Internet Appendix

for

"Seed-Stage Success and Growth of Angel Networks"

December 2018

This Internet Appendix contains the following details which are not reported in the paper due to space constraints: (1) description of start-up financing stages; (2) description of network measures; and (3) results of additional robustness tests that we conduct to rule out possible alternative explanations for our main findings.

IA-1. Description of Start-up Financing Stages

Start-ups raise funds at various stages of their life cycle. Industry participants classify these financing stages as *Seed*, *Series A*, *Series B*, *Series C*, and so on. The academic literature (e.g., see Gompers (1995)) sometimes refers to series A as "early stage," series B as "expansion stage," and series C and beyond as "late stage." The informal definitions of the these stages are as follows:[1]

- *Seed stage:* The purpose of the series seed is for the startup to figure out the product it is building, the market it is in, and the user base. Typically, a seed round helps the company scale to a few employees past the founders and to build and launch an early product.

- *Series A:* Startups that get to this stage have figured out their product and user base, and are trying to establish a viable business model and scale up their operations.

- *Series B:* This stage is all about scaling. Startups that get to this stage have an established product and business model, and are trying to scale up their business model and user base.

- *Series C:* This stage is used by startups to accelerate their growth beyond the Series B stage; e.g., by going international or by making acquisitions. Firms requiring more funds raise them in stages Series D, E, etc.

The startups disclose the financing stage when they raise funds, and this information is reported by CrunchBase and AngelList. Each financing stage may itself involve multiple funding rounds.

IA-2. Description of Network Measures

Co-investment networks may be viewed as a set of nodes and edges. For example, in the network of 6 investors shown below, the nodes are investors and the edges represent co-investment connections between investors. In order to compute centrality measures, networks are represented in the form of $N \times N$ "adjacency" matrices, where N is the total number of investors in the network. The adjacency matrix below represents the co-investment network, where a '1' denotes the presence

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[1]See http://blog.eladgil.com/2011/03/how-funding-rounds-differ-seed-series.html for a more detailed description of these funding stages.

of a co-investment connection between the two investors (e.g., investors I_1 and I_2), whereas a '0' denotes the lack of a connection (e.g., between investors I_1 and I_3).
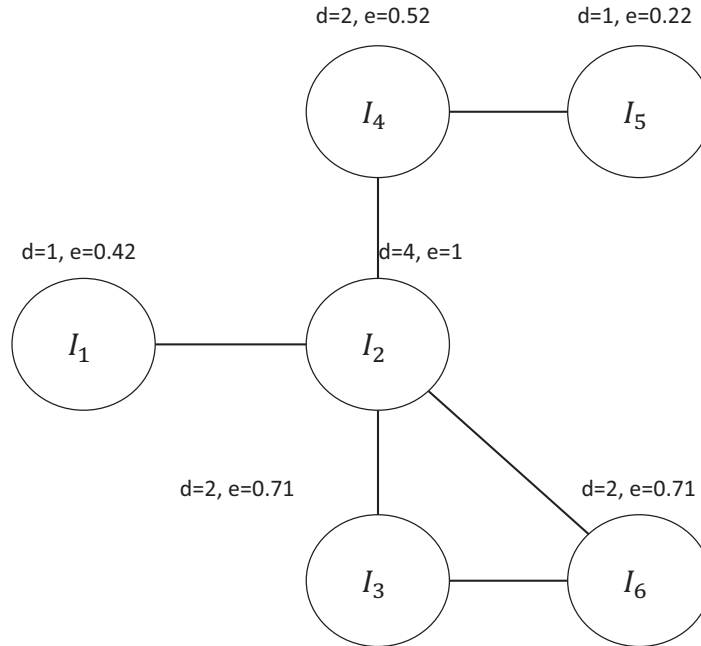
Investor	I_1	I_2	I_3	I_4	I_5	I_6
I_1	-	1	0	0	0	0
I_2	1	-	1	1	0	1
I_3	0	1	-	0	0	1
I_4	0	1	0	-	1	0
I_5	0	1	0	1	-	0
I_6	0	1	1	0	0	-

The network measures are defined as follows:

- *Degree Centrality$_{i,t}$* denotes the total number of co-investment connections that an investor has as of year t. It is obtained by summing the investor's row (or column) vector in the

adjacency matrix. For example, in the network above, investor I_1 has a degree centrality of 1 ('d' in the network figure shows degree centrality of each investor).

- *Eigenvector Centrality$_{i,t}$* measures the relative importance of each investor in the network. It is a recursive degree measure where each investor's eigenvector centrality is the sum of his ties to others weighted by their respective degree centrality. It is the positive eigenvector of the network's undirected adjacency matrix. Mathematically, eigenvector of investor 'i' (ev_i) is given by $ev_i = \sum_j p_{ij}.ev_j$, where p_{ij} takes a value 1 if there is a relationship between investors i and j. We use power iteration method (100 iterations) recommended by Bonacich (1987) to calculate eigenvector centrality of each investor.

- *Eigenvector Centrality Decile$_{i,t}$* represents the decile of *Eigenvector Centrality* to which the individual angel belongs in year t. $\Delta(Eigenvector\ Centrality\ Decile)_{i,t}$ represents change in *Eigenvector Centrality Decile* of angel i from year $t-1$ to t.

- *New Connections$_{i,t}$* is the number of new co-investment connections formed by an investor in year t excluding the new-co-investment connections that arise from any existing portfolio firm that progressed from seed stage to series A stage.

- *New Outside Connections$_{i,t}$* is the number of new out-of-state co-investment connections formed by an investor in year t.

IA-3. Additional Tests

Effect of Other Forms of Success: All our analysis so far has relied on seed-stage success as the measure of angels' successful performance. In Table IA.2, we replicate our main results with *Other Stage Success* (Panel A) and *Successful Exit* (Panel B) as alternative measures of success. As it can be seen, our qualitative results are similar with these alternative measures of success. However, some of the $PreSuccess_{-\tau}$ are also positive and significant in some regressions, which suggests that the parallel trends assumption may not always be met for these alternative measures

of success. This may be because only the more established angels are likely to deliver successful exits and success at later stages.

Falsification test: One concern may be that our results are driven by macro trends, such as large inflow of funds into the angel investor market, that lead to both successful performance of existing seed-stage startups as well as increase in future deal flow for the angel investors. We note that our empirical specification should ameliorate such concerns because such a macro trend should affect both the successful angel and the control group of unsuccessful angels, and hence, cannot drive the γ_τ coefficient which captures the *difference* in the change in the $y-$variable between the two groups. Nonetheless, to further address this concern, we implement a falsification test by creating a variable called *PlaceboSuccess* as follows. For each angel that actually experiences a seed success, we randomly assign *PlaceboSuccess*= 1 to one of the angels in its control group and assign *PlaceboSuccess*= 0 to the successful angel and all other angels in its control group. We then repeat our estimation of the difference-in-differences specification (3) with *PlaceboSuccess* instead of *Seed Success* as the treatment variable, the results of which are presented in Table IA.3. As can be seen, the γ_τ coefficients on the $PostPlaceboSuccess_\tau$ terms are all insignificant, which shows that our results in Section 5 of the paper are capturing the causal effect of successful performance.

Dealing with multiple successes: Another concern with the difference-in-differences specification (3) is that if an investor experiences multiple successes within a gap of a few years, then it complicates the identification of the causal effect of success on y, because a $PostSuccess$ term corresponding to the first success may overlap with a $PreSuccess$ term on account of the second success. We note that this is not a serious concern in our setting because only a few investors experience more than one seed success during the 2005–2014 time period. Nonetheless, to alleviate this concern, we estimate specification (3) using only the first *Seed Success* of every angel investor. As can be seen from Table IA.4, our results are mostly unchanged.

Other tests: Recall that we conducted our analysis only on angel investors that invested in at least 3 portfolio companies during the period 2005–2014. The idea behind this restriction was

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to eliminate angel investors that make one-off investments in startups founded by their family members or friends. We now ease this restriction, and repeat all our tests with *Seed Success* as the measure of success after including all individual angels in the analysis. The results are presented in Table IA.5, and show all our main results hold even without the restriction.

References

Bonacich, P. (1987). Power and Centrality: A Family of Measures. *American Journal of Sociology 92*, 1170–1182.

Gompers, P. A. (1995). Optimal Investment, Monitoring, and the Staging of Venture Capital. *Journal of Finance 50*, 1461–1489.

Table IA.1 Univariate Comparison: Treatment vs. Control samples in Seed Success Year

In this table we present a univariate comparison of the treatment (Successful angels) and control (Unsuccessful angels) groups obtained through the propensity score matching method in the year of *Seed Success*. The last column reports the *t-statistic* of the tests for difference between treatment and control samples. All variables are defined in the Appendix.

	Successful Angels (A: Treatment Group)			Unsuccessful Angels (B: Control Group)			(A-B)
Variable	Mean	Stdev.	N	Mean	Stdev.	N	t-stat
Angel Characteristics							
Start-ups invested	2.218	4.571	2225	2.053	5.409	7225	1.92
Rounds Invested	3.053	6.493	2225	2.925	7.856	7225	1.03
Rounds lead	1.381	3.887	2225	1.480	5.928	7225	-1.09
Experience	3.782	3.260	2225	5.126	2.991	7225	-17.33
Entrepreneurship Experience	0.173	0.378	2225	0.159	0.365	7225	1.54
Degree Centrality	12.791	22.428	2225	12.271	24.876	7225	0.93
Eigenvector Centrality	6.492	9.114	2106	6.198	12.55	7011	1.182

Table IA.2 Effect of Other-stage Success and Successful Exits on Angel Outcomes

In this table, we estimate regression (3) with alternative measures of success to examine the effect of successful performance on angel investor network capital growth and deal flow outcomes. The measure of success is *Other-stage Success* in panel A and *Successful Exit* in panel B. All variables are defined in the Appendix. Standard errors reported in parentheses are robust to heteroskedasticity and are clustered by angels. We use ***, **, and * to denote statistical significance at 1%, 5% and 10% levels, respectively.

Panel A: Effect of Other-stage Success on Angel Outcomes

	$Ln(1 + New$ $Connections_{i,t})$ (1)	$\Delta(Eigenvector$ $Centrality\ Decile)_{i,t}$ (2)	$Ln(1 + New\ Outside$ $Connection_{i,t})$ (3)	$Ln(1 + New$ $Investments_{i,t})$ (4)	$Ln(1 + New\ Lead$ $Investments_{i,t})$ (5)	$Ln(1 + New\ Outside$ $Investments_{i,t})$ (6)	$Other\ Seed$ $Success_{i,t}$ (7	VC $Financing_{i,t}$ (8)
Other stage Success	-0.009	0.022	0.030	0.016	-0.011	0.029	-0.021*	0.000
	(0.011)	(0.019)	(0.023)	(0.010)	(0.008)	(0.019)	(0.012)	(0.013)
$PreSuccess_{-3}$	-0.017	-0.052	-0.035*	-0.016	-0.022*	-0.032	-0.014	-0.017
	(0.018)	(0.032)	(0.021)	(0.019)	(0.013)	(0.020)	(0.013)	(0.015)
$PreSuccess_{-2}$	-0.003	-0.045	-0.028	-0.014	-0.011	-0.024	-0.010	-0.004
	(0.016)	(0.029)	(0.023)	(0.016)	(0.012)	(0.018)	(0.013)	(0.014)
$PreSuccess_{-1}$	0.013	-0.016	-0.012	-0.011	0.010	0.007	0.023*	0.029**
	(0.015)	(0.026)	(0.025)	(0.015)	(0.011)	(0.019)	(0.013)	(0.014)
$PostSuccess_{+1}$	0.099***	0.178***	0.101***	0.140***	0.118***	0.186***	0.129***	0.144***
	(0.020)	(0.053)	(0.024)	(0.016)	(0.012)	(0.020)	(0.015)	(0.019)
$PostSuccess_{+2}$	0.084***	0.204***	0.186***	0.161***	0.021*	0.100***	0.118***	0.132***
	(0.022)	(0.052)	(0.025)	(0.016)	(0.012)	(0.021)	(0.015)	(0.020)
$PostSuccess_{+3}$	0.067***	0.091	0.050*	0.176***	0.013	0.041*	0.024	0.129***
	(0.024)	(0.056)	(0.026)	(0.018)	(0.013)	(0.022)	(0.016)	(0.020)
Obs.	30342	18767	30342	30342	30342	30342	30342	30342
Adj. R^2	0.491	0.177	0.458	0.554	0.603	0.579	0.297	0.468
Investor & Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	Ln(1 + New Connections$_{i,t}$) (1)	Δ(Eigenvector Centrality Decile)$_{i,t}$ (2)	Ln(1 + New Outside Connection$_{i,t}$) (3)	Ln(1 + New Investments$_{i,t}$) (4)	Ln(1 + New Lead Investments$_{i,t}$) (5)	Ln(1 + New Outside Investments$_{i,t}$) (6)	Other Seed Success$_{i,t}$ (7)	VC Financing$_{i,t}$ (8)
			Panel B: Effect of Successful Exits on Angel Outcomes					
Successful Exit	0.020	0.035	0.043**	0.011	0.021	0.039*	0.003	0.008
	(0.015)	(0.026)	(0.021)	(0.016)	(0.013)	(0.021)	(0.013)	(0.014)
PreSuccess$_{-3}$	-0.022	-0.013	-0.015	0.033	0.019	-0.022	0.015	0.004
	(0.018)	(0.031)	(0.020)	(0.021)	(0.017)	(0.022)	(0.014)	(0.015)
PreSuccess$_{-2}$	-0.026	-0.029	0.029	0.032	0.021	0.024	0.018	0.000
	(0.017)	(0.027)	(0.021)	(0.020)	(0.016)	(0.020)	(0.013)	(0.015)
PreSuccess$_{-1}$	-0.020	-0.039	0.042*	0.008	0.024	0.047**	0.033**	0.084***
	(0.016)	(0.024)	(0.023)	(0.019)	(0.015)	(0.023)	(0.013)	(0.015)
PostSuccess$_{+1}$	0.065***	0.325***	0.163***	0.116***	0.095***	0.179***	0.138***	0.202***
	(0.024)	(0.056)	(0.022)	(0.022)	(0.017)	(0.022)	(0.016)	(0.020)
PostSuccess$_{+2}$	0.110***	0.269***	0.154***	0.158***	0.102***	0.187***	0.112***	0.212***
	(0.026)	(0.057)	(0.024)	(0.023)	(0.019)	(0.023)	(0.016)	(0.020)
PostSuccess$_{+3}$	0.115***	0.116*	0.115***	0.164***	0.088***	0.083***	0.090***	0.113***
	(0.028)	(0.060)	(0.026)	(0.025)	(0.020)	(0.022)	(0.016)	(0.021)
Obs.	16533	10230	16533	16533	16533	16533	16533	16533
Adj. R^2	0.565	0.265	0.391	0.569	0.577	0.438	0.347	0.489
Investor & Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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Table IA.3 Falsification Test

This table reports results of falsification tests that investigate the effect of placebo success on future network capital and deal flow of angels. For each angel that experienced a seed success, we randomly assign *PlaceboSuccess*= 1 for one of the angels in the control group and set *PlaceboSuccess*=0 for the successful angel and all other angels in the control group. For each angel-year observation, the dummy variables *Post-PlaceboSuccess*$_\tau$ identify the year $\tau \in \{1, 2, 3\}$ *after* the placebo success year, whereas the dummy variables *Pre-PlaceboSuccess*$_\tau$ identify the year $\tau \in \{-3, -2, -1\}$ *before* the placebo success year. We then estimate the following difference-in-differences regression:

$$y_{i,t} = \alpha + \sum_{\tau=-3}^{\tau=-1} \beta_\tau \times \text{Pre-PlaceboSuccess}_\tau + \sum_{\tau=1}^{\tau=3} \gamma_\tau \times \text{Post-PlaceboSuccess}_\tau + \delta \times \text{PlaceboSuccess} + \sum_{\tau=-3}^{\tau=-1} \zeta_\tau \times Pre_\tau$$

$$+ \sum_{\tau=1}^{\tau=3} \eta_\tau \times \text{Post}_\tau + \mu_i + \mu_t + \epsilon_{i,t}$$

	$Ln(1 + New$ $Connections_{i,t})$ (1)	$\Delta(Eigenvector$ $Centrality\ Decile)_{i,t}$ (2)	$Ln(1 + New\ Outside$ $Connection_{i,t})$ (3)	$Ln(1 + New$ $Investments_{i,t})$ (4)	$Ln(1 + New\ Lead$ $Investments_{i,t})$ (5)	$Ln(1 + New\ Outside$ $Investments_{i,t})$ (6)	$Other\ Seed$ $Success_{i,t}$ (7	VC $Financing_{i,t}$ (8)
PlaceboSuccess	0.019 (0.013)	0.022 (0.016)	0.040* (0.022)	0.026 (0.020)	0.021* (0.012)	0.019 (0.017)	0.020 (0.014)	0.041* (0.023)
$PrePlaceboSuccess_{-3}$	0.051*** (0.017)	0.011 (0.012)	-0.015 (0.020)	0.044** (0.021)	0.012 (0.011)	-0.021 (0.014)	0.011 (0.012)	0.031 (0.020)
$PrePlaceboSuccess_{-2}$	0.030 (0.019)	-0.018 (0.012)	-0.005 (0.022)	0.015 (0.019)	0.021 (0.015)	-0.011 (0.010)	0.019* (0.011)	0.023 (0.018)
$PrePlaceboSuccess_{-1}$	0.028 (0.020)	-0.021* (0.011)	0.031 (0.026)	-0.020 (0.018)	-0.010 (0.012)	-0.022 (0.018)	0.016 (0.010)	0.035* (0.019)
$PostPlaceboSuccess_{+1}$	0.012 (0.019)	-0.024 (0.017)	-0.013 (0.028)	0.023 (0.017)	-0.018 (0.014)	-0.031* (0.016)	-0.014 (0.009)	-0.042** (0.021)
$PostPlaceboSuccess_{+2}$	-0.003 (0.023)	-0.001 (0.020)	-0.022 (0.019)	-0.031 (0.021)	-0.014 (0.013)	-0.019 (0.015)	-0.024 (0.015)	0.018 (0.020)
$PostPlaceboSuccess_{+3}$	-0.031 (0.022)	-0.011 (0.019)	0.003 (0.025)	-0.019 (0.020)	-0.023 (0.017)	-0.031* (0.018)	0.010 (0.014)	0.010 (0.023)
Obs.	54138	48874	54138	54138	54138	54138	54138	54138
Adj. R^2	0.091	0.052	0.135	0.101	0.111	0.128	0.099	0.091
Investor & Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table IA.4 Effect of First Seed Success on Angel's Network Growth and Deal Outcomes

In this table, we estimate regression (3) with *Seed Success* as the measure for success to examine the effect of successful performance on the angel investor's network capital growth and deal flow. For this analysis, we consider include only the first success of each successful angel and generate a control group using propensity score matching method. All variables are defined in the Appendix. Standard errors reported in parentheses are robust to heteroskedasticity and are clustered by angels. We use ***, **, and * to denote statistical significance at 1%, 5% and 10% levels, respectively.

	$Ln(1 + New$ $Connections_{i,t})$ (1)	$\Delta(Eigenvector$ $Centrality\ Decile)_{i,t}$ (2)	$Ln(1 + New\ Outside$ $Connection_{i,t})$ (3)	$Ln(1 + New$ $Investments_{i,t})$ (4)	$Ln(1 + New\ Lead$ $Investments_{i,t})$ (5)	$Ln(1 + New\ Outside$ $Investments_{i,t})$ (6)	$Other\ Seed$ $Success_{i,t}$ (7)	VC $Financing_{i,t}$ (8)
Seed Success	-0.007	-0.021	-0.010	-0.017	-0.012	-0.001	0.021	-0.026*
	(0.017)	(0.013)	(0.024)	(0.012)	(0.010)	(0.011)	(0.014)	(0.014)
$PreSuccess_{-3}$	-0.025	-0.026*	-0.021	-0.035*	-0.016	-0.017	-0.023*	-0.021
	(0.019)	(0.014)	(0.027)	(0.019)	(0.021)	(0.022)	(0.012)	(0.013)
$PreSuccess_{-2}$	-0.031	-0.016	-0.029	-0.027	-0.022	-0.011	-0.011	0.016
	(0.021)	(0.016)	(0.023)	(0.017)	(0.022)	(0.023)	(0.013)	(0.014)
$PreSuccess_{-1}$	0.010	0.011	0.030	0.010	0.030	0.007	0.011	0.034**
	(0.020)	(0.012)	(0.025)	(0.015)	(0.020)	(0.020)	(0.012)	(0.014)
$PostSuccess_{+1}$	0.099***	0.106***	0.109***	0.145***	0.078***	0.165***	0.077***	0.111***
	(0.021)	(0.018)	(0.023)	(0.018)	(0.021)	(0.020)	(0.018)	(0.015)
$PostSuccess_{+2}$	0.051**	0.147***	0.199***	0.077***	0.099***	0.097***	0.092***	0.076***
	(0.024)	(0.021)	(0.020)	(0.016)	(0.023)	(0.023)	(0.017)	(0.018)
$PostSuccess_{+3}$	0.052**	0.040*	0.063**	0.026	0.038	0.046*	0.033*	0.070***
	(0.024)	(0.023)	(0.027)	(0.018)	(0.027)	(0.025)	(0.019)	(0.019)
Obs.	49516	43187	49516	49516	49516	49516	49516	49516
Adj. R^2	0.369	0.102	0.351	0.448	0.453	0.384	0.201	0.267
Investor & Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table IA.5 Effect of Seed Success on Outcomes: Including angels who have invested in fewer than 3 startups

In this table, we estimate regression (3) with *Seed Success* as the measure for success to examine the effect of successful performance on the angel investor's network capital growth and deal flow. For these tests we relax the sample selection criterion that an angel should have invested in at least 3 startups. Thus the sample used here is an unbalanced panel of 12,147 angels. All variables are defined in the Appendix. Standard errors reported in parentheses are robust to heteroskedasticity and are clustered by angels. We use ***, **, and * to denote statistical significance at 1%, 5% and 10% levels, respectively.

	$Ln(1 + New$ $Connections_{i,t})$ (1)	$\Delta(Eigenvector$ $Centrality\ Decile)_{i,t}$ (2)	$Ln(1 + New\ Outside$ $Connection_{i,t})$ (3)	$Ln(1 + New$ $Investments_{i,t})$ (4)	$Ln(1 + New\ Lead$ $Investments_{i,t})$ (5)	$Ln(1 + New\ Outside$ $Investments_{i,t})$ (6)	$Other\ Seed$ $Success_{i,t}$ (7	VC $Financing_{i,t}$ (8)
Seed Success	-0.027	-0.024	-0.030	-0.026	-0.021	-0.019	-0.023	-0.026
	(0.023)	(0.016)	(0.028)	(0.020)	(0.020)	(0.017)	(0.019)	(0.020)
$PreSuccess_{-3}$	-0.041	-0.031	-0.044*	-0.025	-0.011	-0.033*	-0.039**	-0.022
	(0.033)	(0.020)	(0.025)	(0.020)	(0.016)	(0.019)	(0.017)	(0.016)
$PreSuccess_{-2}$	-0.033	0.023	-0.028	-0.011	-0.009	-0.016	-0.019	-0.004
	(0.034)	(0.019)	(0.026)	(0.010)	(0.018)	(0.017)	(0.018)	(0.014)
$PreSuccess_{-1}$	-0.007	0.016	0.002	-0.001	0.011	0.007	-0.006	0.028
	(0.032)	(0.017)	(0.023)	(0.020)	(0.019)	(0.016)	(0.018)	(0.019)
$PostSuccess_{+1}$	0.088***	0.057***	0.034*	0.091***	0.032	0.102***	0.029*	0.077***
	(0.033)	(0.019)	(0.020)	(0.021)	(0.020)	(0.017)	(0.016)	(0.019)
$PostSuccess_{+2}$	0.041	0.089***	0.102***	0.050**	0.051**	0.057***	0.088***	0.030**
	(0.031)	(0.022)	(0.021)	(0.023)	(0.021)	(0.018)	(0.019)	(0.014)
$PostSuccess_{+3}$	0.058*	0.041	0.043*	0.012	0.022	0.041**	0.068***	0.024
	(0.031)	(0.026)	(0.025)	(0.024)	(0.019)	(0.017)	(0.020)	(0.019)
Obs.	126374	117925	126374	126374	126374	126374	126374	126374
Adj. R^2	0.213	0.122	0.237	0.300	0.256	0.266	0.173	0.192
Investor & Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes