professional background, this does not seem to be the case (Ahern and Dittmar, 2012). In addition, companies listed on the OSE made sure to retain the board's overall (mostly male) CEO experience (Bertrand, Black, Jensen, and Lleras-Muney, 2019; Eckbo, Nygaard, and Thorburn, 2022b).

[1]For discussions of these issues, see Linck, Netter, and Yang (2008), Duchin, Matsusaka, and Ozbas (2010), Masulis and Mobbs (2011), Adams and Funk (2012), Agarwal, Qian, Reeb, and Sing (2016), Kim and Starks (2016), and Cullen and Perez-Truglia (2023).

Since demographic characteristics combine in complex ways to generate a director's understanding of a company's firm-specific capital, they provide a noisy estimate of director quality. Our contribution is to introduce a novel measure of what we label *director informativeness*: the ability of an insider to interpret the valuation implications of new material information about the firm's operations that emerges through board deliberations. We then use the market reaction to directors' (nonroutine) insider trades, which in Norway must be reported within twenty-four hours, as our instrument for measuring informativeness. This instrument captures the market's perception of the insider's fundamental understanding of potential price-sensitive information about firm value. This perception likely reflects not only the insider's personal characteristics but also latent gender-specific frictions in a board's monitoring and advising functions.[2]

The market reaction to insider trades has distinct econometric advantages as an instrument for director informativeness. For example, as we test for differences in the respective market reactions to trades by male and female directors of the *same* firm, we control for the nature of the underlying information that causes all these directors to trade. This control allows our tests to identify the existence of gender-specific insider performance, if any. As explained below, our main proposition is that the market reaction will be gender neutral if investors view the informativeness of male and female directors to be equal. Moreover, our instrument has the advantage of being a high-frequency summary statistic, as the number of observations is the same as the number of insider trades over the sample period. This, of course, is in contrast to the relatively low-frequency data on director demographic characteristics.

Our analysis exploits all daily trades and shareholdings of the insider population on the OSE during the period 1997–2016, which covers the second generation of insider trading regulations. Although they do not condition on gender, Eckbo and Smith (1998) analyze insider trades at the

[2]The tradition of associating private information with the market reaction to (legal) insider trades goes back at least to Jaffe (1974), Finnerty (1976) and Seyhun (1986). Examples of the voluminous subsequent literature that interpret the market reaction is similar ways include Seyhun (1988), Rozeff and Zirman (1988), Eckbo and Smith (1998), Lakonishok and Lee (2001), Jeng, Metrick, and Zeckhauser (2003), Fidrmuc, Goergen, and Renneboog (2006), Marin and Olivier (2008), Ravina and Sapienza (2009), Cohen, Malloy, and Pomorski (2012), and Biggerstaff, Cicero, and Wintoki (2020). Bhattacharya and Daouk (2002) discuss insider trading regulations in stock markets around the world.

monthly frequency on the OSE during the first-generation regulatory regime (1985–1996), while Hvide and Nielsen (2023) examine OSE-trades by nonexecutive insiders. Also, while our study is the first in the literature to identify the treatment effect on insider trading of a shock to the female proportion of the total director network, several studies outside Norway have otherwise conditioned insider information and trading performance on gender.[3]

We test the following four empirical propositions pertaining to gender-based director informativeness and trading activity:

P1 *Director informativeness*: Suppose Norway's mandatory gender balancing results in the appointment of female directors whose skill sets are such that they rapidly become as informed about firm value as their male counterpart. Then the post-quota average market reaction to female insider (non-routine) purchases, measured as the cumulative abnormal announcement return (CAR), will be similar to that of male insider purchases in the same firm.[4]

P2 *Board connectivity*: Regardless of gender, CAR will increase in the connectivity of the board's director network. This follows because, in addition to the individual directors' own personal qualities, gaining access to an extended network of peer-company insiders enhances the value of the insiders' own firm-specific information.

P3 *Director trading performance*: When the level of director informativeness is gender neutral, the holding-period-adjusted insider trading performance will also be gender neutral. This performance measure differs from CAR since insiders never purchase and then sell the shares (a round trip) within the short-term CAR event window itself. Testing for long-term differences in performance across male and female directors requires adjusting for director-specific holding periods.

P4 *Shock-induced director trading propensity*: Under gender-neutral director informativeness,

[3]See, e.g., Wang, Shin, and Francis (2012), Inci, Narayanan, and Seyhun (2017), Clacher, Osma, Scarlat, and Shields (2021), and Mobbs, Tan, and Zhang (2021). We discuss some of this evidence below.

[4]As is common in the literature on insider trades, we focus in particular on insider purchases since such transactions are not confounded by a demand for liquidity. Also consistent with this literature, we confirm empirically that there is only negligible abnormal performance following insider sales (Cohen, Malloy, and Pomorski, 2012).

the propensity to trade in reaction to a significant exogenous price shock—here represented by the financial crisis—will also be gender neutral. This follows because an insider's degree of informativeness is used to assess whether the exogenous price drop has caused the firm to be (temporarily) undervalued enough to warrant a purchase.

Our first and major empirical finding is that, consistent with P1, the quota law causes the average CAR to (non-routine) purchases by female directors to jump from statistically insignificant to about the level of male directors, which itself is positive and significant both before and after the quota law. This result suggests that, as they comply with the quota, firms appoint female directors who according to the market reaction are as informed about their respective firms' value prospects as their male counterparts. Using cross-sectional regressions with CAR as dependent variable, we further show that this post-quota market reaction is robust to conditioning the trades on new incoming female directors and on whether the female director trades take place relatively early in the post-quota period. In other words, it appears that the post-quota level of female director informativeness quickly converges to that of male directors. One likely channel for this rapid increase in the level of informativeness is the increase in female director committee participation following the substantial inflow of new female directors.

Second, turning to P2, while the Norwegian quota law left the total director network size largely unchanged, the replacement of male directors with female directors did change the degree of network connectivity. Using the Pagerank network centrality score as our network connectivity measure (Page, Brin, Motwani, and Winograd, 1999; Newman, 2018), we show that the market reaction to insider trades (male and female) is increasing in the connectivity of the board's overall director network. This finding is both intuitive and reassuring as a network-driven communication and information channel arises naturally when connected individuals operate in related industries and use related supply chains and similar production technologies—potentially enhancing the insiders' understanding of the factors driving their own firm value.[5]

[5]Without considering gender diversity, several papers show evidence consistent with a positive industry-related network effect on insiders' trading decisions. See, e.g., Døskeland and Hvide (2011), Alldredge and Cicero (2015), and Ben-David, Birru, and Rossi (2019) for evidence linking insider trading decisions by executives to information

Interestingly, under P2, we are able to rule out that the positive network connectivity effect is driven by the degree of busyness of a few individual directors (male or female). As is common in the literature, we measure a busy director as one who sits on three or more boards (in our case covering all listed firms). While, on the one hand, having multiple directorships can be a sign of director quality (Ferris, Jagannathan, and Pritchard, 2003; Masulis and Mobbs, 2011; Field, Lowry, and Mkrtchyan, 2013), directors serving on multiple boards may also be over-committed—lacking time and attention to devote to any particular firm (Fich and Shivdasani, 2006; Cashman, Gillan, and Jun, 2012; Falato, Kadyrzhanova, and Lel, 2014). What we find is that, in cross-sectional regression with the market reaction to insider trades as a dependent variable, adding director-level busyness as an explanatory variable receives an insignificant coefficient estimate while the board-level network connectivity remains positive and significant.[6]

Third, under P3, we test whether the positive market reaction to non-routine primary insider purchases maps into differential abnormal performance across male and female insiders. Here, our contribution to the literature on insider trading goes beyond gender as we use data that are hard to come by to systematically account for the insider's actual holding periods. Controlling for the actual holding period is important since the insider would realize the positive announcement return only if he/she sells during the cross-sectionally fixed event window (typically one week) used to measure the announcement return (which they never do in our data). In other words, as also noted by Gao, Ma, Ng, and Wu (2022), only a holding-based analysis can effectively integrate informed decisions *not* to sell in the performance analysis.

Our long-term performance analysis is performed on the portfolio of OSE-listed companies weighted by the total insider holding ω_{it} in firm i on day t. We subject this insider portfolio to two modern portfolio performance measures. The first tests whether insiders of firm i "buy low

about their corporate customers. There is also evidence that the degree of network connectivity is associated with greater CEO compensation, governance practices, corporate innovation activity, and insider trading. See, e.g., Renneboog and Zhao (2011), Bouwman (2011), Wang, Shin, and Francis (2012), Akbas et al. (2016) Chuluun, Prevost, and Upadhyay (2017), Goergen et al. (2019) Afzali and Martikainen (2021), El-Khatib, Jandik, and Jandik (2021), and Chang and Wu (2021).

[6]This finding also suggests that using aggregate board-level measures of busyness rather than individual director-level measures, which is not uncommon on the extant corporate governance literature (Sarabi and Smith, 2021), tends to conflate busyness with network connectedness.

and sell high" – that is, whether $Cov(\Delta\omega_{it}; r_{i,t+\tau}) > 0$, where $r_{i,t+\tau}$ is the excess stock return of firm i over the next τ days, which allows putative private information to last between one and six months.[7] The other performance measure that we report is the more traditional "Jensen's alpha" parameter (Jensen, 1968). The conclusion from both these two performance measures is the same: Regardless of gender, insiders do not realize statistically significant long-term abnormal returns either before or after the quota law became active.

Finally, turning to P4, we study changes in the trading propensities of male and female directors during the financial crisis period 10/2008–12/2010, when Norway's gender quota was already in place. Since the crisis-induced price shocks were exogenous to the OSE-listed firms, a significant increase in the propensity to purchase shares may be driven by inside information that the exogenous shock has caused the stock to be temporarily underpriced. Hence, this particular quasi-experiment provides a particularly powerful setting for testing whether director informativeness is indeed equal across male and female directors. As P4 states, if the degree of director informativeness is gender-neutral, then the trading intensity in response to the crisis-generated price shock will also be gender neutral. This proposition is also supported by our evidence: We find a similar increase in the purchase intensities of male and female insiders during the crisis period.

2 Institutional setting and data

2.1 The gender quota

In June of 2003, the Norwegian government proposed a quota law, which contained a sunset provision: the quota requirement would be canceled if firms complied voluntarily by the end of 2005. Although some firms—in particular companies with large government share ownership—began to increase female board representation, the observed degree of compliance was ultimately

[7] Grinblatt and Titman (1993) applies a similar covariance statistic (with $\tau = 1$) to measure the performance of actively managed US mutual funds based on quarterly ownership data. Eckbo and Smith (1998) apply a conditional version of the holding-based covariance statistic to monthly data on insider trades on the OSE, while Ferson and Khang (2002) and Ferson and Wang (2021) apply variations of this methodology to the performance of actively managed U.S. funds using daily data.

deemed insufficient by the government. Hence, in December of 2005, the government mandated the quota and gave firms two years to comply as directors in Norway are appointed for a term of two years. As a result, it took until the annual general shareholder meetings in year 2007 before the quota was fully implemented. We therefore use year 2008 as the start of the post-quota period in our empirical analysis.

The quota law is restricted to the executive-board directors of Norwegian public limited companies ("Allmennaksjeselskap" or ASA), with private limited companies ("Aksjeselskap" or AS) being exempted. The corporate forms ASA and AS correspond to the United Kingdom's Public Limited Company (PLC) and Private Limited Company (Ltd), respectively. Of the total population of ASA, less than half are at any time traded on the Oslo Stock Exchange (OSE), which are also the listed firms used in this study. In addition to the executive board, Norway mandates certain companies to have a second (and typically larger) supervisory boards, which is not involved in executive decisions and not subject to the gender quota. Also, while Norway's co-determination law mandates a company's employees to select up to one-third of the executive-board seats, the gender quota applies to the shareholder-elected directors only.

Under the quota law, the required fraction of each gender ranges from 33% to 50% depending on the company's board size. For example, an ASA board with five directors must have a minimum of 40% female directors (two women), while the female requirement is 50% for boards with four and six members (two and three women, respectively).[8]

2.2 Insider trading regulations

Our sample period begins in January 1997 when Norway began implementing its second-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). The law defines inside information as

[8]Norway recently expanded its quota law to include AS. By 2028, the quota will cover all ASA and AS with at least 30 employees or sales above 50 mill NOK (about $5 mill.).

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. We choose the 1996 legislation as our starting point as legal insiders had to, for the first time, publicly report their trades within one day (which typically happens prior to next day's stock-market opening).

Moreover, the Norwegian law assigns an enhanced responsibility for *primary insiders*—board members and top management, including the chief executive officer (CEO) and the chief financial officer (CFO)—to report their trades to the market. Although our empirical analysis includes data on all insider holdings and trades, our main empirical tests focus on primary insiders. The law also specifies certain insider trading blackout periods, including prior to corporate earnings announcements. Moreover, companies are obligated to maintain on an ongoing basis an internal list of individuals with 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.

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). 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.[9]

2.3 Board data

We collect firm-level data on board size (shareholder-elected directors of the executive board only), 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

[9]For further information on Norway's insider trading regulations, see Sections 6 (on issuer's obligations) and Section 7 (on primary insider's obligations) of NOU 2017:4.

the evolution of board size and the number and percentage of females on the boards of OSE-listed Norwegian firms (listed ASA) over the 1998–2016 period. As shown, the average and median number of shareholder-elected directors stays at five over the sample period. To give some more information about the distribution, over all firm-years the number of directors ranges from 3 to 11, with five directors in the first (lowest) quartile and six directors in the third quartile (the number of board *seats* is slightly lower as, in a few cases, both an incoming and an outgoing director is recorded in the same year).

The percentage female directors was less than 10% in 1998 and increased to 20% just 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 doubling of the number of female directors. Specifically, in 2005, there are a total of 227 listed ASA with 20% or 227 of the directors being female. In 2008, immediately following full quota compliance, there are 265 listed ASA with 40% or 530 female directors. As only a few female directors sit on more than one board (shown in Panel B of Figure 1), the total number of different females on these boards is only slightly lower.

Panel B of Figure 1 shows 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 ASA (EST draw a similar conclusion also for the broader population of all ASA, see their Figure 1). In both 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.[10]

[10] A director's participation on an important board committee likely affects the director's informativeness. As of 2009, Norwegian law mandates ASA to have the all-important audit committee. A cursory check of the 2009 (post-quota) annual reports of ten of the largest ASA listed on OSE shows that the audit committee had at least one female member in all cases. This is perhaps not surprising since, with an average board size of only five directors—of which 40% are from each gender—both male and female directors are likely required to populate the most important board committees. As a study of board committees is not necessary for the main conclusions of this paper, we leave further committee details to future research.

2.4 Director networks

Figure 2 illustrates the connectedness of OSE boards. For two OSE boards to be connected, at least one of the directors must sit on both boards. Using standard terminology from 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. Note that when outside directors are executives in competing businesses, what seems like an unconnected node in this figure still represents an informal link to the company where that director is an executive.

Figure 2 shows the change in the network from the year 2002 (the year before the first public discussion of a possible gender quota) to the year 2008 (the first year of full quota compliance). Panels A and B illustrate networks calculated separately for female and male board members. Not surprisingly, the female network has expanded between the two years while the male network have contracted (fewer edges). Panels C and D illustrate the network for all board members, regardless of gender. To show the effect of the gender reform, solid (red) dots are companies with at least one female on the board, while gray (blue) dots represent all-male boards (in year 2008, the few remaining all-male boards are foreign firms listed on the OSE, which are not regulated by the quota law).

To further clarify how gender-based networks have changed, Table 1 provides additional information on the changes from 2002 to 2008. Consider first the 2002 networks shown in Figure 2. The first row of Table 1 shows that, between the total number of 554 ASA, there are 730 links (directors on two boards) where the director is a male and only 33 links where the director is a female. In 2008 this picture has reversed. Between the total number of 401 ASA in 2008, there are now 208 links due to a male director—and 318 links due to a female director—sitting on two boards. This reversal also holds for gender-based networks within the subgroup of listed ASA.

2.5 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 or from 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 2, 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 whose 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, they label an insider trade in month t 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 2). One reason for this difference is the low frequency of stock- and option-based executive compensation plans among OSE companies (prior to 1999, stock options as a form of managerial compensation was extremely tax disadvantaged as the exercise value was taxed as regular income in the year of the option grant). While we include all trades when computing insider holdings, as indicated

below, we eliminate routine trades in some of the analyses of announcement effects.

Panel B of Table 2 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 carry out 11.5%. While not tabulated, this percentage increases from 7.1% before 2008 to 15.3% afterward. 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 2, we follow Inci et al. (2017) and report, for each insider, the average annual number and value of trades per year during the tenure period of the insiders. This measure is not affected by the low fraction of female insiders early in our sample period, and therefore provides 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—is 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 the 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 billions of 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, male executives trade substantially more

than female directors. For both categories of primary female insiders (director and top executive), the percentage of all trades jumps noticeably following the 2005 board quota law (which gave firms until 2008 to fully comply). As expected, given the quota-induced inflow of new females, this increase is greater for female directors than for female executives.

3 Proposition 1: Female director informativeness

3.1 On CAR as a measure of informativeness

In this section, we estimate the market reaction (CAR) to non-routine insider purchases before and after mandatory gender-balancing. The literature estimating CAR around reported insider trades goes back to Jaffe (1974) and Seyhun (1986) on U.S. data.[11] A typical finding in this literature is a positive market reaction to insider buys with no statistically significant market reaction to insider sales, which his also true for our study (hence, we concentrate on insider purchases). Furthermore, in the existing 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.

We reiterate that gender-based differences in CAR (if any) do not identify the underlying differences in directors' skills or abilities to monitor and advise firm operations. Rather, the power of our test comes from the fact that, for any individual trade announcement, the estimated CAR captures the market's perception of the *combined net impact* of the insider's underlying skill set for firm value. Some relevant aspects of this skill set have been documented elsewhere. In particular, in their Table V, Ahern and Dittmar (2012) find when comparing "new" (incoming) female directors with "exiting" male directors that there are no notable statistical differences in educational background (higher education and MBA) or primary outside occupations (consultant,

[11] 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 in 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.

attorney, vice president).

The one exception to this is "CEO experience", which Ahern and Dittmar (2012) report is significantly lower than for male directors (retained or exiting). However, after excluding directors' CEO experience in the very smallest Norwegian firms (such as sole proprietorships), Eckbo et al. (2022a,b) show that the overall "large-firm CEO experience" of boards does *not* decline significantly after quota implementation.

Finally, the typical public industrial firm in our study has five shareholder-elected directors and two major board committees (auditing and compensation). As shown earlier (Eckbo, Nygaard, and Thorburn, 2022a), prior to the quota constraint, the majority of industrial firms had all-male boards. A five-director all-male board faced two options to fulfill the 40% gender requirement: retain all male directors and add three females, or replace two male directors with two females. The vast majority elected the second option, causing the average board size to remain at five. Although we do not have detailed data on committee memberships, there is little reason to believe that 40% female directors of a five-director board would be systematically excluded from committee assignments. Indeed, anecdotal evidence suggests that the large influx of female directors after 2005 has increased female director representation on the auditing committee, which by itself may have helped to further promote female director informativeness.

In sum, based on documented individual characteristics, there is no obvious reason to believe that incoming female directors in response to the quota law are significantly less qualified than the exiting male ones, nor that the board's overall qualification has substantially declined. The main contribution of our empirical analysis below is to provide a first test of whether market participants draw a similar inference about directors when inferring director informativeness from insider trading announcements.

3.2 Conditional abnormal return (CAR) estimation

We estimate the average CAR as the conditional abnormal return parameter γ after stacking the single-company specification in Eq. (1) into one large panel that contains all companies with

non-routine insider trades:

$$r_{it}^{e} = \alpha_i + \beta_i^m r_{mt}^{e} + \gamma D_{it} + \varepsilon_{it}. \tag{1}$$

Here, r_{it}^{e} and r_{mt}^{e} are the excess returns to firm i and the equal-weighted market portfolio of OSE stocks over day t, respectively, in excess of the risk-free rate measured as the Norwegian Interbank Offered Rate (NIBOR). Moreover, D_{it} is a generic element of the matrix $\mathbf{D}$ of dummy variables. In the system represented by (1) the asset pricing parameters α_i and β_i^m are estimated separately for each company (corresponding to firm-fixed effects). This panel estimation is attractive, as it is econometrically efficient to estimate all parameters simultaneously.

Key to this estimation is the construction of the matrix $\mathbf{D}$. Suppose we want to estimate $CAR(-1, 1)$, i.e., over the three-day event window centered on the trading day. When estimating an event that occurs at time t in firm i, line i of the matrix $\mathbf{D}$ contains ones at time $t-1$, t and $t+1$ and zero otherwise. More generally, when estimating $CAR(-\tau_1, \tau_2)$, the relevant matrix row contains ones for time t, τ_1 observations before the event and τ_2 observations after the event, and otherwise zero.

Importantly, this 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 observations. By construction, the event parameter γ measures the average daily abnormal return across all event windows. The cumulative abnormal return over an event period is then: $CAR(-\tau_1, \tau_2) = \tau_k \gamma$, where τ_k is the number of trading days in the event window ($\tau_k = 1 + \tau_1 + \tau_2$).[12]

[12] We have 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 reported below. 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.

3.3 Conditional tests of Proposition 1

Table 3 shows the average CAR estimates for each of the two periods before and after quota implementation, respectively (1997–2007 and 2008–2016). Most importantly, the table documents a statistically significant increase in the average $CAR(-1,1)$ and $CAR(-1,5)$ for female insiders from zero in the pre-quota period to a significant 0.15% and 0.14% in the post-quota period. For males, however, the average CAR is significantly positive regardless of the subperiod, with CAR-values of about 0.15% for the two shortest windows $(-1,1)$ and $(-1,5)$. In other words, the board gender-balancing has caused the market to view male and female non-routine primary insider trades as equally informative.

Next, we consider whether the main result in Table 3 depends on a number of female director characteristics using cross-sectional regressions with CAR as dependent variable of the general form:

$$CAR_i(\tau_1, \tau_2) = a_i + b_1\mathbf{Controls} + b_2 DirectorCharacteristic_i + \varepsilon_i.$$

Here $CAR_i(\tau_1, \tau_2)$ is the estimated cumulative abnormal return starting τ_1 days before and ending τ_2 days after the announcement.[13] The vector of control variables (**Controls**) consists of the (log) market capitalization of the firm (*MktCap*) and the (log) size of the insider trade (*TradeValue*).

In Table 4 (Panel A) we restrict the sample to trades by new female directors entering boards in 2006 or 2007 and follow their trades over the full post-quota period 2006–2016. Here, the variable *Director characteristic* is a dummy variable that equals one if the female director entered during the two-year board-reform grace-period, here represented by year 2006, year 2007, or both years, and zero otherwise. The purpose is to account for the possibility that firms differ significantly in terms of their ability to quickly identify and hire the most qualified female director candidates.

As shown, there is no evidence that the estimated CAR in any of the event windows depends on whether the incoming female directors were hired early or late in the two-year grace period. In Internet Appendix Table IA.5, which also focuses on the 2006–2016 period, we further show that

[13] Note that this CAR is estimated using the residual-return approach discussed in footnote 12.

the average CAR does not differ between trades by new female directors and pre-quota directors who were kept on the boards. This evidence suggests that the new incoming female directors are perceived by the market to quickly catch up with firm-specific information.[14]

In Table 4 (Panel B), we also investigate whether the market reaction to insider trades depends on the individual director's board tenure. Since we do not have data on board memberships prior to 1998, we start in year 2000 and construct three alternative tenure–durations of *1 year*, *2 years*, or *3 or more years*. Moreover, since tenure is a general property of a director, we estimate the impact of these tenure variables on CAR using all trades, regardless of gender, over the period 2000–2016. As shown in Panel B of Table 4, regardless of the length of the event window, we find no statistically significant effects of tenure on CAR.

In sum, the evidence in Table 3 show a dramatic treatment effect of Norway's quota law in terms of increasing the market's perception of female director informativeness to a level commensurable with that of male directors. As stated in Proposition 1, a perception by the market that purchases by male and female directors are equally informative further supports extant evidence of a value-neutral treatment effect of Norway's quota law for OSE-listed companies.

4 Proposition 2: Director network connectivity

As suggested by the evidence in Table 3, Norway's board reform appears to have attracted highly competent female directors into OSE-listed firms, which in turn has increased the stock market's confidence in the information signaled by female insider trades. We next test whether this perceived degree of informativeness is also related to the board's network connectivity—as suggested by our Proposition 2. Again, a network-driven information effect is particularly intuitive when firms within the network operate in related industries and use related supply chains, which is likely to enhance a director's assessment of the value of her inside information.

To test for a network effect on the market reaction to insider trades, we estimate the following

[14] In Internet Appendix Table IA.6, using trades during the pre-quota period 1998–2005, we also show that the market does not react differently to trades by board members that were subsequently let go during the grace period 2006–2007 to make room for female directors.

cross-sectional regression model:

$$CAR_i(\tau_1, \tau_2) = \alpha_i + \beta_1 MktCap_i + \beta_2 TradeValue_i + \beta_3 Connectivity_i + b_4 Busyness_i + \varepsilon_i. \quad (2)$$

Here, $CAR_i(\tau_1, \tau_2)$ is the cumulative abnormal stock return to insiders in firm i over the event window (τ_1, τ_2), centered on the insider's trading date (day 0). The regressors again include the two control variables the (log) market capitalization of the firm (*MktCap*) and the (log) size of the insider trade (*TradeValue*). We further include the board's Pagerank centrality score, (*Connectivity*) (Page, Brin, Motwani, and Winograd, 1999), and the dummy variable *Busyness*, which takes a value of one when the individual director sits on more than two boards at the same time and zero otherwise. We calculate Pagerank first using the boards of all OSE-listed ASA and, second, all ASA.[15]

The results are shown in Table 5, where the dependent variable is $CAR(-1, 1)$ in Panel A and $CAR(-1, 5)$ in Panel B. In columns (1) and (2) the sample contains trades by all primary insiders (both directors and executives), while columns (3) and (4) restricts the sample to trades by directors only. As seen from the number of observations, executives trade much more often than directors ($N = 8,092$ versus $2,495$, respectively). Focusing first on the association between CAR and network connectivity in Panel A, the variable *Connectivity* receives a positive and highly statistically significant coefficient in all regressions where this variable is included (columns 1, 2 and 4). In Panel B, where the dependent variable is more noisy because it expands the event window from three to seven days, *Connectivity* receives a highly significant coefficient in Column (1), where it is measured using all listed ASA. Overall, this evidence provides strong support for Proposition 2.[16]

[15] 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).

[16] The evidence of a positive coefficient on *Connectivity* shown in Table 5 is consistent with the results in Akbas, Meschke, and Wintoki (2016), Goergen, Renneboog, and Zhao (2019), and El-Khatib, Jandik, and Jandik (2021)

Since a board's network connectedness and its *aggregate* busyness are necessarily mechanically correlated measures (Sarabi and Smith, 2021; Tonetto, 2023), a natural question arises as to what extent the positive impact of the board's connectedness reflects director busyness. We answer this question in columns (3) and (4) of Table 5 where we ask whether the busyness of an *individual* director affects the market's perception of that director's informativeness (the CAR). Note first that, as summarized earlier in section 2.3 and shown in Panel B of Figure 1, Norway's quota law did not materially change the number of directors with multiple board seats. Hence, we test the potential implication of director busyness using the entire sample period.

The effect of *Busyness* is an empirical issue as, on the one hand, busy directors may be less effective monitors due to time constraints while, on the other hand, they may be particularly effective in terms of advising smaller and younger firms (Field et al., 2013). The empirical answer from columns (3) and (4) of Table 5 is that the market reaction to insider trading is unaffected by the individual director's degree of busyness—a finding that, to our knowledge, is new to the literature on insider trading in particular, but also to the board literature in general.

We next turn to the question of whether the increased information content of purchases by female primary insiders also have 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.

5 Proposition 3: Gender-based insider trading performance

Up to this point, we have shown that director informativeness is gender neutral as judged by the market reaction to non-routine purchases by primary insiders. Proposition 3 holds that, when the degree of director informativeness is gender-neutral in this sense, there should also be no statistically significant difference in the insider trading performance of male and female directors.

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).

In this section, we examine this proposition using both holding-based and return-based measures of performance. We report performance results estimated separately for the two subperiods before and after the implementation of Norway's gender quota: 1/1997–12/2007 and 1/2008-12/2016, respectively.[17]

5.1 Cross-sectional holdings-based performance

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:

$$cov(\omega_{it}; r_{i,t+\tau}) = E\left[\omega_{it}(r_{i,t+\tau} - E[r_{i,t+\tau}])\right] = E\left[(\omega_{it} - E[\omega_{it}])r_{i,t+\tau}\right] > 0. \tag{3}$$

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*:

$$HCM = \frac{1}{T-2}\sum_{t=1}^{T}\frac{1}{N_t}\left(\sum_{i=1}^{N_t} cov\left(\omega_{it} - \omega_{i,t-1}; r_{i,t+\tau} - E[r_{i,t+\tau}]\right)\right). \tag{4}$$

N_t is the number of companies listed on OSE 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 $\Delta\omega_{it} \equiv \omega_{it} - \omega_{i,t-1}$, and (iii) the stock's risk-adjusted τ-period future expected stock return $E[r_{i,t+\tau}]$.[18]

To compute *HCM*, we adopt the following four specifications. First, to allow for potentially

[17] While not tabulated, using the total sample period 1/1997–12/2016 in the estimation yields results that are consistent with those reported below.

[18] Beginning with Grinblatt and Titman (1993), studies of mutual fund performance have employed variations of *HCM* using quarterly holdings data (Ferson and Khang, 2002; Ferson and Wang, 2021). In the literature on insider trading, the only other study employing this type of performance measure is Eckbo and Smith (1998). They used monthly returns to analyze insider trading on OSE during the period 1985–1992, which covers Norway's first-generation insider trading regulations under which insiders were required to report their trades within one

long-lived inside information, we report results for each of the following three alternative return horizons $(t+\tau)$:

$$\tau \equiv \begin{cases} \text{1 month} & \text{short-lived insider information} \\ \text{3 months} & \text{intermediate-lived insider information} \\ \text{6 months} & \text{long-lived insider information} \end{cases} \tag{5}$$

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

$$\omega_{it} \equiv \begin{cases} \omega_{it}^{ow} = s_{it}/S_{it} & \text{insider ownership weight} \\ \omega_{it}^{vw} = p_{it}s_{it}/\sum_{i=1}^{N_t} p_{it}s_{it} & \text{insider value weight} \end{cases} \tag{6}$$

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.[19]

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

$$\Delta\omega_{it} \equiv \begin{cases} \omega_{it} - \omega_{i,t-1} & \text{insider weight change} \\ \omega_{it} - \omega_{i,t-1}^{m} & \text{market-adjusted insider weight change} \end{cases} \tag{7}$$

where $\omega_{i,t-1}^{m}$ is firm i's value-weight in the OSE market portfolio at time $t-1$. We explore both

month. Using the notation in Eq. (4), Eckbo and Smith (1998) replace the bracketed expression with the following:

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

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. (8) below to account for possibly time-varying expected returns.

[19] 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.

definitions of weight changes 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 $\omega_{it} - \omega^m_{i,t-1}$ corrects for such "buy-and-hold" changes in the market-based weights.[20]

Fourth, $E[r_{i,t+\tau}]$ is computed as the predicted return from the following four-factor model (Fama and French, 1993; Carhart, 1997):[21]

$$r^e_{it} = \alpha^{4f}_{it} + \beta^m_i \left(r_{mt} - r_{ft}\right) + b^{smb}_i SMB_t + b^{hml}_i HML_t + b^{mom}_i MOM_t + \epsilon^e_{it}, \tag{8}$$

Here, $r^e_{it} = r_{it} - r_{ft}$ is the return to firm i in month t in excess of the risk-free rate (the monthly NIBOR). On date $t-1$, we estimate the four-factor model in Eq. (8) using five years of monthly return data. This yields a rolling (time varying) vector of OLS-estimated coefficients $\left\{\hat{\alpha}_{i,t-1}, \hat{\beta}^m_{i,t-1}, \hat{b}^{smb}_{i,t-1}, \hat{b}^{hml}_{i,t-1}, \hat{b}^{mom}_{i,t-1}\right\}$, which are then used to generate an estimate of the expected return $E[r_{i,t+\tau}]$.

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 trade and holding information for *all* insider trades. That is, contrary to the event-study analysis in Section 3.1 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 6 show the result of the estimation of *HCM*, classified by gender, for each the two periods 1/1997–12/2007 (Panel A) and 1/2008-12/2016 (Panel B). Columns (3) and

[20] 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.

[21] 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).

(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 the values of HCM in columns (1)–(6) indicate that insiders' abnormal performance is statistically insignificant at conventional levels.

5.2 Returns-based performance (Jensen's alpha)

In this section, we 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.[22] 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 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

$$\alpha_{pt} \equiv \begin{cases} \alpha_{pt}^{4f} = r_{pt}^{e} - \left[\widehat{\beta}_p^m \left(r_{mt} - r_{ft}\right) + \widehat{b}_p^{SMB} SMB_t + \widehat{b}_p^{HML} HML_t + \widehat{b}_p^{MOM} MOM_t\right] \\ \alpha_{pt}^{rb} = r_{pt}^{e} - \left[\widehat{\beta}_{p,t-1}^{rb} \left(r_{mt} - r_{ft}\right)\right] \end{cases} \tag{9}$$

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 5.1 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

[22] As illustrated by Ferson and Wang (2021), 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. "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). See also Ferson (2010) and Wermers (2011) for further reviews of alternative performance measures.

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.

Table 7 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. Starting with the four-factor alphas, columns (1), (2), (4) and (5) show that none of the alpha estimates for the two insider portfolios are statistically significant on conventional levels for either the male of the female insiders. More important for our Proposition 3, in columns (3) and (6) we use a long-short portfolio to directly test for differences between the male and female portfolio performances. The results show no statistically significant gender-specific differences in the four-factor abnormal performance measures. This conclusion also holds when using the average rolling-beta estimation shown in Table 7, where the recursive CAPM-alpha estimates allow for time variation in the estimated portfolio factor sensitivities (betas).

As stated in our Proposition 3, the absence of gender-based differences in insider trading performance shown in Table 6 and Table 7 suggests that a fundamental treatment effect of Norway's mandatory board gender balancing has been to bring in female directors who exhibit no lower degree of insider informativeness than their male counterparts. Together with our evidence in Table 3 of a gender neutral market reaction to insider purchase announcements, and in Table 5 of a positive impact on both male and female insiders of the degree of board network connectivity, this evidence also corroborates the conclusion of Eckbo, Nygaard, and Thorburn (2022a) that Norway's gender quota most likely has had a value-neutral valuation impact on companies listed on OSE.

6 Proposition 4: Insider trading during the financial crisis

In this section, we examine gender-based insider trading during the financial crisis period, defined here as the period from October 2008 through December 2010. As shown in Panel B of Figure 2, by this time, the male and female director networks were of similar magnitudes. Moreover, since the firm-specific price drops caused by the financial crisis are exogenous to each firm, it is likely that insiders of a given firm agree on the degree of mispricing that may have been caused by the crisis. As stated in the introduction, our Proposition 4 is that, under gender-neutral director informativeness, differences in the propensity to trade during the crisis will also be gender neutral.

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 peak 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 8, we use quarterly data to estimate the effect of the financial crisis on directors' trading propensity, using the following probit specification:

$$Y_{jit} = \alpha + \beta_1 \mathit{Crisis}_t + \beta_{\mathbf{2}}' \mathbf{Controls}_{jit} + \epsilon_{jit}, \tag{10}$$

where the latent dependent variable Y_{jit} takes a value of one if there is at least one trade by director j of firm i in quarter t and zero otherwise. By combining our data on board size with insider trades, we are able to calculate the number of directors on each board that do *not* trade in the quarter ($Y_{jit} = 0$) 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 $Y_{jit} = 0$ for that firm in quarter t, $j = 1, \ldots, 4$. Note also that, 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.

$Crisis_t$, the key variable of interest, is a dummy that takes a value of one during the 27-month crisis period 10/2008–12/2010. As shown, regardless of gender, 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 significantly increase their respective purchase propensities—and decrease their sales propensities—during the crisis period. Even more important for our Proposition 4: The magnitude of the coefficient estimates on purchase transactions is almost identical, with *Crisis* coefficient estimates of 0.229 and 0.227, respectively.

Turning to the vector $\mathbf{Controls}_{jit}$, it contains other characteristics of the company that can also affect the probability of trading. These characteristics include *MarketCap* (the natural log of the firm's market capitalization), *Volatility* (the firm's quarterly stock return volatility), *Liquidity* (the average daily bid/ask spread quoted for stocks in the last quarter), 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.

In Table 8, the signs of the coefficients of the non-crisis variables in the vector $\mathbf{Control}_{jt}$ are intuitive: More volatile firms—where the scope for insider opinion is larger—increase purchase propensities, as does more liquid stocks (since liquidity is measured using the bid/ask spread, it is the lowest for the most liquid stocks where trading is cheaper). It suggests that insiders of both gender tend to concentrate their trades in less opaque firms. In sum, Figure 4 and Table 8 show that female directors not only substantially increased their purchases during the financial crisis, but were also as likely as their male counterparts to purchase stocks (in the Internet Appendix,

Figure IA.2 and Table IA.9 show similar conclusions when using two alternative measures of insider trades).

Moreover, while not tabulated, performance tests show that neither male nor female directors realize significantly positive abnormal trading performance based on their crisis-period trades. Hence, consistent with Proposition 4, this evidence suggests that male and female directors are symmetrically informed about the likelihood of short-term underpricing (if any) caused by the exogenous crisis shock.

7 Conclusion

We use the market reaction to insider trading to provide new evidence on the treatment effect of Norway's forced board gender balancing on the market reaction to insider trades by male and female directors. This market reaction provides the market's own consensus opinion of the quality of the insider's private information about the firm's operations and value prospects. As such, it provides a direct window into what we label *director informativeness*, a concept that is based on not only the insider's formal background but also an instantaneous evaluation by investors of more intangible skill-related (and state-dependent) factors behind the insiders' decisions to trade. Our main proposition (P1) states that, for the treatment effect of Norway's gender quota to be truly value-neutral, the informativeness of the incoming female directors must be no less than that of male directors.

Our empirical evidence strongly supports that, following the implementation of Norway's quota law, the trades of incoming female directors are no less informative than their male counterparts. Specifically, after the quota-implementation, the average market reaction to non-routine purchases by female primary insiders for the first time becomes significantly positive and of a similar magnitude to that of male directors. Moreover, consistent with our second proposition (P2), as expected when the director informativeness is in fact gender-neutral, the market reaction is also increasing in the connectivity of the director network in a gender-neutral fashion. We further show that, for

either gender, director busyness (defined as a director sitting on more than two boards at a time) does *not* affect the market's perception of individual director informativeness.

With our third empirical proposition (P3), we argue that, for male and female directors to be truly equally informative, there should be no difference in their insider-trading performance. This proposition cannot be tested using the relative market reaction (CAR) to insider trades. This follows because, for an insider to realize the positive market revaluation created by her own purchase transaction, she must sell by the end of the event period used to measure the CAR value—which literally never happens. We therefore perform a full-fledged performance analysis that takes into account each insider's actual holding periods—the period over which the insider does *not* trade. The result of this analysis, which by itself is a methodological contribution to the performance measurement literature, is again consistent with gender-neutral director informativeness: Neither gender realizes abnormal insider performance over the sample period. 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).

Finally, consistent with our fourth proposition (P4), we find that, during the financial crisis period, which occurred soon after the OSE-listed companies had fully complied with the gender quota, both male and female directors respond to the exogenous price decline by significantly increasing their insider purchase propensities—and in equal levels. Since we show that these trades did not create abnormal performance, the gender-neutrality of the crisis-induced purchase intensity further supports our main conclusion: that of gender-neutral director informativeness.

As in any portfolio rebalancing designed to restore an individual's optimal asset allocation, the propensity to purchase shares in this particular setting is also a function of the insider's risk aversion, with greater risk aversion likely lowering the individual insider's crisis-induced stock repurchase intensity. Our evidence of gender-neutral shock-induced purchase intensity therefore also suggests that the female directors as a group may not exhibit greater risk aversion than their male counterparts, an interesting topic that we leave for future research.

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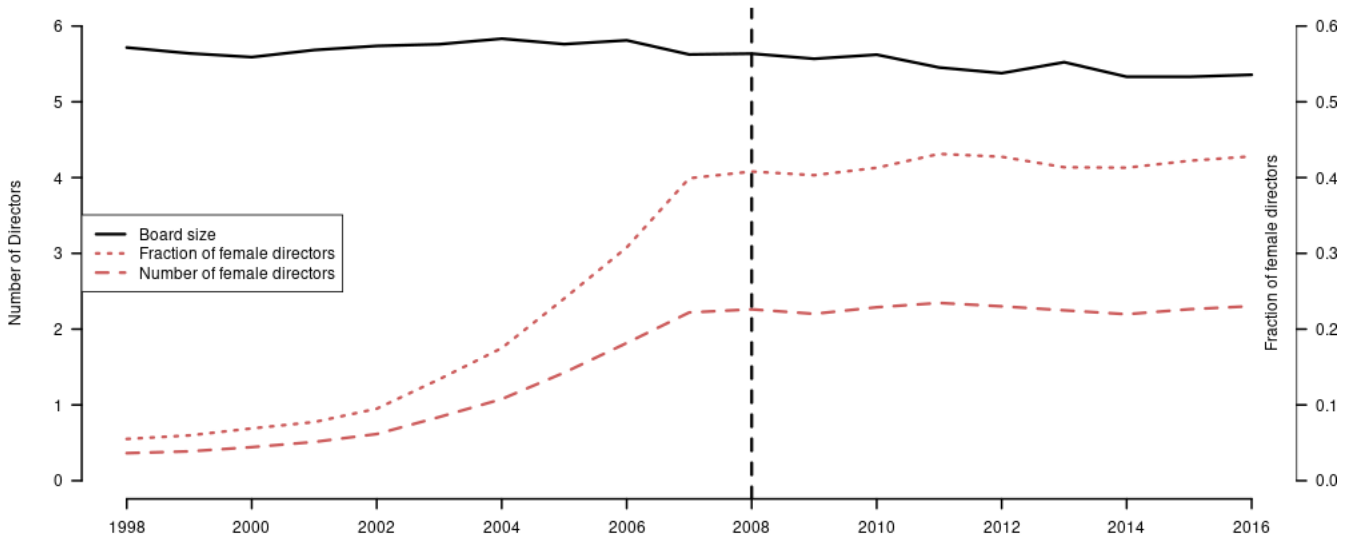
Figure 1: Board size and fraction female directors

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

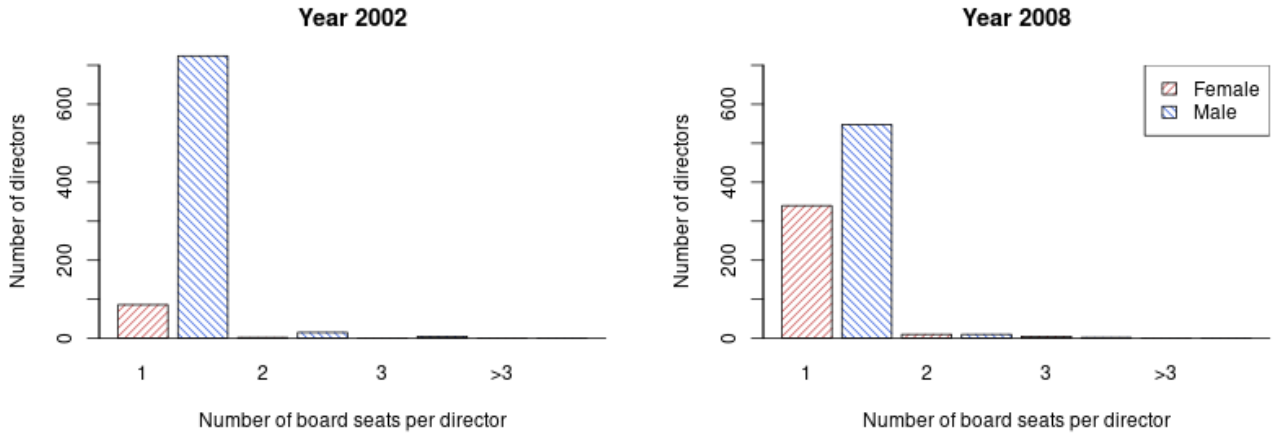
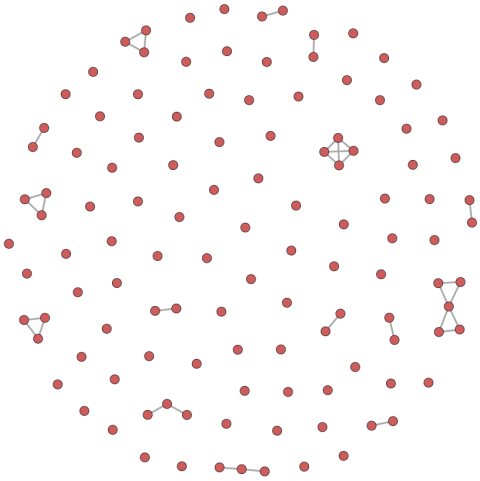


Figure 2: Evolution of board network links and gender composition – ASA companies

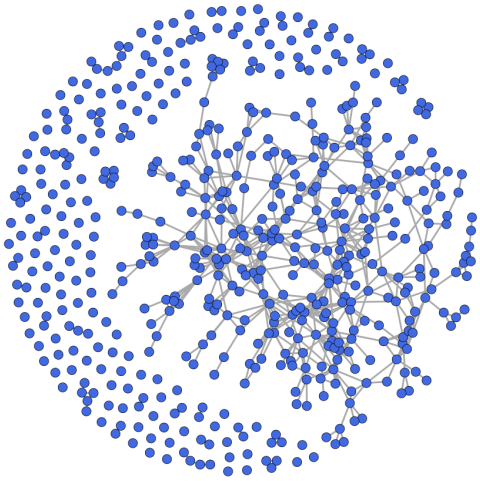
The figure illustrates the network structure of the boards of Norwegian ASA companies. Each node is a company board. A link (line) between two boards indicates that at least one director sits on both boards. Panels A and B shows networks calculated separately for female (left) and male (right) directors. Panel C and D show the network for all board members, regardless of gender. Red dots are companies with at least one female on the board. 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.

Panel A: Year 2002

Female network

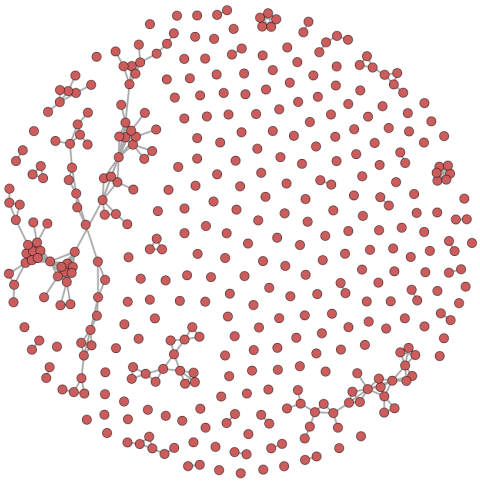


Male network



Panel B: Year 2008

Female network



Male network

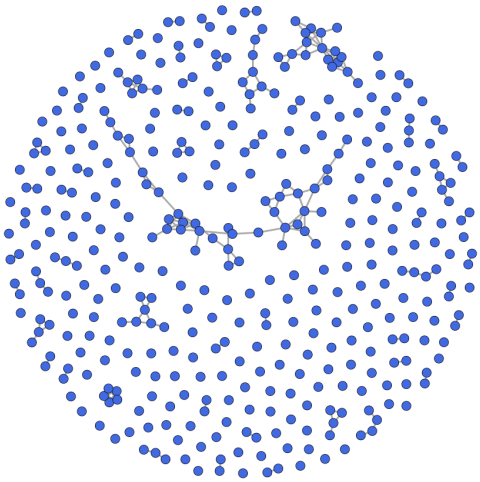
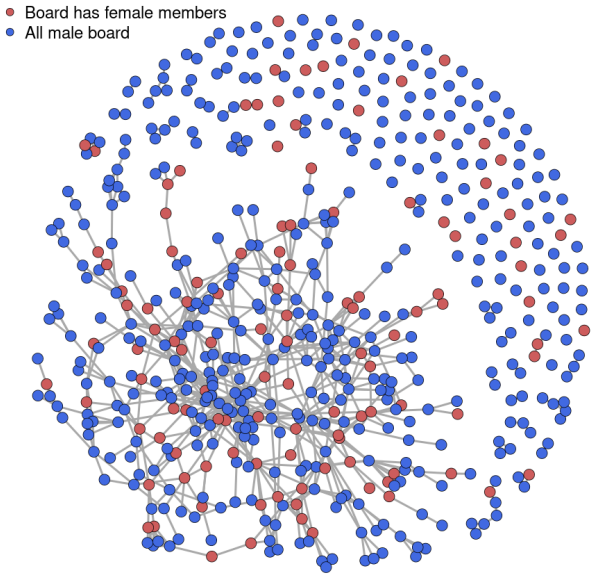


Figure 2: (Continued)

Panel C: Year 2002



Panel D: Year 2008

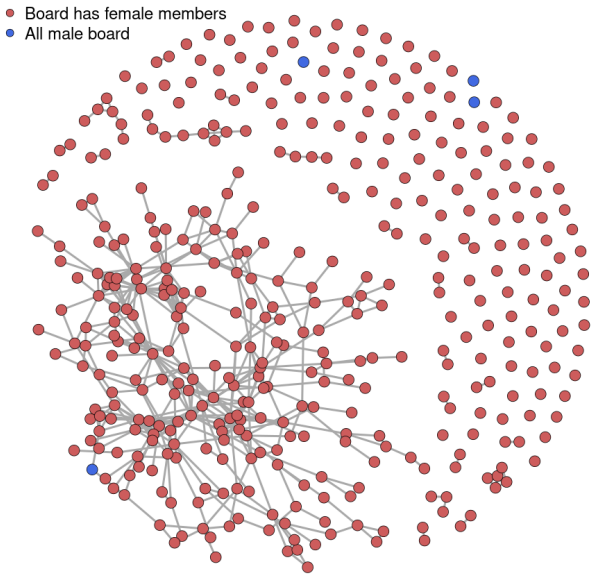
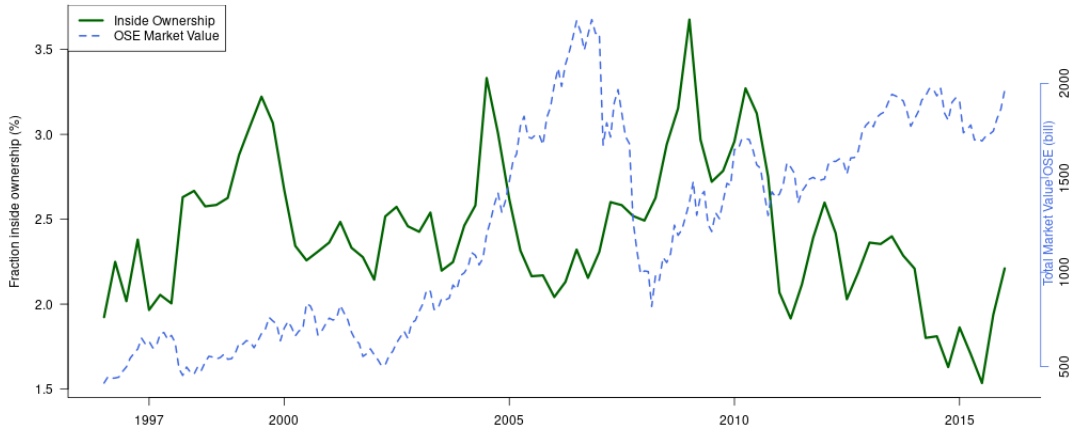


Figure 3: Average insider ownership and fraction of primary-insider trades by females

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

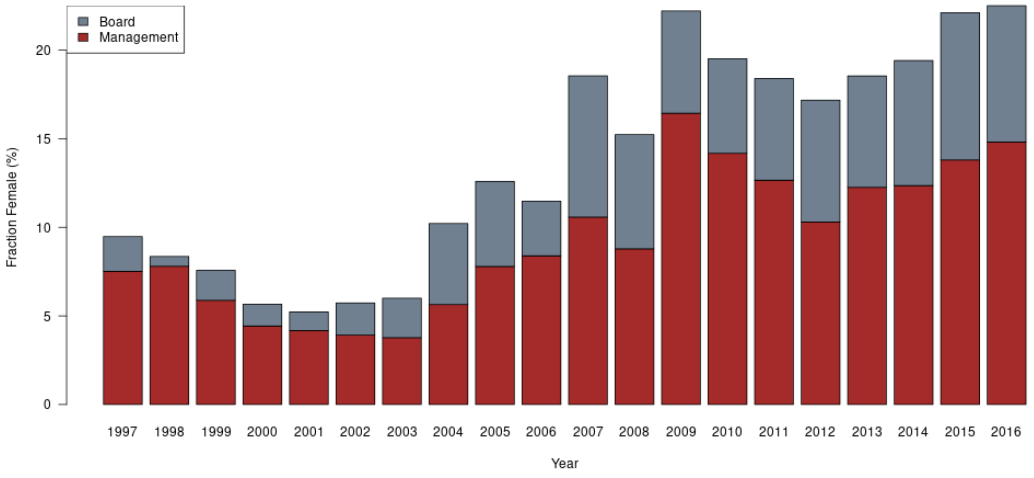
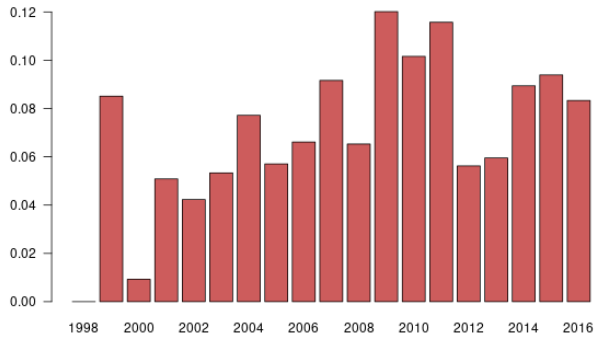


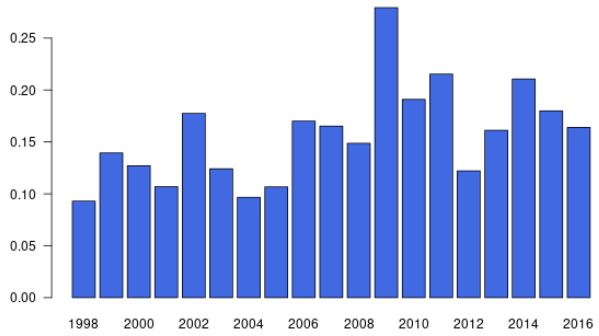
Figure 4: Fraction of male and female directors that trade

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*.

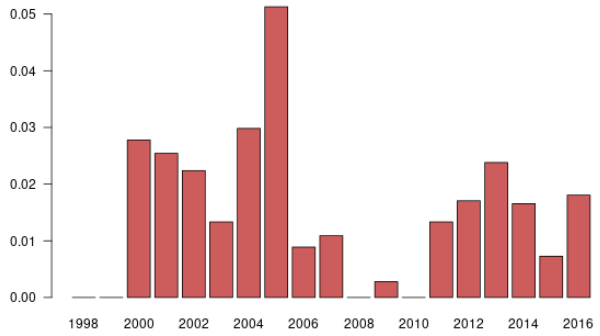
Panel A: Female buy trades



Panel B: Male buy trades



Panel C: Female sell trades



Panel D: Male sell trades

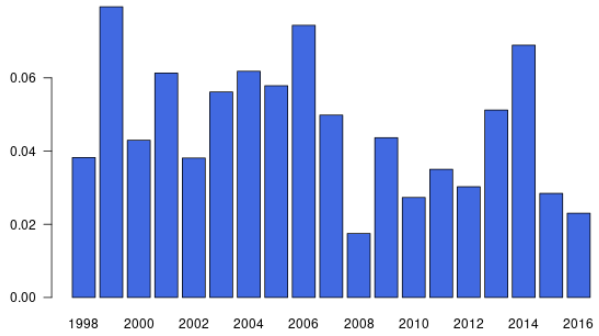


Table 1: Gender-specific board network-links before and after quota implementation

A network link is when a director sits on two boards. The table shows the gender-specific number of network links for the male and female board networks in 2002 (at the start of the political quota discussion) and in 2008 (right after full quota compliance) for all ASA and ASA listed on OSE. The numbers in brackets show the number of links in percent of the number of companies of all ASA and listed ASA, respectively.

Year	Number of ASA	Number of male links	Number of female links	Number of listed ASA	Number of male links	Number of female links
2002	554	730	33	177	145	15
		(131%)	(5%)		(82%)	(8%)
2008	401	208	318	204	92	137
		(51%)	(79%)		(45%)	(67%)

Table 2: 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 3: Market reaction to non-routine primary insider purchases classified by gender

The table reports the cumulative 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:

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

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 4: CAR regressions investigating director characteristics

The tables report cross-sectional regressions of the following form:

$$CAR_i(\tau_1, \tau_2) = a + b_1 MktCap_i + b_2 TradeValue_i + b_3 DirectorCharacteristic_i + \varepsilon_i,$$

where $CAR_i(\tau_1, \tau_2)$ is the estimated CAR starting τ_1 days before the announcement of the insider trade, and ending τ_2 days after the announcement. We investigate both $CAR(-1, 1)$ (Columns 1-3) and $CAR(-1, 5)$ (Columns 4-6). Further analysis showing estimates using $CAR(-1, 20)$ and $CAR(-1, 50)$ is given in the Internet Appendix. $MktCap$ is the log of the market capitalization of the firm and $TradeValue$ is the log of the kroner amount of the trade. In Panel A $DirectorCharacteristic_i$ is an indicator variable equal to one if the director is female and (1) enter the board in 2006 *(Female director entering 2006)*, (2) enter the board in 2007 *(Female director entering 2007)*, or (3) enter either of 2006 or 2007 *(Female director entering 2006 or 2007)*. The sample is all trades by identified directors in the period 2006-2016. In panel B the $DirectorCharacteristic_i$ is an indicator variable equal to one if the director entered the board (1) the same year *(First year on the board)*, (2) One year earlier *(Second year on the board)* or (3) Two or more years earlier *(Three or more years on the board)*. The sample is all trades by identified directors in the period 2000-2016.

	Event windows for the cumulative abnormal return					
	$CAR(-1,1)$			$CAR(-1,5)$		
A. Entering female directors						
(Intercept)	0.0848***	0.0847***	0.0845***	0.1173***	0.1165***	0.1168***
	(0.0190)	(0.0190)	(0.0190)	(0.0311)	(0.0311)	(0.0311)
MktCap	−0.0039***	−0.0039***	−0.0039***	−0.0068***	−0.0068***	−0.0068***
	(0.0009)	(0.0009)	(0.0009)	(0.0015)	(0.0015)	(0.0015)
TradeValue	0.0001	0.0000	0.0001	0.0024*	0.0024*	0.0024*
	(0.0008)	(0.0008)	(0.0008)	(0.0013)	(0.0013)	(0.0013)
Female director entering 2006	0.0051			0.0153		
	(0.0115)			(0.0189)		
Female director entering 2007		−0.0041			0.0025	
		(0.0083)			(0.0136)	
Female director entering 2006 or 2007			−0.0010			0.0071
			(0.0068)			(0.0112)
Adj. R^2	0.0116	0.0116	0.0115	0.0133	0.0128	0.0131
Num. obs.	1457	1457	1457	1457	1457	1457
B. Board Tenure						
(Intercept)	0.0736***	0.0701***	0.0733***	0.1375***	0.1331***	0.1363***
	(0.0162)	(0.0162)	(0.0161)	(0.0294)	(0.0295)	(0.0293)
MktCap	−0.0034***	−0.0033***	−0.0033***	−0.0073***	−0.0071***	−0.0072***
	(0.0008)	(0.0008)	(0.0008)	(0.0014)	(0.0014)	(0.0014)
TradeValue	0.0001	0.0000	0.0001	0.0016	0.0015	0.0016
	(0.0007)	(0.0007)	(0.0007)	(0.0012)	(0.0012)	(0.0012)
First year on board	0.0008			−0.0019		
	(0.0030)			(0.0055)		
Second year on board		0.0057*			0.0052	
		(0.0030)			(0.0054)	
Three or more years on board			−0.0048*			−0.0024
			(0.0026)			(0.0047)
Adj. R^2	0.0091	0.0109	0.0108	0.0121	0.0125	0.0122
Num. obs.	1978	1978	1978	1978	1978	1978

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 5: Determinants of CAR: Network connectivity v. director busyness

The table reports cross-sectional regressions of the following form:

$$CAR_i(\tau_1, \tau_2) = a + b_1 MktCap_i + b_2 TradeValue_i + b_3 Connectivity_i + b_4 Busyness_i + \varepsilon_i,$$

where $MktCap$ is the log of the market capitalization of the firm, $TradeValue$ is the log of the kroner amount of the trade, $Connectivity$ is the Pagerank measure of network connectedness calculated either for listed ASA only or all ASA, and $Busyness$ is an indicator variable that equals one if the individual director sits on more than 2 boards at the same time and zero otherwise. Columns (1) and (2) uses all primary insider trades, while columns (3) and (4) is restricted to trades by directors only. The sample period is 1/1998–12/2016. Standard errors in brackets.

	Trades by directors and executives		**Trades by directors only**	
	(1)	(2)	(3)	(4)
A: Dependent variable: $CAR(-1,1)$				
Intercept	0.0534***	0.0573***	0.0809***	0.0882***
	(0.0074)	(0.0078)	(0.0146)	(0.0152)
MktCap	−0.0027***	−0.0027***	−0.0034***	−0.0040***
	(0.0003)	(0.0003)	(0.0007)	(0.0007)
TradeValue	0.0004	0.0001	-0.0004	-0.0004
	(0.0003)	(0.0003)	(0.0006)	(0.0006)
Connectivity (listed ASA)	0.5084***			0.9167***
	(0.1525)			(0.3124)
Connectivity (all ASA)		0.7815***		
		(0.2947)		
Busyness			0.0022	-0.0001
			(0.0035)	(0.0038)
Adj. R^2	0.0093	0.0096	0.0101	0.0134
Num. obs.	8092	7480	2495	2386
B: Dependent variable: $CAR(-1,5)$				
Intercept	0.1163***	0.1258***	0.0809***	0.1661***
	(0.0127)	(0.0134)	(0.0146)	(0.0277)
MktCap	−0.0053***	−0.0054***	−0.0034***	−0.0077***
	(0.0005)	(0.0005)	(0.0007)	(0.0013)
TradeValue	-0.0003	-0.0007	-0.0004	-0.0003
	(0.0005)	(0.0006)	(0.0006)	(0.0011)
Connectivity (listed ASA)	0.7908***			0.9289
	(0.2608)			(0.5686)
Connectivity (all ASA)		0.8734*		
		(0.5041)		
Busyness			0.0022	-0.0050
			(0.0035)	(0.0069)
Adj. R^2	0.0121	0.0129	0.0101	0.0137
Num. obs.	8092	7480	2495	2386

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 6: Holdings-based primary insider performance

This table shows performance estimates using holdings-based performance evaluation. The two sets of portfolio weights are defined in Eq. (7) 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:

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

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 1/1997–12/2007 (Panel A) and 1/2008–12/2016 (Panel B). The columns labeled 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/`).

A: Pre-quota period, 1/1997–12/2007

	Insider-ownership portfolio weights			Insider-value portfolio weights		
	Female (1)	Male (2)	p(diff) (3)	Female (4)	Male (5)	p(diff) (6)
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
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
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

B: Post-quota period, 1/2008–12/2016

	Insider-ownership portfolio weights			Insider-value portfolio weights		
	Female (1)	Male (2)	p(diff) (3)	Female (4)	Male (5)	p(diff) (6)
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
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
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 7: 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 Eq. (6) 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 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. The two performance metrics, α_p^{4f} and α_p^{rb} are defined in Eq. (9) 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/`).

	Insider-ownership portfolio weights			**Insider-value portfolio weights**		
	Female (1)	Male (2)	Male− Female (3)	Female (4)	Male (5)	Male− Female (6)
A: Pre-quota period, 1/1997–12/2007						
Four-factor alpha estimates:						
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)
Average rolling-beta CAPM estimates 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)
B: Post-quota period, 1/2008–12/2016						
Four-factor alpha estimates:						
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)
Average rolling-beta CAPM estimates 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)

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

The table reports coefficient estimates of the probit model in Eq. (10) in the text for the likelihood of an insider trade by an individual director (board member) in a given quarter, 1998–2016. The variable *Female* is an 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

A Appendix

The table below summarizes the main findings of four studies that report various potential treatment effects of Norway's quota law on the population of OSE-listed firms. The four studies are Ahern and Dittmar (2012) (AD), Matsa and Miller (2013) (MM), Bøhren and Staubo (2014) (BS), and Eckbo et al. (2022a) (ENT). ENT also includes a replication of the earlier studies, where replication means successfully generating the main result of the earlier study when adopting their sample and methodology (before moving on to the paper's own analysis). N is the number of unique (treated) sample firms, CAR is cumulative abnormal stock return, and IV is instrumental variable.

The most important potential treatment effect addressed by AD and ENT is the stock market reaction (CAR) to the initial quota announcement (February 22, 2002) shown here in Panel A. This treatment effect has the power to reveal the surprise impact of the quota on firm value. The studies also estimates potential long-term effects on stock returns and cash flows (ROA and Tobin's Q in panels B and C), and on changes in board CEO experience and attempts by OSE-listed firms to avoid the quota by converting their corporate legal form (panels D and E).

The main findings are as follows:

(1) ENT rejects AD's claim that the stock market reacted negatively to the initial quota announcement of Norway's quota law. The rejection follows after properly adjusting the standard error of AD's own CAR-estimate for the contemporaneous cross-correlation of stock returns, which renders it insignificantly different from zero.

(2) ENT rejects AD's claim of a significantly negative impact on the long-run performance (Jensen's alpha, stock returns, Q, or ROA). This follows after properly instrumenting AD's own IV analysis, which fails to identify a statistically significant correlation between a firm's female director shortfall and Q.

(3) Rather than expanding its board size of five directors, the typical OSE-listed firm with an all-male board chose to comply with the quota by replacing two males with females. This shows that firms viewed the expected cost of expanding board size from five to eight member (by adding three females), which would also have fulfilled the quota requirement, as an upper bound on the quota compliance costs. ENT further document that, when complying, shareholders managed to maintain the board's level of large-firm CEO experience and did not increase director busyness.

(4) ENT rejects claims by AD and BS that firms responded to the quota by converting their legal status from ASA to AS, which would require delisting from the OSE. This rejection follows as both AD and BS confound quota avoidance with delistings due to events involving bankruptcy and corporate takeovers. In fact, not a single OSE-listed ASA delisted for reasons other than these unrelated types of events.

The overall conclusion is that the treatment effects of the quota on all of the variables (CAR, ROA, Q, CEO experience, and ASA to AS conversions) are both economically and statistically insignificant. This suggests that the supply of qualified female directors candidates in Norway was high enough to avoid negative valuation consequences of the quota:

Summary of selected studies of Norway's gender quota

The four studies shown in this table are Ahern and Dittmar (2012) (AD), Matsa and Miller (2013) (MM), Bøhren and Staubo (2014) (BS), and Eckbo, Nygaard, and Thorburn (2022a) (ENT). ENT also includes a replication of the earlier studies, where replication means successfully generating the main result of the earlier study when adopting their sample and methodology (before moving on to the paper's own analysis). N is the number of unique (treated) sample firms, CAR is cumulative abnormal stock return, and IV is instrumental variable.

Study	N	**Main conclusion**	**Is the earlier conclusion replicated by ENT?**	**How does ENT change the earlier conclusion?**
A. Firm value: CAR centered on February 22, 2002				
AD	94	CAR significantly negative.		
ENT	143	CAR statistically insignificant.	Yes, using AD's methodology.	Reversal news within event window. Correcting std.err. for cross-correlation eliminates AD's significance.
B. Firm performance: profitability (ROA)				
MM	104	Significantly negative ROA effect.		
ENT	559	No significant effect of quota on ROA.	Yes, using MM's sample period.	The negative ROA-effect exists in the crisis year 2008 only and disappears when extending the post-quota period beyond 2009.
C. Firm value: Tobin's Q				
AD	122	Significantly negative effect of quota on Q.		
ENT	239	No significant effect of quota on Q.	Yes, using AD's methodology.	Since AD's instrument is correlated with firm size it violates IV exclusion restriction. Excluding government firms eliminates significance, as does moving AD's base-year from 2002 to 2001.
D. Board CEO experience				
AD	122	Significant reduction in experience for the most affected firms.		
ENT	559	No significant change in CEO experience following quota.	Yes, using a diff-in-diff regression.	Small-firm CEO experience falls while Large-firm CEO experience (in ASA and 1% largest AS) does not. AD's results are driven by small firms (0-2 employees).
E. Legal conversions from ASA to AS				
BS		Conversion likelihood increases with shortfall female directors.		
ENT	264	Conversion decision is independent of board gender composition.	Yes, using BS' back-filled dependent variable.	Adding year fixed effects eliminates the backfilling bias in BS and renders board gender composition insignificant for the conversion decision.

Director informativeness following board gender-balancing: Evidence from insider trading
Internet Appendix

B. Espen Eckbo and Bernt Arne Ødegaard

July 2025

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A Section 2: Institutional setting and data

Figure IA.1: Number of board seats held by male and female directors in 2002 and 2008—across all ASA

The distribution of the number of directorships in all (not just listed) ASA held by individual male and female directors in years 2002 and 2008, respectively. Board data are from the national *Brønnøysund Registry Centre*, 1998-2016.

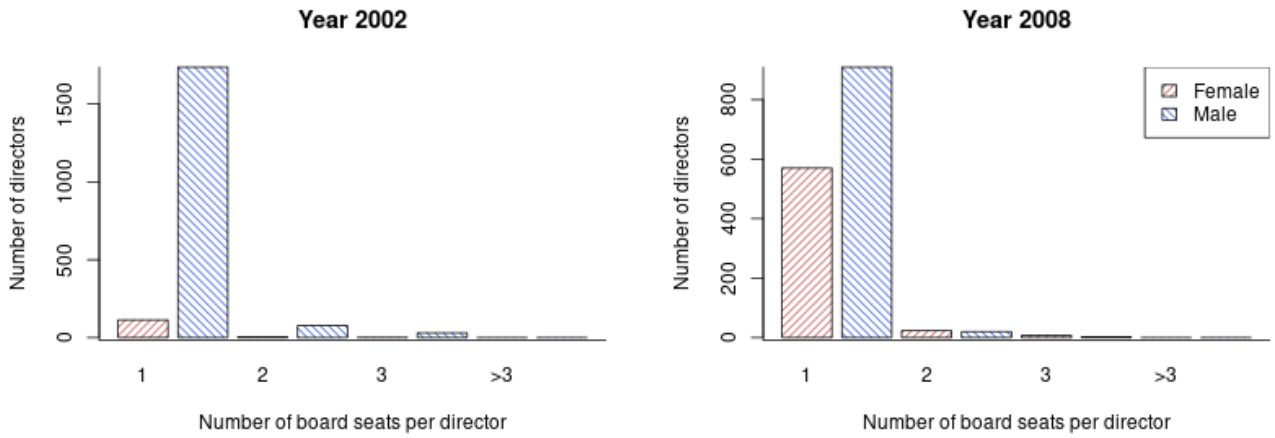

Table IA.1: Annual primary insider trades by gender and value, OSE 1997-2016

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.2: 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

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

B.1 Gender differences in CAR

In the paper we show estimates for two subperiods, 1997-2007 and 2008-2016. Appendix Table IA.3 shows corresponding estimates for the whole period 1997-2008.

Table IA.3: 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:

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

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

B.2 The potential effect on CAR of other director characteristics

As discussed in the paper, we consider whether the main result in paper Table 3 depends on a number of director characteristics using cross-sectional regressions with CAR as dependent variable of the general form:

$$CAR_i(\tau_1, \tau_2) = a_i + b_1 \mathbf{Controls} + b_2 DirectorCharacteristic_i + \varepsilon_i.$$

Here $CAR_i(\tau_1, \tau_2)$ is the estimated cumulative abnormal return starting τ_1 days before and ending τ_2 days after the announcement. The vector of control variables (**Controls**) consists of the (log) market capitalization of the firm (*MktCap*) and the (log) size of the insider trade (*TradeValue*).

To perform these analysis it has been necessary to refine the insider sample to include only directors which can be matched with the company board lists. The total number of trades by identified board members in the period 1998–2016 is 2263.

The director characteristics we consider are

1. Director properties directly related to the regulation on gender balanced boards.
   (a) New female directors coming on board in 2006 or 2007 (incoming directors). We investigate their trades in the period after the board reform (2006–2016).
   (b) The directors *not* let go when the board needed space for the new female directors (retained directors). We investigate their trades in the period 2006–2016
   (c) The board members let go when the company needed space for the new female directors. For these we need to look at the performance of their trades in the period while they were still directors (1998–2005).
2. General properties of board members that may affect how the market view their trades
   (a) Experience – is the reaction to a director trade related to director tenure on the board?

In the paper we showed results for 1(a) entering female directors in the period 2006 to 2007, and for 2(a) director board tenure. The paper table reported results for $CAR(-1, 1)$ and $CAR(-1, 5)$. For completeness Table IA.4 reports corresponding estimates for $CAR(-1, 25)$ and $CAR(-1, 50)$).

Table IA.4: CAR regressions investigating director characteristics. Female directors entering 2006 and 2007, and Director tenure. $CAR(-1,25)$ and $CAR(-1,50)$.

This table supplements paper Table 4 which reported the same regressions with $CAR(-1,1)$ and $CAR(-1,5)$ as dependent variables. This table reports results using $CAR(-1,25)$ (columns 1-3) and $CAR(-1,50)$ (columns 4-6). The tables report cross-sectional regressions of the following form:

$$CAR_i(\tau_1,\tau_2) = a + b_1 MktCap_i + b_2 TradeValue_i + b_3 DirectorCharacteristic_i + \varepsilon_i,$$

Here $MktCap$ is the log of the market capitalization of the firm and $TradeValue$ is the log of the kroner amount of the trade. In Panel A $DirectorCharacteristic_i$ is an indicator variable equal to one if the director is female and (1) enter the board in 2006 *(Female director entering 2006)*, (2) enter the board in 2007: *Female director entering 2007)*, or (3) enter either of 2006 or 2007: *Female director entering 2006 or 2007)* The sample is all trades by identified directors in the period 2006-2016. In Panel B $DirectorCharacteristic_i$ is an indicator variable equal to one if the director entered the board (1) the same year *(First year on board)*, (2) One year earlier *(Second year on board)*, or (3) Two or more years earlier *(Three or more years on board)*. The sample is all trades by identified directors in the period 2000-2016.

	Event windows for the cumulative abnormal return					
	$CAR(-1,25)$			$CAR(-1,50)$		
A. Entering female directors						
(Intercept)	0.1903***	0.1905***	0.1903***	0.4576***	0.4604***	0.4573***
	(0.0569)	(0.0569)	(0.0569)	(0.1053)	(0.1052)	(0.1052)
MktCap	−0.0103***	−0.0103***	−0.0103***	−0.0216***	−0.0214***	−0.0213***
	(0.0027)	(0.0027)	(0.0027)	(0.0050)	(0.0050)	(0.0050)
TradeValue	0.0017	0.0017	0.0017	0.0002	−0.0002	−0.0002
	(0.0024)	(0.0024)	(0.0024)	(0.0045)	(0.0045)	(0.0045)
Female director entering 2006	−0.0028			−0.0258		
	(0.0345)			(0.0639)		
Female director entering 2007		−0.0040			−0.0704	
		(0.0249)			(0.0460)	
Female director entering 2006 or 2007			−0.0037			−0.0566
			(0.0205)			(0.0379)
Adj. R^2	0.0081	0.0081	0.0081	0.0118	0.0133	0.0132
Num. obs.	1457	1457	1457	1457	1457	1457
B. Board Tenure						
(Intercept)	0.2661***	0.2466***	0.2562***	0.5746***	0.5630***	0.5659***
	(0.0509)	(0.0512)	(0.0508)	(0.0886)	(0.0891)	(0.0883)
MktCap	−0.0143***	−0.0138***	−0.0144***	−0.0282***	−0.0279***	−0.0285***
	(0.0024)	(0.0024)	(0.0024)	(0.0042)	(0.0042)	(0.0042)
TradeValue	0.0025	0.0026	0.0026	0.0014	0.0015	0.0015
	(0.0022)	(0.0022)	(0.0022)	(0.0038)	(0.0038)	(0.0038)
First year on board	−0.0247***			−0.0250		
	(0.0095)			(0.0165)		
Second year on board		0.0121			0.0007	
		(0.0094)			(0.0164)	
Three or more years on board			0.0090			0.0177
			(0.0081)			(0.0141)
Adj. R^2	0.0187	0.0162	0.0160	0.0223	0.0212	0.0220
Num. obs.	1978	1978	1978	1978	1978	1978

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

1 (b) Directors in place before 2006 (Retained directors) It is of interest to compare the market reactions to trades by the new directors with those of directors that were *not* let go to make room for the new female directors (retained directors). To that end we add indicator variables equal to one if this is a trade by a retained director. Since we want to compare these directors with those brought on board as a result of the board regulation (incoming directors), we restrict the sample to the period after the regulation, 2006–2016. We do this for two cases. One for all directors, the other for just female directors. Table IA.5 reports the results. We find no significant coefficients on the indicator variables related this being a retained director.

Table IA.5: CAR regressions investigating retained directors

The tables report cross-sectional regressions of the following form:

$$CAR_i(\tau_1, \tau_2) = a + b_1 MktCap_i + b_2 TradeValue_i + b_3 DirectorCharacteristic_i + \varepsilon_i,$$

where $MktCap$ is the log of the market capitalization of the firm and $TradeValue$ is the log of the kroner amount of the trade. In Panel A the $DirectorCharacteristic_i$ is an indicator variable equal to one if the director was on the board before 2006 *(Retained Director)*. In Panel B the $DirectorCharacteristic_i$ is an indicator variable equal to one if the director is female and was on the board before 2006 *(Retained female director)*. The sample is all trades by identified directors in the period 2006-2016.

	Event windows for the cumulative abnormal return			
	$CAR1(-1,1)$	$CAR(-1,-5)$	$CAR(-1,25)$	$CAR(-1,50)$
A: Retained directors				
(Intercept)	0.0831***	0.1138***	0.1907***	0.4509***
	(0.0191)	(0.0313)	(0.0572)	(0.1059)
MktCap	−0.0038***	−0.0067***	−0.0103***	−0.0214***
	(0.0009)	(0.0015)	(0.0027)	(0.0050)
TradeValue	0.0001	0.0025*	0.0017	0.0006
	(0.0008)	(0.0013)	(0.0024)	(0.0045)
Retained director	−0.0024	−0.0044	0.0005	−0.0127
	(0.0034)	(0.0055)	(0.0101)	(0.0186)
Adj. R^2	0.0118	0.0132	0.0080	0.0120
Num. obs.	1457	1457	1457	1457
B: Retained female directors				
(Intercept)	0.0843***	0.1169***	0.1902***	0.4563***
	(0.0190)	(0.0311)	(0.0569)	(0.1052)
MktCap	−0.0038***	−0.0069***	−0.0103***	−0.0212***
	(0.0009)	(0.0015)	(0.0027)	(0.0050)
TradeValue	0.0000	0.0025*	0.0016	−0.0003
	(0.0008)	(0.0013)	(0.0024)	(0.0045)
Retained female director	−0.0064	0.0109	−0.0063	−0.0743
	(0.0103)	(0.0168)	(0.0307)	(0.0569)
Adj. R^2	0.0117	0.0131	0.0081	0.0129
Num. obs.	1457	1457	1457	1457

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

1 (c) Directors leaving in 2006 or 2007 period (exiting directors). We next investigate the informedness of the directors that were let go during the period when boards needed to be filled with a sufficient number of female directors. Is it the case that the directors let go were the least experienced/valuable (low informativeness)? If so, does the market signal that the trades of these directors were less informed while they were directors? That is, we look at the trades of these directors in the 1998–2005 period. We implement this with indicator variables equal to one if this is a trade by a director that exited in 2006 or 2007. We distinguish three cases:

- Director exited the board in 2006
- Director exited the board in 2007
- Director exited the board in 2006 or 2007.

For this analysis we consider all exiting directors. The majority of exiting directors ' were male, but there are a few female cases. The hypothesis about low informativeness is not gender specific, it is therefore natural to do this estimation for all exiting directors. Table IA.6 shows the results where the indicator is one if this is a trade by a director that exited the board in 2006 or 2007. We see that none of these variables show a significant effect.

Table IA.6: CAR regressions investigating exiting directors

The tables report cross-sectional regressions of the following form:

$$CAR_i(\tau_1, \tau_2) = a + b_1 MktCap_i + b_2 TradeValue_i + b_3 DirectorCharacteristic_i + \varepsilon_i,$$

where $MktCap$ is the log of the market capitalization of the firm and $TradeValue$ is the log of the kroner amount of the trade, and $DirectorCharacteristic_i$ is an indicator variable equal to one the if (1) *Director exited in 2006*, (2) *Director exited in 2007*, or (3) *Director exited in 2006 or 2007*. The sample is all trades by identified directors in the period 1998–2005.

	Event windows for the cumulative abnormal return					
	$CAR(-1,1)$			$CAR(-1,5)$		
A. Dependent variable: $CAR(-1,1)$ **and** $CAR(-1,5)$						
(Intercept)	0.0509**	0.0508**	0.0509**	0.1749***	0.1766***	0.1769***
	(0.0238)	(0.0238)	(0.0238)	(0.0507)	(0.0505)	(0.0506)
MktCap	−0.0027**	−0.0027**	−0.0027**	−0.0079***	−0.0079***	−0.0079***
	(0.0011)	(0.0011)	(0.0011)	(0.0024)	(0.0024)	(0.0024)
TradeValue	0.0007	0.0007	0.0007	−0.0005	−0.0006	−0.0005
	(0.0009)	(0.0009)	(0.0009)	(0.0019)	(0.0019)	(0.0019)
Director exited in 2006	−0.0001			0.0097		
	(0.0085)			(0.0181)		
Director exited in 2007		−0.0004			−0.0115	
		(0.0106)			(0.0225)	
Director exited in 2006 or 2007			−0.0003			0.0015
			(0.0068)			(0.0144)
Adj. R^2	0.0035	0.0035	0.0035	0.0112	0.0112	0.0108
Num. obs.	806	806	806	806	806	806
B: Dependent variables: $CAR(-1,25)$ **and** $CAR(-1,50)$						
(Intercept)	0.5185***	0.5197***	0.5184***	0.9581***	0.9533***	0.9570***
	(0.0836)	(0.0834)	(0.0835)	(0.1318)	(0.1314)	(0.1315)
MktCap	−0.0270***	−0.0270***	−0.0270***	−0.0477***	−0.0475***	−0.0476***
	(0.0040)	(0.0040)	(0.0040)	(0.0063)	(0.0063)	(0.0063)
TradeValue	0.0029	0.0029	0.0029	0.0023	0.0023	0.0022
	(0.0032)	(0.0032)	(0.0032)	(0.0050)	(0.0050)	(0.0050)
Director exited in 2006	0.0037			−0.0187		
	(0.0298)			(0.0470)		
Director exited in 2007		0.0072			−0.0131	
		(0.0371)			(0.0585)	
Director exited in 2006 or 2007			0.0053			−0.0172
			(0.0237)			(0.0374)
Adj. R^2	0.0508	0.0508	0.0508	0.0650	0.0648	0.0650
Num. obs.	806	806	806	806	806	806

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

C Section 5: Insider performance

The paper shows estimates for the two subperiods 1997–2006 and 2007-2008. In IA Tables IA.7 and IA.8 we show corresponding estimates for the whole period 1997–2016.

Table IA.7: Holdings-based primary insider performance, 1997–2016

This table shows performance estimates using holdings-based performance evaluation. The two sets of portfolio weights are defined in Eq. (7) 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:

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

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 entire sample period, 1/1997–12/2016. The columns labeled 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/`).

	Insider-ownership portfolio weights			**Insider-value portfolio weights**		
	Female (1)	Male (2)	p(diff) (3)	Female (4)	Male (5)	p(diff) (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.8: Returns-based primary insider portfolio performance, 1997–2016.

The performance estimates reported in this table are based on monthly portfolio returns and re-balancing. The three sets of portfolio weights are defined in Eq. (6) 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 Male–female portfolio is long in male and short in female insider weights, respectively. The estimation is done for entire sample period 1/1997–12/2016. The two performance metrics, α_p^{4f} and α_p^{rb} are defined in Eq. (9) 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/`).

	Insider-ownership portfolio weights			**Insider-value portfolio weights**		
	Female (1)	Male (2)	Male−Female (3)	Female (4)	Male (5)	Male−Female (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
$(1/N)\sum r_{pt}^e$	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

D Section 6. Insider trading during the financial crisis

D.1 Alternative measures of insider trading

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):

$$Insider\ Direction_{it} = \frac{\sum_j Buy_{ijt} - \sum_j Sell_{ijt}}{\sum_j Buy_{ijt} + \sum_j Sell_{ijt}}, \tag{1}$$

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

$$Insider\ Shares_{it} = \frac{Shares\ Purchased_{it} - Shares\ Sold_{it}}{Shares\ Purchased_{it} + Shares\ Sold_{it}}, \tag{2}$$

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.2 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.

Figure IA.2: 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/`).

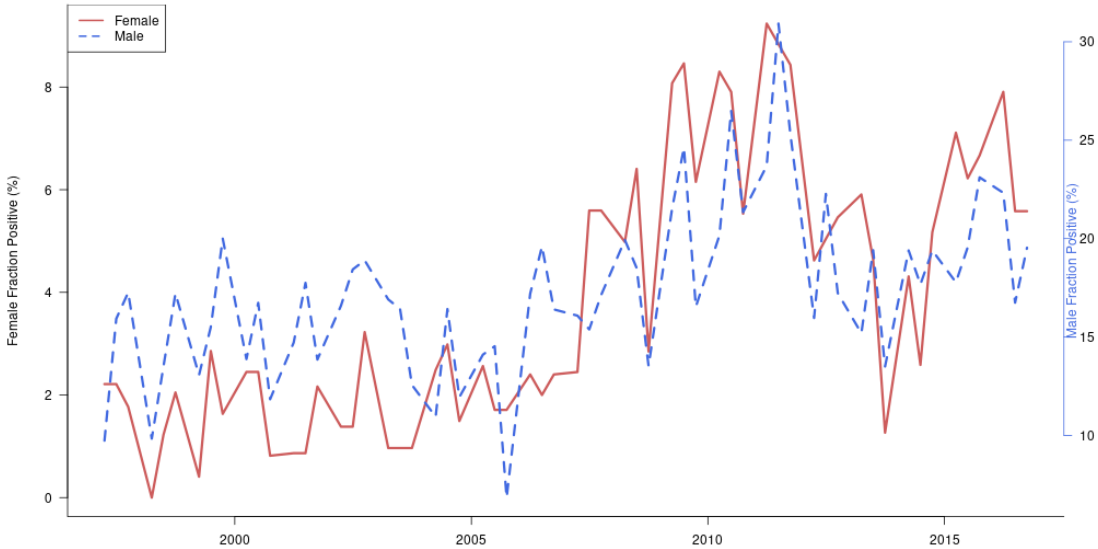

Table IA.9: Effect of financial crisis on two alternative measures of insider trades

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

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