Does Algorithmic Trading Affect Forced CEO Turnover?

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Research Question

- Does algorithmic trading (AT) affect CEO turnover-return sensitivity?
  - AT is a trading method executing orders using automated pre-programmed trading instructions.
  - CEO turnover-return sensitivity refers to the negative association between the likelihood of forced CEO turnover and stock return.

CEO Turnover

- CEO turnover is a key decision made by corporate boards, which greatly impacts shareholder value.
  - CEOs formulate corporate strategies and make resource allocation decisions. CEOs consider potential changes in the firm's economic environment and adapt accordingly.
- Directors require high-quality information.
  - Directors consider multiple internal and external characteristics to assess whether CEOs are able to adapt to changes in the business and economic environment.

CEO Turnover-Performance Sensitivity

- Directors rely on firm performance (e.g., stock returns) in forced CEO turnover decisions.
  - Prior research finds a negative relation between the likelihood of forced CEO turnover and firm performance.
  - Properties and information content of performance measures affect the turnover-performance sensitivity.
- Stock returns not only reflect the realized outcomes of managerial efforts but also incorporate *investors' assessment of the CEO-firm match quality* in enhancing firm value.
  - AT may affect the usefulness of this information source.

Algorithmic Trading

- AT is one of the most notable innovations in financial markets in a few decades (Stiglitz 2014).
  - Recently, the share of High Frequency Trading, which is a subset of AT, in equity markets is approximately 50% of the total markets in Europe and the US.
- Financial market consequences of AT (e.g., stock liquidity and price discovery) are well documented.
- Recent literature examines *real effects* of AT on corporate managers such as investment and disclosure.

Algorithmic Trading and Price Discovery

- The existing literature on AT makes a distinction between the two components of price discovery by investors (e.g., Weller 2018).
  1. Incorporating existing information into prices, and
  2. Acquiring new information

AT and Incorporating Existing Information

- AT rapidly incorporates public information into prices.
  - Algorithms utilize a rich array of market information to very quickly assess the state of the market and trade.
  - AT orders more efficiently translate information into prices through increased quoting efficiency.
- AT improves market efficiency with respect to public information once the information is disclosed.
  - Monitoring Channel – Information precision increases with AT and thus CEO turnover decision will become more sensitive to stock returns when AT is high.

AT and Acquiring New Information

- AT free-rides on order flow and front-run informed trades.
  - AT establishes a short-term long/short position in anticipation of the price move-up or down based on signals.
  - AT attempts to infer the existence of large buyers and sellers to free-ride on order flows and front-run informed trades.
- AT discourages investors' costly information acquisition activities (Weller 2018; Lee and Watts 2021)
  - Changes to the profitability of acquiring information change the amount acquired (Grossman and Stiglitz 1980).
  - Learning Channel – Stock returns are less likely to incorporate investors' private information about the CEO-Firm match when AT is high, reducing the turnover-return sensitivity.

Research Design

$$
\begin{aligned}
FORCED = {} & \beta_1 RET + \beta_2 AT + \boldsymbol{\beta_3\, RET \times AT} + \beta_4 SIZE + \beta_5 BTM + \beta_6 VOL \\
& + \beta_7 EARNVOL + \beta_8 AIM + \beta_9 ROA + \beta_{10} ANALYST + \beta_{11} IOR \\
& + \beta_{12} DIV + \beta_{13} DUALITY + \beta_{14} OWN + \beta_{15} AGE + \beta_{16} TENURE \\
& + \sum RET \times Firm\ Characteristics + \phi_i + \eta_t + \varepsilon,
\end{aligned}
\qquad (1)
$$

- *Forced*: an indicator of the forced CEO turnover
- *AT*: the (decile-ranked) first principal component from PCA using four AT proxies
  - ***Odd-Lot Ratio (OLR)*:** The fraction of volume associated with abnormally small trades (i.e., the total volume executed in quantities smaller than 100 shares divided by total volume traded).
  - ***Cancel-to-Trade Ratio (CTR)*:** the number of full or partial cancellations divided by the number of trades
  - ***Trade-to-Order Ratio (TTOR)*:** the total volume traded divided by the total volume across all orders placed
  - ***Average Trade Size (ATS)*:** the number of shares traded divided by the number of trades

Data

- The intersection of Compustat / CRSP / MIDAS / ExecuComp
- Sample Period: 2012 ~ 2019
  - MIDAS data starts from 2012
- 11,857 firm-year observations that correspond to 1,755 unique firms

Descriptive Statistics

	N	Mean	STD	Q1	Median	Q3
FORCED	11,828	0.036	0.186	0.000	0.000	0.000
ATPCA	11,828	0.000	1.429	-0.874	-0.052	0.842
OLR	11,828	2.652	0.714	2.192	2.706	3.176
CTR	11,828	3.270	0.446	2.967	3.209	3.488
TTOR	11,828	0.968	0.428	0.703	1.016	1.280
ATS	11,828	2.360	0.367	2.098	2.338	2.601
RETURN	11,828	0.063	0.435	-0.200	-0.003	0.236
SIZE	11,828	7.927	1.631	6.800	7.780	8.994
BTM	11,828	0.528	0.404	0.250	0.449	0.735
VOL	11,828	0.018	0.008	0.012	0.016	0.022
EARNVOL	11,828	0.043	0.051	0.013	0.027	0.052
AIM	11,828	0.056	0.195	0.002	0.007	0.027
EARN	11,828	0.049	0.123	-0.010	0.018	0.081
ANALYST	11,828	2.198	0.784	1.609	2.303	2.833
IOR	11,828	0.772	0.232	0.693	0.837	0.930
DIV	11,828	0.609	0.488	0.000	1.000	1.000
DUALITY	11,828	0.448	0.497	0.000	0.000	1.000
OWN	11,828	0.021	0.068	0.001	0.003	0.011
AGE	11,828	4.040	0.124	3.970	4.043	4.111
TENURE	11,828	1.919	0.820	1.338	1.946	2.532
BRDMEET	11,828	0.073	0.333	0.000	0.000	0.000

Descriptive Statistics: Correlations among AT proxies

		(1)	(2)	(3)	(4)
(1)	*ATPCA*				
(2)	*OLR*	**0.851**			
(3)	*CTR*	**0.697**	**0.302**		
(4)	*TTOR*	**-0.684**	**-0.277**	**-0.812**	
(5)	*ATS*	**-0.737**	**-0.931**	**-0.101**	**0.115**

Structure of Analyses

1. Main Result
2. Robustness Test
3. Cross-Sectional Tests
4. Additional Tests

Structure of Analyses

1. **Main Result**
   - **AT and Forced CEO Turnover**
2. Robustness Test
3. Cross-Sectional Tests
4. Additional Tests

Main Results

	FORCED		
	(1)	(2)	(3)
RET	**-0.058*** **	**-0.100*** **	**-0.151** **
	(0.007)	**(0.014)**	**(0.075)**
AT	-0.050***	-0.094***	-0.092***
	(0.016)	(0.022)	(0.023)
RET* × *AT		**0.089*** **	**0.085*** **
		(0.021)	**(0.024)**
Firm Characteristics × *RET*	No	No	Yes
Firm Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	11,828	11,828	11,828
Adjusted R^2	0.078	0.080	0.081

- The turnover-return sensitivity exhibits a notable decline of approximately **56.3%** when AT shifts from the bottom to the top decile (-0.563 = 0.085/-0.151)

Structure of Analyses

1. Main Result
2. **Robustness Test**
   - **Instrumental Variable Estimation**
3. Cross-Sectional Tests
4. Additional Tests

Instrumental Variable Estimation

- Instrumental Variable: Lagged Stock Price (Weller 2018)
  - In the presence of a minimum tick size of one cent, high-price stocks have a relatively fine price mesh, which favors algorithmic traders over human traders for continually replacing stale limit orders with updated quotes.
    - The minimum tick size, one cent, accounts for 10 basis points for a $10 stock as compared to 1 basis point for a $100 stock.
- *PRICE* is the decile-ranked average stock price measured before the measurement window of *AT*.

IV Estimation Result

	AT	*RET* × *AT*	*FORCED*
	(1)	(2)	(3)
	1st Stage Result		2nd Stage Result
RET × *PRICE*	0.119***	0.511***	
	(0.017)	(0.023)	
PRICE	0.075***	-0.186***	
	(0.018)	(0.016)	
RET* × *AT			**0.137****
			(0.060)
AT			-0.237*
			(0.140)
RET	-0.000	0.270***	-0.120***
	(0.010)	(0.015)	(0.027)
First-Stage Diagnostics			
Kleibergen-Paap *rk* LM statistic		61.432***	
Kleibergen-Paap rk Wald *F* statistic		34.545	
Firm Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	11,602	11,602	11,602
Adjusted R^2	0.858	0.837	0.037

Structure of Analyses

1. Main Result
2. Robustness Test
3. **Cross-Sectional Tests**
   - **Firm Characteristics**
   - **Informed Trading Intensity**
   - **Board Characteristics**
4. Additional Tests

Cross-Sectional Tests – Firm Characteristics

- Directors will learn from stock returns when investors are likely to possess informational advantages.
  1. Investors are collectively better in assessing growth opportunities and industry factors such as product market competition.
     - High growth opportunities (*INTCAP*)
     - High product market competition (*PMC*)
     - High product obsolescence risks (*PROD*)
  2. Investors' information advantages also stem from their geographic presence, so they can better impound local information into stock prices.
     - Greater geographic dispersion of investors *(GEODIV)*

	FORCED							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RET	-0.081***	-0.130*	-0.071***	-0.108	-0.065***	-0.162**	-0.053**	-0.130
	(0.018)	(0.077)	(0.020)	(0.077)	(0.020)	(0.082)	(0.021)	(0.084)
AT	-0.054**	-0.052*	-0.041	-0.034	-0.063**	-0.060**	-0.068**	-0.066**
	(0.026)	(0.027)	(0.028)	(0.029)	(0.027)	(0.027)	(0.030)	(0.031)
RET × *AT*	0.050*	0.044	0.021	0.007	0.043	0.036	0.026	0.023
	(0.026)	(0.029)	(0.030)	(0.032)	(0.030)	(0.030)	(0.032)	(0.035)
HIGH INTCAP	0.064**	0.061**						
	(0.025)	(0.027)						
HIGH INTCAP × *RET*	-0.045*	-0.038						
	(0.027)	(0.031)						
HIGH INTCAP × *AT*	-0.099***	-0.099**						
	(0.038)	(0.038)						
HIGH INTCAP* × *RET* × *AT	**0.105****	**0.107****						
	(0.044)	**(0.044)**						
HIGH PMC			0.051**	0.053**				
			(0.021)	(0.021)				
HIGH PMC × *RET*			-0.049*	-0.053*				
			(0.027)	(0.027)				
HIGH PMC × *AT*			-0.098***	-0.102***				
			(0.036)	(0.036)				
HIGH PMC* × *RET* × *AT			**0.127*****	**0.134*****				
			(0.044)	**(0.044)**				
HIGH PROD					0.040*	0.047**		
					(0.021)	(0.022)		
HIGH PROD × *RET*					-0.065**	-0.079***		
					(0.029)	(0.031)		
HIGH PROD × *AT*					-0.060*	-0.058*		
					(0.035)	(0.035)		
HIGH PROD* × *RET* × *AT					**0.088***	**0.087***		
					(0.046)	**(0.046)**		
HIGH GEODIV							0.031	0.036*
							(0.022)	(0.022)
HIGH GEODIV × *RET*							-0.050	-0.060**
							(0.030)	(0.030)
HIGH GEODIV × *AT*							-0.083**	-0.089**
							(0.035)	(0.035)
HIGH GEODIV* × *RET* × *AT							**0.098****	**0.110****
							(0.048)	**(0.047)**
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Characteristics × *RET*	No	Yes	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11,828	11,828	11,087	11,087	10,031	10,031	8,790	8,790
Adjusted R^2	0.081	0.082	0.081	0.082	0.063	0.064	0.093	0.093

Cross-Sectional Tests – Informed Trading

- AT will reduce the turnover-return sensitivity to a greater extent for firms with greater ex-ante informed trading activities.
- Informed Trading Intensity (ITI)
  - Bogousslavsky et al. (2024) use Schedule 13D trades (i.e., observed informed trades) and train their algorithms to measure the intensity of unobservable informed trading.
- ITI can be decomposed into
  - Impatient Informed Trading Intensity (*IPI_IMP*)
  - Patient Informed Trading Intensity (*ITI_P*)

	FORCED					
	(1)	(2)	(3)	(4)	(5)	(6)
RET	-0.078***	-0.184**	-0.070***	-0.158*	-0.073***	-0.210***
	(0.020)	(0.082)	(0.020)	(0.081)	(0.020)	(0.081)
AT	-0.077***	-0.078***	-0.067**	-0.068**	-0.075***	-0.078***
	(0.026)	(0.028)	(0.027)	(0.028)	(0.026)	(0.027)
RET × *AT*	0.055*	0.056*	0.047	0.047	0.058**	0.062**
	(0.029)	(0.032)	(0.030)	(0.032)	(0.029)	(0.031)
HIGH ITI	0.012	0.013				
	(0.019)	(0.019)				
HIGH ITI × *RET*	-0.046	-0.049*				
	(0.028)	(0.028)				
HIGH ITI × *AT*	-0.044	-0.042				
	(0.031)	(0.031)				
HIGH ITI* × *RET* × *AT	**0.080***	**0.077***				
	(0.043)	**(0.044)**				
HIGH ITI_P			0.034*	0.037*		
			(0.019)	(0.019)		
HIGH ITI_P × *RET*			-0.062**	-0.069**		
			(0.027)	(0.027)		
HIGH ITI_P × *AT*			-0.056*	-0.056*		
			(0.030)	(0.030)		
HIGH ITI_P* × *RET* × *AT			**0.090****	**0.090****		
			(0.042)	**(0.042)**		
HIGH ITI_IMP					0.029	0.034*
					(0.019)	(0.019)
HIGH ITI_IMP × *RET*					-0.058**	-0.068**
					(0.029)	(0.028)
HIGH ITI_IMP × *AT*					-0.041	-0.039
					(0.031)	(0.031)
HIGH ITI_IMP* × *RET* × *AT					**0.071**	**0.069**
					(0.045)	**(0.045)**
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm Characteristics × *RET*	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11,292	11,292	11,292	11,292	11,292	11,292
Adjusted R^2	0.085	0.087	0.085	0.087	0.085	0.087

Cross-Sectional Tests – Board Characteristics

- Directors will learn from stock returns when they have the expertise to do so, or the quality of their information set is poor.
  1. Directors' prior industry experience as a CEO (*INDEXP*)
  2. The quality of directors' own information set can be captured by their insider trading pattern.
     1. Percentage of outside directors trading the firm's stock during the year (*INSTRADE*)
     2. Insider trading profitability of outside directors (*INSPROFIT*)

	FORCED					
	(1)	(2)	(3)	(4)	(5)	(6)
RET	-0.087***	-0.132*	-0.084***	-0.138*	-0.090***	-0.147**
	(0.017)	(0.076)	(0.017)	(0.075)	(0.016)	(0.075)
AT	-0.071***	-0.070***	-0.077***	-0.074***	-0.077***	-0.076***
	(0.025)	(0.026)	(0.024)	(0.025)	(0.024)	(0.025)
RET × *AT*	0.057**	0.054*	0.053**	0.048*	0.067***	0.063**
	(0.027)	(0.028)	(0.026)	(0.028)	(0.025)	(0.027)
HIGH INDEXP	0.023	0.022				
	(0.024)	(0.024)				
HIGH INDEXP × *RET*	-0.034	-0.032				
	(0.028)	(0.029)				
HIGH INDEXP × *AT*	-0.064*	-0.063*				
	(0.037)	(0.037)				
HIGH INDEXP* × *RET* × *AT	**0.089****	**0.087****				
	(0.043)	**(0.044)**				
LOW INSTRADE			0.016	0.016		
			(0.019)	(0.019)		
LOW INSTRADE × *RET*			-0.049*	-0.048*		
			(0.027)	(0.028)		
LOW INSTRADE × *AT*			-0.050*	-0.051*		
			(0.029)	(0.029)		
LOW INSTRADE* × *RET* × *AT			**0.107****	**0.108****		
			(0.043)	**(0.043)**		
LOW INSPROFIT					0.028	0.026
					(0.020)	(0.020)
LOW INSPROFIT × *RET*					-0.035	-0.032
					(0.028)	(0.028)
LOW INSPROFIT × *AT*					-0.058*	-0.057*
					(0.031)	(0.031)
LOW INSPROFIT* × *RET* × *AT					**0.074***	**0.072***
					(0.043)	**(0.043)**
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm Characteristics × *RET*	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11,828	11,828	11,828	11,828	11,828	11,828
Adjusted R^2	0.081	0.082	0.081	0.082	0.080	0.082

Structure of Analyses

1. Main Result
2. Robustness Test
3. Cross-Sectional Tests
4. **Additional Tests**
   - **AT and Accounting Performance Sensitivity**
   - **AT and Special Board Meeting Frequency**

Additional Tests

- AT and Turnover-Accounting Performance Sensitivity
  - Boards may shift to accounting performance in response to higher levels of algorithmic trading activities.
- Special Board Meeting Frequency
  - Boards may engage in more information collection and processing activities when AT increases.
  - This tendency would be more pronounced when evaluating the CEO-firm match quality is costlier.
    - When CEOs are young or CEOs were hired externally.

Turnover-Accounting Performance Sensitivity

	AT	*RET* × *AT*	*ROA* × *AT*	*FORCED*
	(1)	(2)	(3)	(4)
		1st Stage Result		2nd Stage Result
RET × *PRICE*	0.117***	0.511***	0.084***	
	(0.017)	(0.023)	(0.011)	
ROA × *PRICE*	0.057*	-0.004	0.407***	
	(0.030)	(0.022)	(0.026)	
PRICE	0.045*	-0.184***	-0.142***	
	(0.025)	(0.020)	(0.015)	
RET* × *AT				**0.133****
				(0.061)
ROA* × *AT				**-0.186***
				(0.102)
AT				-0.071
				(0.194)
RET	0.001	0.270***	-0.002	-0.120***
	(0.010)	(0.015)	(0.006)	(0.027)
ROA	0.004	0.020	0.272***	0.049
	(0.017)	(0.013)	(0.017)	(0.042)
First-Stage Diagnostics				
Kleibergen-Paap *rk* LM statistic		44.643***		
Kleibergen-Paap rk Wald *F* statistic		16.058		
Firm Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	11,602	11,602	11,602	11,602
Adjusted R^2	0.858	0.837	0.895	0.038

Special Board Meeting Frequency

	BRDMEET		
	(1)	(2)	(3)
AT	**0.040***	**-0.002**	**0.015**
	(0.024)	**(0.027)**	**(0.027)**
YOUNGCEO		0.004	
		(0.019)	
AT × YOUNGCEO		**0.061*** **	
		(0.023)	
OUTSIDECEO			-0.022
			(0.020)
AT × OUTSIDECEO			**0.049***
			(0.030)
Firm Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	11,828	11,828	11,828
Adjusted R^2	0.521	0.521	0.521

Conclusion

- Algorithmic trading activity affects boards' CEO turnover decisions.
  - Prior research primarily focuses on the effects of AT activity on financial market variables (e.g., liquidity).
  - Real effects of Algorithmic Trading.
- Decision-makers other than managers such as directors also learn from stock prices.
  - Most prior studies focus on managerial learning from price.


PURDUE UNIVERSITY
Thank you!

Characteristics of Algorithmic Trading

- The use of extraordinarily high-speed and sophisticated computer programs for generating, routing, and executing orders.
- Observe markets in real time.
  - Use of co-location services and individual data feeds offered by exchanges and others to minimize latencies.
- Short holding periods and usually neutral positions at the end of the day.
- Profit changes are extremely time-sensitive and AT executes a huge number of trades with a very small profit per trade.
  - Huge number of orders and cancellations

Algorithmic Trading Strategies

- *Directional* – AT establishes a short-term long or short position in anticipation of the price move-up or down based on signals.
- *Order anticipation* – AT attempts to infer the existence of large buyer/seller in order to buy/sell ahead of the order.
  - Yang and Zhu (2019); Van Kervel and Menkveld (2019); Hirschey (2018).

Algorithmic Trading Strategies

- Other strategies include
  - *Passive market-making*. It involves submitting non-marketable orders on both sides (buy and sell). Profits are earned by earnings the spread between bids and offers.
  - *Arbitrage*. It generally seek to capture pricing discrepancies between related products or markets, such as between an ETF and its underlying basket of stocks.
  - *Structural*. It attempts to exploit structural vulnerability in the market (e.g., latency).