



“When to Hold and When to Fold”: Simulating Portfolio Returns to Angel Investing in Early Stage Ventures

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Abstract. We use a large scale simulation to explore returns to angel investing in the context of real-world constraints in the first empirical examination of investment timing, termination and re-investment. Prior studies calculate angel returns as a single portfolio of investments, as if angels make hundreds of investments simultaneously and hold them all until exit or failure. We sample the largest available angel returns data set while varying portfolio size, investing window and portfolio hold time. Our Monte Carlo analysis simulates more than 11 million portfolios with over 240 million hypothetical investments. The results suggest that angel investing presents more variability and lower returns than reported in prior studies. Low returns are also associated with follow-on investment, which suggests that angels may tend to escalate commitment to poorly performing investments. The study highlights the importance of examining angel investing returns in the context of real-world constraints.

Keywords: angel investment; investment returns; escalation of commitment; exits; investment window.

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He said, “If you’re gonna play the game, boy/You gotta learn to play it right/
You’ve got to know when to hold ’em/Know when to fold ’em
... the secret to survivin’/Is knowin’ what to throw away/And knowin’ what to
keep.” *The Gambler (lyrics by Don Schlitz)*

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1. Introduction

Business angel investing is an important source of risk capital for early-stage ventures (e.g. White and Dumay, 2017; Drover et al., 2017; Wallmeroth et al., 2018). In recent years, a decrease in early stage institutional venture capital (VC) has led some angels to fund portfolio companies from seed stage to exit (Mason et al., 2016a; 2019; Owen et al., 2019). Unfortunately, despite experience, due diligence processes (Harrison and Mason, 2017) and post-investment involvement (Politis, 2016), up to 75% of business angel investments generate negative real returns (Mason and Harrison, 2002a; Wiltbank et al., 2009).

Angel returns have not, however, been investigated as rigorously as VC performance (e.g., Mason et al., 2016b; Bonini et al., 2019). Data are rare, inconsistently reported and sometimes unreliable (e.g. Cochrane, 2005; McDonald and DeGennaro, 2016; Mason and Harrison, 2008), even when datasets are relatively large and sourced from specific angel investment groups (Mason and Harrison, 2002b; Wiltbank and Boeker, 2007; Roach, 2010; Capizzi, 2015; Coleman and Robb, 2018; GoBeyond, 2019; Antretter et al., 2020). Measuring angel returns poses special challenges (Wiltbank et al., 2009), including selection bias, non-response bias, survivorship bias, expiration bias and backfill bias (McDonald and DeGennaro, 2016). Correlational methods designed to estimate “average returns” can yield misleading results due to the presence of rare and/or extreme outliers (Capizzi, 2015; Drover et al., 2017). Further, most prior studies report returns for a portfolio of investments, which assumes that all investments are made simultaneously and always held until exit (Gregson et al., 2017).

Angel investments are illiquid equity investments negotiated in private with high transaction costs (Sohl, 2003). In theory, angels accept risk to seek above-market returns (Antretter et al., 2020). The VC literature suggests it is unlikely that any individual angel investor could make enough investments to meet this expectation (e.g. McClure, 2015), but this remains mostly unexplored in the angel investment literature (Roach, 2010; Gregson et al., 2017). This is especially problematic because angel investors effectively rely on the entrepreneur to manage market risk (Fiet, 1995; Harrison et al., 2016). Angel research has focused primarily on the individual investor making choices deal-by-deal rather than on a portfolio basis (McDonald and DeGennaro, 2016; White and Dumay, 2017). Portfolio-based research has subsequently suffered from dramatic simplifications, such as returns analysis assuming an individual angel could make hundreds of investments simultaneously.

To address this shortcoming, we focus on the real-world investment portfolio as the unit of analysis. Since investment timing can significantly bias returns calculations (DeGennaro and Dwyer, 2014), our study responds to the call for a “better understanding of exit options and strategies and a focus on the current low percentage of investments achieving adequate returns” (Maxwell, 2016, p. 137;

Wennberg and DeTienne, 2014). Gregson et al. (2017) suggested that minimizing the risk of poor returns required larger portfolios than most individuals or groups could reasonably generate and that reinvestment rate is a critical element in measuring angel returns. Zhou and Kato (2017) explored the role of time and engagement on individual investment performance, in contrast with a ‘fail early’ or ‘early exit’ philosophy (Peters, 2009).

We significantly extend these studies by simulating time variability to explore the impact of investment timing, termination and re-investment on angel returns at the portfolio level. We use data from the Angel Investor Performance Project (AIPP), the largest and most reliable angel returns dataset (McDonald and DeGennaro, 2016) and implement a more sophisticated Monte Carlo simulation based on Gregson et al. (2017).² In so doing, we seek to better inform theory, practice, and policy regarding angel activity. Angels and angel groups may be relying on unrealistic premises for investment strategy. The perception of high returns has a catalysing effect on the early stage financing market, encouraging entrepreneurial recycling, legitimising angel activity, and stimulating others to become involved (Mason and Harrison, 2006).

Our study addresses two questions. First, what are the effects of investment timing (window) and termination (hold time) on returns for angels in groups? We anticipate that the timing of investment activity impacts real returns. Prior angel returns studies have assumed, conveniently but erroneously, that all investments occur simultaneously in Year 0 and are always held until failure or exit. We use an advanced simulation technique to generate hypothetical portfolios in which investments in a portfolio are made over the course of years, rather than simultaneously. We also use the technique to enable portfolios to be terminated prior to the exit of all investments, to explore the theory of “patient” investing. We propose that angel returns, measured using a modified internal rate of return (MIRR), will be directly affected by total portfolio hold time as an inverted “U” shape. Overly short hold times would reduce returns (the ‘fail early’ phenomenon), and long hold times reduce MIRR to the reinvestment rate (the ‘living dead’ phenomenon; Ruhnka et al., 1992; Mason and Harrison, 2002a). For the first time, we provide evidence on the implications of both investment timing and termination on angel returns.

Second, what is the effect of re-investment or follow-on funding on returns for angels in groups? Research on VC suggests that investment escalation is associated with sub-optimal decision-making, and by implication with lower returns (e.g. Birmingham et al., 2003; Devigne et al., 2016; Yamakawa and Cardon, 2017). There is, however, little equivalent evidence for angel investment (Huang and Pearce, 2015; Zhou and Kato, 2017), nor is there any evidence on the

2. There is scope to extend this research using other databases such as CrunchBase (e.g. Block et al., 2019) and PitchBook (e.g. Cumming and Zhang, 2019). While these have been increasingly used in venture capital studies, there remain concerns as to the fullness and representativeness of their coverage of angel investments (Oranburg, 2015).

relative importance of escalation effects (lower returns) versus syndicate-based learning effects (higher returns). Prior research has focused primarily on the decision event for individual investments (e.g. Sleesman et al., 2012; Staw, 1981). Our simulation approach facilitates a more detailed investigation of the risks and benefits of re-investment at the portfolio level.

Our results show that the longer the investment window during which the investments are being made, the lower the investment returns. This is the first empirical evidence that “patient” angel investing, often identified in the literature as a benefit of angel finance as compared with VC, is a poor financial decision for the investor. The results also suggest that re-investment is a signal for low returns from investments by angels in groups, implying negative rather than positive escalation effects.

2. Hypothesis Development

We briefly present the basic framework for portfolio-based investment returns in the context of angel investing to identify the real-world constraints that have generally been overlooked in prior studies.

2.1. Investment Timing and Termination

Investment timing is the expected time to reach the optimal investment trigger (Grenadier and Wang, 2005). Timing is especially fraught in angel investing, where opportunities may be time-sensitive and based on factors outside the investor’s control, such as patent filings, availability of key human resources, and changes in market conditions. Unlike institutional venture capitalists, however, angels are generally under no pressure either to make an investment within a set time period or to exit an investment (Gregson, 2014). The angel research literature has generally argued that angel capital is “patient capital” in terms of holding period. In theory, angels could maintain their investment in a project until it no longer earns the opportunity cost of the investment (DeGennaro and Dwyer, 2014). However, Harrison et al. (2016) conclude that only a minority of angels could be defined as being exit-centric investors. Despite the clear importance of timing in angel investing, prior studies have consistently measured returns as if all investments are made simultaneously and held until exit or failure. This is in contrast to the VC literature, where it has been demonstrated that both expected returns and probability of pre-exit termination decline with more rounds of financing (Guler, 2007). Our first hypothesis proposes that incorporating an investment window reduces portfolio returns, as prior studies with simultaneous investment yield returns significantly higher than standard opportunity cost of capital (reinvestment rate).

H1: Portfolio angel investments made over a period of time (real-world investment window) yield lower average/median returns compared to portfolios of investments made simultaneously at time zero.

We expect angel investing returns to be affected by total portfolio hold time as an inverted “U” shape. First, high information asymmetries, where sellers (entrepreneurs) have some amount of private information and buyers (investors) are relatively uninformed (Levin, 2001), would reduce returns for overly short hold times. Generally speaking, failures occur before successful exits (Mason and Harrison, 2002a).

Second, long hold times (which reflect a ‘continuation bias’ in the market; Khanin and Mahto, 2013) should reduce returns to the reinvestment rate. The holding period is longer for ‘living dead’ angel investments than for either successful exits or liquidations (Mason and Harrison, 2002a). Even if longer held investments are less likely to fail (Zhou and Kato, 2017), there is a negative relationship between performance and the time structure of equity provision (Bonini et al., 2019). Holding even successful investments long enough should revert to the reinvestment rate. We therefore propose:

H2: Average/median returns to angel investment initially increase and then decrease with portfolio termination (holding) time.

2.2. Re-investment

Follow-on funding (re-investment) by angel investors is complex and poorly understood (Kuratko et al., 1997). Entrepreneurial growth ventures often require multiple rounds of funding. Re-investment by the same VC funder, however, is typically associated with under-performing portfolio companies (e.g. Birmingham et al., 2003; Khanin and Mahto, 2013; Guler, 2007). It may also refer to “the proclivity for decision makers to maintain commitment to a losing course of action, even in the face of quite negative news” and manifests as a behavioural pattern of “throwing good money (or resources more generally) after bad” (Sleesman et al., 2012, p. 541). The potential for sequential investments can serve as a monitoring tool with the option to continue or abandon the project at each stage (Dixit et al., 1994) to potentially improve successful exit rates (Tian, 2011). Success, however, depends on investors’ terminating unsuccessful investments based on updated information.

Recent UK evidence suggests that up to 80% of angel investment has been into existing portfolio companies (Mason and Harrison, 2015; Mason et al., 2019). Such re-investment decisions may be explained by numerous theories. Self-justification and the perception of personal responsibility for negative performance may drive irrational hope (Staw, 1981). This could be offset in the

context of group decision-making, an effect seen by reduced escalation in venture capital when more funds are involved in a given investment (Birmingham et al., 2003). Strong prior investment experience may make investors more willing to terminate a poorly performing investment (Hayward and Shimizu, 2006). However, experienced investors may also be more comfortable persisting with projects in the face of changing market conditions and instability (DeTienne et al., 2008). Angels might re-invest based on expectancy theory (Vroom, 1964), especially when anticipated payoffs are large (Ryan, 1995). A less charitable interpretation is that angels are subject to anchoring effects (e.g. Staw, 1981), cognitive dissonance (Chang et al., 2016), self-efficacy bias (Harrison et al., 2015), and the desire to avoid appearing incompetent (e.g. Zhou and Kato, 2017). In theory, maintaining commitment may enable additional data collection, but angels may overlook negative information or fail to update their assessment of an investment based on new information (Nisbett et al., 1982). Negative signals may be difficult to observe or interpret due to the high level of information asymmetry between entrepreneurs and angels. The default decision may therefore be to support, rather than terminate, an otherwise poorly performing investment (Sleesman et al., 2018; Guler, 2007), especially if exit is difficult or costly (Amit et al., 1998). The implications of information asymmetries at the deal-by-deal level may be mitigated at the portfolio level through incentive alignment, involvement, learning effects (Botelho et al., 2021), and the overall effect of investment diversification (Bonini et al., 2018; Gregson et al., 2013). These reinforce the importance of a portfolio approach to the analysis of the returns to angel investment.

To our knowledge, there is no prior published simulation analysis of angel re-investment in a portfolio context. The AIPP dataset distinguishes between initial investments and follow-on investments; we use this to compare the results of simulated portfolios of investments with and without follow-on investment activity. Based on the limited prior research on venture capital and the preponderance of psychological effects in play for angels, we propose the following hypothesis:

H3: Angel investment portfolios with re-investment, defined as a venture receiving at least one follow-on investment from a prior investor, will be associated with lower returns than the overall population of angel investment portfolios.

We note that the AIPP dataset does not distinguish between a ‘drawdown’ investment commitment and a re-investment. A draw-down occurs when the venture demands funds already committed by the investor for certain milestones being reached. Re-investment is an opportunity for investors to invest again in response to the new venture raising additional funds. Draw-downs are relatively rare in angel investing; we follow prior studies in treating the AIPP investments

as discrete and independent. We note the importance of addressing this in future research.

3. Methodology

A Monte Carlo simulation is a well-established method to robustly test hypotheses via repeated sampling of an extant dataset (Kroese et al., 2014). Since individual angel investment returns are highly skewed, average returns analysis of a given dataset are unlikely to effectively represent the experience of actual individual angels or angel groups. The sampling-based methodology of Monte Carlo simulation creates potential portfolios to more effectively explore real-world outcomes.

We generally follow the Monte Carlo simulation method described in Gregson et al. (2017), but significantly extend the analysis using new parameters and heuristics to incorporate real-world factors missing from all prior analyses.

3.1. Data Set

The simulation examines the same Angel Investor Performance Project (AIPP) dataset used in prior analyses (Wiltbank and Boeker, 2007; McDonald and DeGennaro, 2016; Gregson et al., 2017; Zhou and Kato, 2017) and published publicly online via Right Side Capital Management. The AIPP dataset includes data collected via a self-reported online questionnaire on angel investing activity from 86 angel investing groups in the United States (U.S.). According to the published information (Wiltbank and Boeker, 2007), these groups represented a total of 539 individual investors who made 3097 investments, resulting in 1137 exits.

In our study, the AIPP dataset was cleaned using the same processes as Gregson et al. (2017), representing responses from 13% ($n = 70$) of investors who reported data on exits.³

In contrast with Gregson et al. (2017), our study used all 452 resulting investments without eliminating the investments held longer than 13 years. The

3. Consistent with Gregson et al. (2017), we entered zero for exit cash for those records with no data in the exit year ($n=7$). One record shows a \$10,000 investment and a \$2.4M return in the same year. This investment generates approximately 33% of the total financial return of the dataset, measured as IRR. We note this because its inclusion in the analysis for small portfolios (e.g. $N < 25$ investments) sometimes generates portfolios with effectively infinite IRR or MIRR, because the Year 0 return on this investment is larger than the sum of all other investments in the randomly generated portfolio. The simulation has no mechanism to incorporate an infinite return rate in average calculations; a flaw that was not identified in Gregson et al. (2017).

novel method we apply for portfolio termination resolves any possible outlier impact of these investments.⁴

3.2. Monte Carlo Simulation

Monte Carlo simulation samples from an extant dataset to generate novel datasets (Rubinstein and Kroese, 2016). We follow Gregson et al. (2017) in the general method for sampling the dataset to create investment portfolios.⁵ Once the portfolio is generated, average and median IRR and MIRR are calculated and recorded for that portfolio. The portfolio is then cleared and the process repeated to generate a returns “profile” for that portfolio size.⁶ For MIRR calculations, we used a 5% capital cost. Gregson et al. (2017) demonstrated that MIRR results converged to the reinvestment rate because of the long hold time of most portfolios. We utilized a reinvestment rate of 15%. For the re-investment analyses, we vary portfolio size from 5 to 450 investments, which replicates simulation parameters of Gregson et al. (2017) for a clear comparison of results.

For the timing and portfolio termination analyses, however, we made three changes to the simulation parameters. First, we distinguish between portfolios of less or more than 25 investments. For portfolios of 5 to 24 investments, we generated 10,000 portfolios and investigated every portfolio size (portfolio sizes of 5, 6, 7... 24) to reduce the likelihood that high variability in returns would skew results for smaller portfolios. Second, for portfolios equal to or greater than 25 investments, we ran 1,000 simulations and used a step of 25 investments (e.g. N=25, N=50, N=75, etc.) to simplify reporting. Third, we limited maximum portfolio size to 250 investments. We chose this limit because few if any of the largest angel networks in the U.S. have made this many investments. The results in Gregson et al. (2017) strongly suggested that results converged rapidly above 100 investments and no significant changes in results were demonstrated above 250 investments.

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4. In addition, we note that although individual investments in the dataset may have experienced different termination events (acquisition, dissolution, write-off), our analysis only considers the financial return at the termination point identified by the investor.
 5. Following Gregson et al. (2017), we assume that each investment in the AIPP dataset is equally likely (uniform distribution). For a given portfolio size (e.g. 50 investments), the simulation uses Excel’s (pseudo) random number generator (McCullough and Heiser, 2008) to select investments from the dataset of 452 investments. In selecting an investment, Excel randomly generates a number between 1 and 452; that investment is copied from the dataset to the portfolio under construction. This is repeated as many times as needed given the portfolio size (e.g. 50 investments).
 6. For example, if the simulation is creating portfolios of 50 investments, and we have specified 1000 portfolios, then Excel samples the dataset 50,000 times to generate the “profile” of 1000 portfolios each with 50 investments. Consistent with Gregson et al. (2017) and general practice, our simulation samples with replacement. For comparative purposes, we recorded portfolio IRR and MIRR in the same categories as Gregson et al. (2017) utilized (<0%, 0-10%, 10-20%, 20-35%, 35-50%, 50-75%, 75-100%, 100-250%, 250-500%, >500%).

3.3. Timing

Our first significant extension from Gregson et al. (2017) involves generating an “investment window” for each portfolio as well as re-running the entire simulation for varying termination scenarios. The reality is that angels and angel networks do not make dozens, much less hundreds of investments in a single year. For example, the Central Texas Angel Network has made less than 200 investments in roughly 16 years. We therefore incorporated an “investment window” into the simulation that varies from zero to ten years. Consider a simulation run with an “investment window” of five years. As each portfolio is generated, each investment in the portfolio is assigned a random start year ranging from zero to four. The prior Gregson et al. (2017) analysis, and all prior studies of angel investing datasets, assume an investment window of zero years: dozens or hundreds of investments made simultaneously.

The simulation was run for investment windows of 1, 2, 4, 6, 8, and 10 years for small portfolios (5-24 investments). Consider a portfolio size of 10 investments. It should be self-evident that the “one-year window” replicates the prior Gregson et al. (2017) analysis. For the two-year window analysis, each investment is randomly assigned to start either in Year 0 or Year 1. That simulation is then re-run 10,000 times to generate the average “profile” for the given portfolio size (10 investments) for the 2 year investment window. Then the simulation was re-run with an investment window of 4 years. Each of the investments are randomly assigned to start in Year 0, 1, 2, or 3, 10,000 of those portfolios are generated, and the profile recorded. Then the simulation is re-run in its entirety for windows of 6, 8, and 10 years. This entire process was replicated for all portfolio sizes from 5-24 investments.

For larger portfolios (25-250 investments), the simulation was run with investment windows of 0, 5, and 10 years. This was done because the computational time of running the simulation increases dramatically with large portfolios and the results of the Gregson et al. (2017) analysis suggested that variation across investment windows would be less dramatic for large portfolios.

3.4. Termination

Our second major extension of prior analyses is to simulate a hypothetical limit on portfolio hold time (termination). It is helpful to clarify the distinction between the termination of any individual investment in the dataset from a disciplined approach to portfolio management that incorporates termination. In the dataset, the “termination” event for any given investment is the point at which the investor’s ownership stake ends, presumably due to venture acquisition or dissolution, or because the investor abandons the stake as a write-off. For our analysis, we explored the possibility that a disciplined investor would close out a

portfolio after a given period of time. This is roughly analogous to a venture capital firm's expectation that a given fund has a time horizon for generating returns.

To simulate hold time, the entire process just described was repeated, but with a defined portfolio termination year. For example, when the hold time was set to 15 years, then each investment outcome was truncated at 15 years from the start of the portfolio. This represents the investors simply writing off any investments that had not yet exited. It is important to note the interaction of the "timing" and "termination" effects. If, for example, the investment window is 10 years, and the hold time is limited to 5 years, it is possible that an investment is started in year 10 and terminated in year 15, giving it only 5 years to exit. This is the "discipline" that venture capital funds observe as fiduciaries of their investment capital, in contrast with a theory of "patient" capital for angel investors. Methodologically, this is simpler to implement than the investment window analysis, as the IRR/MIRR calculations simply ignore any returns beyond the specified time limit.

The Gregson et al. (2017) simulation generated 90,000 portfolios incorporating 20,475,000 randomly selected investments from the dataset. Our treatment is more than an order of magnitude larger. Each "run" of the simulation across all portfolio sizes represents 220,000 portfolios (because of the larger number of runs for smaller portfolios) and 4,525,000 randomly selected investments (smaller than the Gregson analysis because we stopped at portfolio size of 250 investments). We then re-ran that entire simulation for the 6 different investment windows (0-10 years step 2) for the smaller portfolios and 3 different investment windows (0, 5, 10 years) for the larger portfolios. That total treatment was then replicated for each of the 9 different hold times (10-26 years step 2). This results in a total of 23,220,000 portfolios with 414,450,000 randomly selected investments from the dataset.

3.5. Re-Investment

For the re-investment simulation, we split the dataset into two subsets: one with investments that had re-investment or follow-on funding, the other with investments that did not. The dataset includes 339 exited investments without follow-on investments and 113 exited investments with follow-on. We ran the original Gregson et al. (2017) simulation on each of the datasets, generating 180,000 more portfolios based on 40,950,000 randomly selected investments.

The total analysis therefore encompasses 23,940,000 portfolios and 529,650,000 randomly selected investments. The extensive output data generated by the scope of the analysis creates severe limitations on data reporting. For this paper, we show selected visualizations that identify key findings to address our hypotheses.

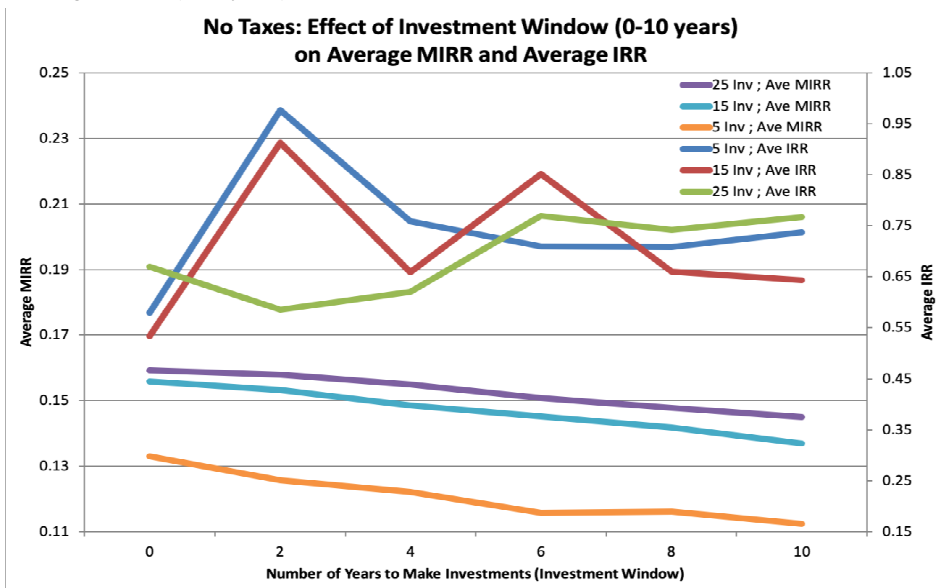
4. Results

4.1. Timing

Returns analyses of portfolios, including Gregson et al. (2017), have treated portfolios as if all investments were initiated simultaneously at time = 0. This is a gross oversimplification of the angel investment process and distorts the actual returns profile (McDonald and DeGennaro, 2016). The impact of adding an investment window to the simulation is, perhaps, the most important improvement of this analysis over all prior angel returns analyses. Although the implementation of investment timing into the simulation is relatively straightforward, reporting the results is quite challenging, simply because of the large amount of output. We begin with the analysis of small portfolios (5-25 investments).

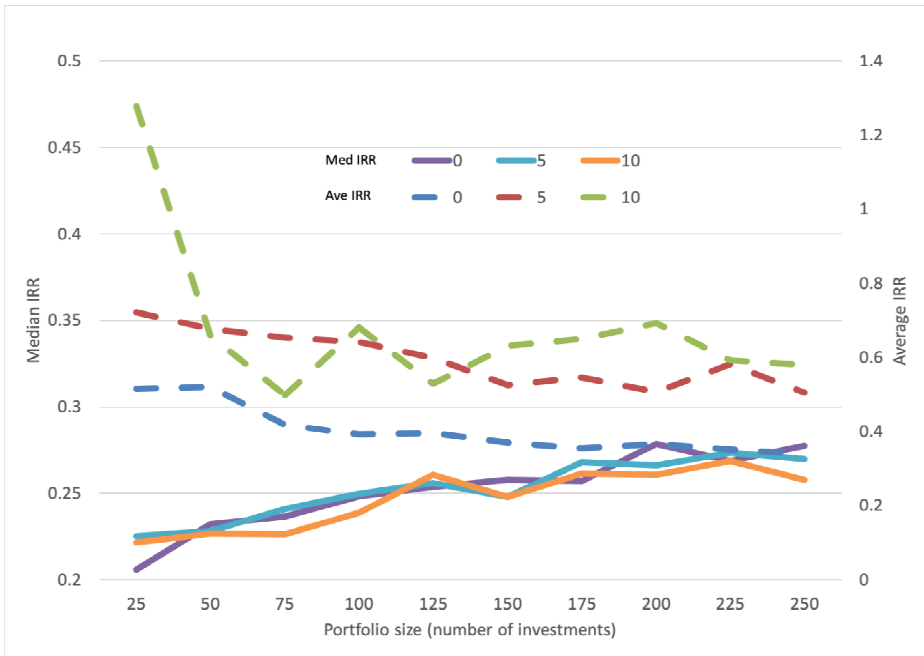
It is important to appreciate the immediate impact of the investment window on IRR. Figure 1 shows average IRR and average MIRR for varying portfolio sizes (5, 15 and 25 investments) and the investing window (0-10 years). Despite simulating 10,000 portfolios, the resulting average IRR figures appear nearly random. By contrast, average MIRR shows the real impact of the investing window. At every portfolio size, average MIRR falls as the investment window increases. For the smallest portfolios, MIRR falls from 13% to nearly 11%. For portfolios of 25 investments, the decline is also evident, from 16% to 14%.

Figure 1: Average MIRR and IRR for varying portfolio sizes (5, 15 and 25 investments) and the investing window (0-10 years)



The longer the investment window during which investments are made, the lower the returns. Extending the analysis to large portfolios confirms the prior results from Gregson et al. (2017) in the new context of real-world investing. The results in Figure 2 for larger portfolios show that average IRR rises slightly with increased investment window, while median IRR is either unchanged or falls slightly with increased investment window. Investing over time, reflecting real-world behaviour, generates lower returns than the imaginary simultaneous portfolio investment, especially for smaller portfolios (which are generally more realistic). Ironically, caution, prudence and hesitancy do not appear to be rewarded in portfolio-based angel investing. Hypothesis 1 – *portfolio angel investments made over a period of time (investment window) rather than simultaneously at time zero yield lower average median returns* – is generally supported.

Figure 2: Average IRR and Median IRR for large portfolios (25-250 investments) and investing window (0, 5, 10 years)



4.2. Termination

We now turn to investment termination (hold time). Although the literature has tried to address the issue of “patient” angel investing (Harrison et al., 2016), no quantitative analyses have been conducted to investigate the impact on angel investing returns. We incorporated a portfolio “termination” time to explore

whether disciplined investing presents benefits over “patient” investing. Figure 3 shows the average IRR for portfolio sizes ranging from 25 to 250 investments and holding periods from 10 to 26 years for a 10 year investing window. The results show that there is little or no benefit to average IRR for long portfolio hold times.

Figure 3: Average IRR: Number of Investments and Holding Time

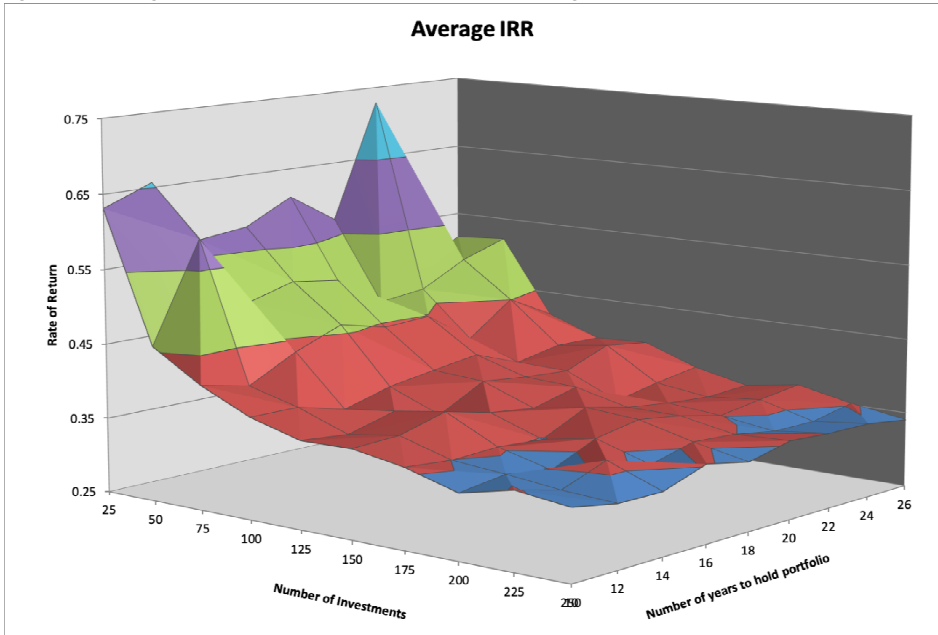
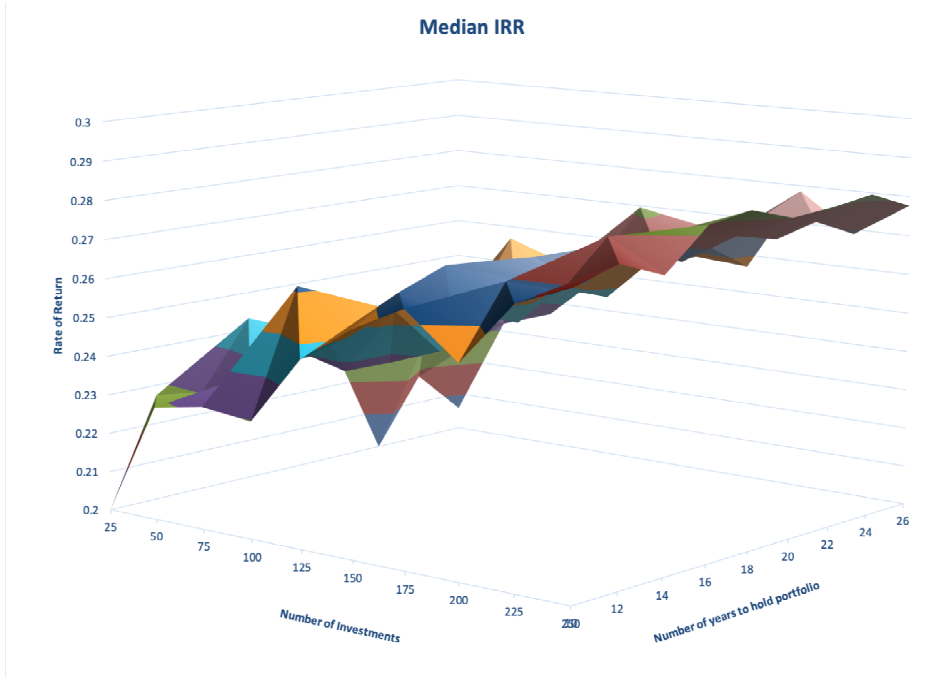


Figure 4 shows the results for median IRR, again for the 10 year investing window. We confirm the prior general results from Gregson et al. (2017) as portfolio size increases, but there is no clear evidence that returns improve with hold time at any portfolio size.

Figure 4: Median IRR: Number of Investments and Holding Time with 10 year investing window



Figures 5 and 6 show the Median MIRR results for larger portfolios across hold times for a 1 year investment window (Figure 5) and a 10 year investment window (Figure 6). It should be obvious, especially in the 10 year investment window, that longer hold time improves returns. In the case of the 10 year investment window, having too early a termination time appears to miss out on some successful exits. In the 1 year investment window, very long portfolio hold times (> 20 years) may show some decline in returns. But this is definitely not the case for the 10 year investment window, which is a more accurate reflection of real-world angel investing. Therefore, Hypothesis 2 - *Returns to angel investment initially increase and then decrease with portfolio termination (holding) time.* - is not supported.

Figure 5: Median MIRR: Number of Investments and Holding Time with 1 year investing window

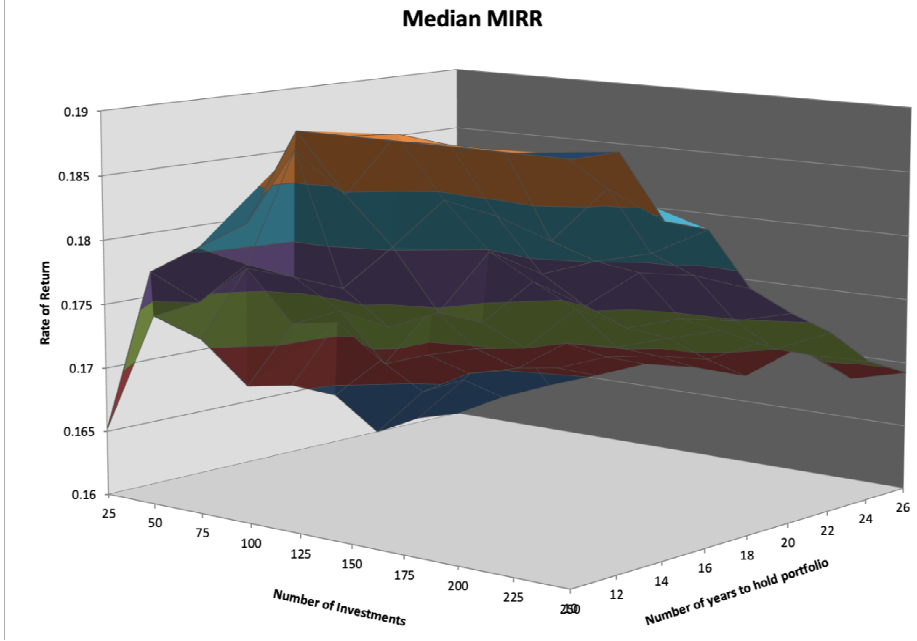
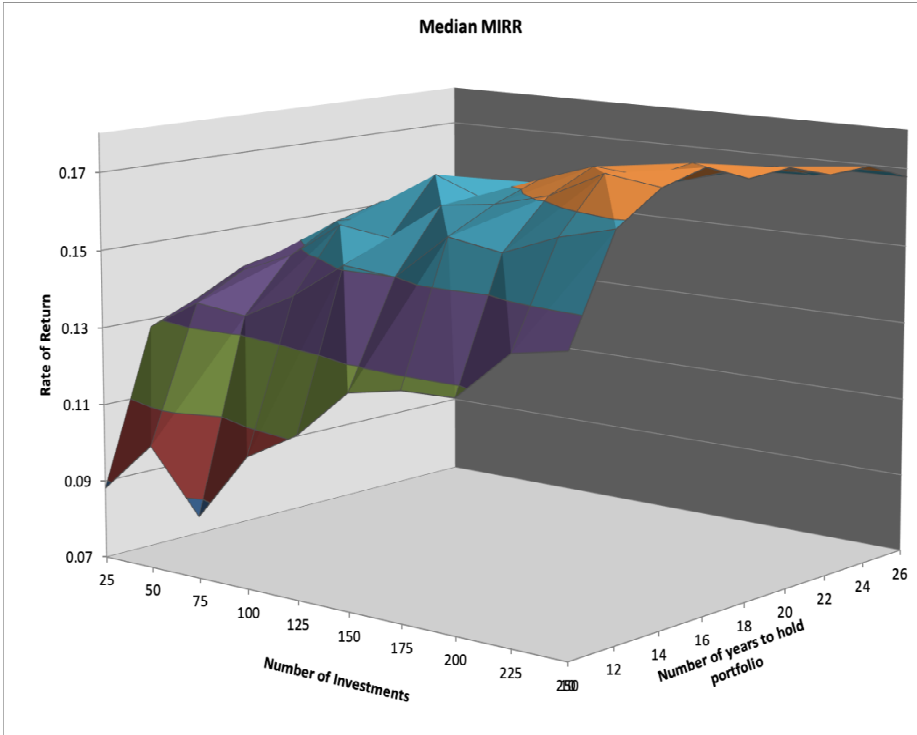


Figure 6: Median MIRR: Number of Investments and Holding Time with 10 year investing window



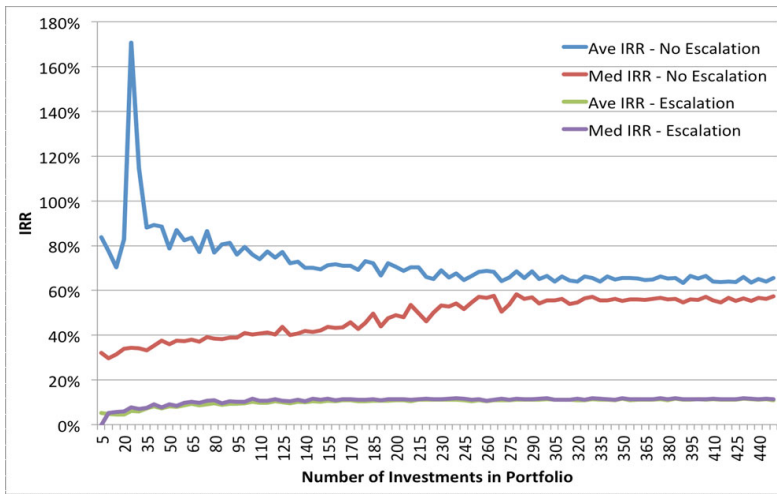
The upshot of the analysis appears to be that angel investors cannot easily improve portfolio outcomes with either discipline (terminating investments) or patience (holding indefinitely). This is somewhat consistent with anecdotal and limited quantitative research suggesting that the most successful angel investments are obtained during a relatively limited window. The quantitative result has never been formally generated, and ironically may be at least partially contingent on the real-world constraint of making investments over an investment window rather than all at once. If angels *could* make dozens or hundreds of investments simultaneously, it is possible that “patient” investing would be suboptimal.

One additional result is worth noting. To our knowledge, no prior studies of angel investing returns have considered the direct impact of capital gains tax on terminating investments prior to exit. In theory, a disciplined angel investor (or group) could benefit by writing off low-performing investments and claiming a tax credit rather than waiting for a poor or mediocre exit. This would seem especially likely in situations with large portfolios, where “winners” are rare and tend to happen quickly. In addition to the treatments described, we re-ran the entire simulation incorporating a tax credit (estimated as 25% of the write-off value). The results were inconclusive and therefore not reported here in detail. For small portfolios, the inherent randomness of returns far exceeded any apparent tax benefit from portfolio termination. When hold time exceeded 20 years, some large portfolio simulation results showed very small decreases in MIRR as hold time increased. While this is suggestive of the potential benefit of disciplined investing in the context of tax policy, the results were not clear enough for prescriptive theory (see Harrison et al., 2020, for further discussion on tax effects on angel returns using the AIPP dataset). In practice, the long hold times (>20 years) made practical application seem somewhat irrelevant.

4.3. Re-investment

The difference in returns between exits with follow-on investment and those without is dramatic. Figure 7 shows the full range of median and average IRRs for all portfolio sizes with follow-on and no follow-on. For investments with follow-on, there are some benefits in IRR terms of increasing portfolio size up to around 70 investments; however, beyond that, increasing portfolio size does not lead to any perceptible increase in average or median IRRs. By contrast, for exits without follow-on, median IRR rises fairly consistently with portfolio size, such that at portfolios with 250 investments, the gap between portfolios with follow-on and those without is some 46 percentage points based on median IRR (12% for follow-on and 58% for non- follow-on). The spike in average IRR for the “no follow-on” dataset is one example of the high variability of results for small portfolios, consistent with Gregson et al. (2017).

Figure 7: Average and Median IRR for portfolios with and without follow-on

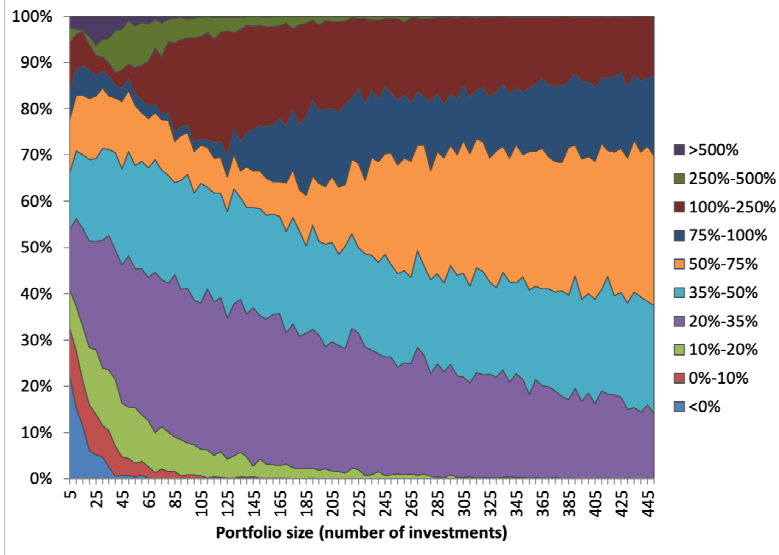


Figures 8 and 9 show the median IRR profile (by range category) of portfolios with follow-on and without follow-on, respectively. These provide the full returns profile by portfolio size, providing additional detail of the apparent lack of success associated with follow-on investing. Consider the case of portfolios of approximately 100 investments. For the investments without follow-on, about 10% of simulated portfolios generated median IRR below 20%, while more than 20% of simulated portfolios generate median IRR above 100%. By contrast, for the investments with follow-on, roughly 20% of simulated portfolios generated *negative* median IRR, and there are effectively no portfolios with median IRR above 50%. Although the simulation approach does not allow us to unequivocally attribute causality and directionality in the relationship, in the dynamics of the investment process, escalation is manifest in poor investment outcomes. This result is consistent with an interpretation of follow-on investment as a consequence of poor initial investment decision-making, rather than a strategic reinvestment decision to support and realise venture growth (Drummond, 2014).

Figure 8: Median IRR profile for portfolios with follow-on



Figure 9: Median IRR profile for portfolios without follow-on



Therefore, Hypothesis 3 – *Re-investment, defined as a venture receiving at least one follow-on investment from a prior investor, will be associated with lower returns* – is supported. To take one example, which reflects the overall pattern in our results, we found that median IRR for portfolios with 50 investments with follow-on is 9%, while median IRR for portfolios with 50 investments without follow-on is 36%. In other words, the results suggest something significant differentiates between deals where angels re-invest and deals where they do not. Clearly, further research is needed to determine whether

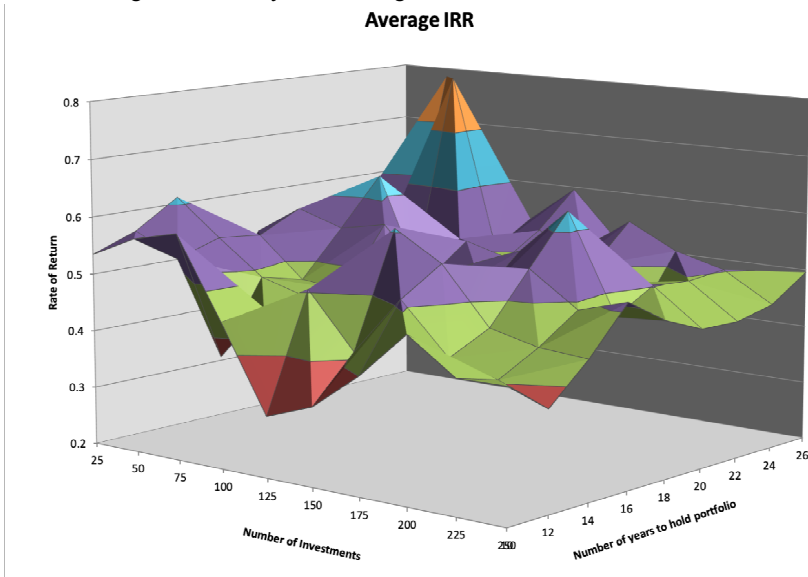
this is a result of psychological effects, poor investment discipline, or something entirely different.

5. Discussion

This study demonstrates that real-world constraints drive the risks and benefits of angel investing activity. First and foremost, it is inaccurate to report angel investing returns as if angels or angel groups can make dozens or hundreds of investments within a single year. Real-world returns to angel investing are likely lower than reported in prior studies that rely on this assumption. The story is slightly different with regard to disciplined versus patient investing. Our simulation results show that while angels do not directly benefit from indefinite hold times, they are also not significantly harmed by holding their investments, especially when investments are not all made simultaneously.

In terms of predictability of large portfolio results, the results and visualizations (both from Gregson et al., 2017 and our study) of average MIRR (or median IRR or median MIRR) appear to suggest that increasing the number of investments reduces variability of likely portfolio returns. This may not be the case with long investing windows. For example, as shown in Figure 10 for a 10 year investing window, randomness in average IRR results is quite pronounced, despite running 1000 portfolios for each portfolio size. Some of the “ruggedness” is due to the granularity of the simulation (portfolio size steps of 25), but the peaks and troughs clearly demonstrate that the variation of investment start times can create significant swings in portfolio returns.

Figure 10: Average IRR for 10-year investing window



Our finding that re-investment is signalled by lower portfolio returns and the lack of support for our portfolio termination hypothesis is consistent with other evidence on angel exits (Johnson and Sohl, 2012; Mason et al., 2016b). It appears that angel returns will be maximised by grooming ventures for a quick trade sale rather than seeking to build revenues (Peters, 2009; Mason et al., 2016b). The “patient capital” practice appears to be one of default behaviour in the absence of exit opportunities, rather than intent (Harrison et al., 2016). Angels may generally secure better returns by supporting their portfolio companies to get to breakeven and early exit rather than patiently hoping for long-term returns. While our findings show that for long investment windows angels are not significantly harmed by holding their investments, the lack of pressure to exit may have other effects, such as reducing angel capacity to take on new investments and limiting levels of available early-stage risk capital and the recycling of talent and investment in the community (Gregson et al., 2013).

5.1. Limitations and Opportunities for Future Research

Despite its size and overall quality, the AIPP dataset has limitations. First, some investors may be reluctant to acknowledge or report on unsuccessful exits (Harrison et al., 2016; McDonald and DeGennaro, 2016); therefore, selection bias may be present in the results (DeGennaro and Dwyer, 2014; Wiltbank and Boeker, 2007). Second, it is difficult to assess how representative these findings are for the general population of angel groups. For example, some angel groups may be more or less professionally organized and managed (Kerr et al., 2011), which may influence returns. Third, the AIPP dataset is temporally and geographically specific to the U.S. (and regions where angel groups are active), and the exit process may vary across space and time. Further research is suggested to examine returns from a broader distribution of angel groups and groups from other countries, which would benefit greatly from access to more recent, comprehensive and complete angel investment datasets. Fourth, our assessment and discussion of escalation is predicated on the requirement for angels to invest again, but the AIPP dataset does not allow us to clearly distinguish between good escalation and bad escalation. Reinvestment may also imply a longer holding time than those without reinvestment. Finally, the AIPP dataset only captures data on the value of the initial investment made and the capital returned at exit. It does not identify any intermediate returns cash flows (in the form of dividend payments, directors’ fees and so on) which could affect the calculation of actual investor returns (Mason and Harrison, 2002a).

A process model for angel reinvestment decisions remains a fruitful area for further research. One attractive direction is extending research on the role of emotion in decision-making. Prior studies have focused on the initial investment decision (Cardon et al., 2017; Mitteness et al., 2012; Murnieks et al., 2016). The reinvestment decision presents a comparable decision-point with the added issue

of sunk costs to impact emotional attachment and judgement (e.g. Sleesman et al., 2012; Wong et al., 2006). This would represent a major step forward in developing our understanding of the dynamics of the investment escalation process and its implications for angel returns. Our results also suggest extending this research to examine collaborative decision-making, and the group context in which angels make decisions (Sleesman et al., 2018). Group decision-making, as represented by angel groups, can offer a number of benefits, including error reduction, knowledge aggregation, expansive knowledge and fuller understanding of a given situation (e.g. Kerr and Tindale, 2004; Sunstein and Hastie, 2015). Given that it is typical for investors to revise their expectations over time (Bacon-Gerasymenko et al., 2016), further study is suggested to examine how and when angels review their exit horizon expectations.

Our results suggest that angels appear to be unaware of, or ignore the downside risks in continuing to invest; the termination decision may be neither obvious nor easy. Angels generally lack effective contracting and control mechanisms (Ibrahim, 2008) and experience high emotional attachment to their investments (Harrison and Mason, 2017; Cataldi and Downen, 2020). Unlike VCs, angels can act with long investment horizons in the absence of fiduciary pressures to exit. At the same time, angels may be subject to high normative pressures from within their angel group (Ibrahim, 2008) and the local ecosystem (Harrison and Mason, 2008). To return to *The Gambler*, even if angel investors “know when to hold ’em [and] know when to fold ’em,” they are not always in a position to act on this knowledge.

6. Conclusion

This study presents the first empirical examination of the effects of timing, termination and re-investment on angel returns. We make three contributions to the angel investment returns literature. First, we show that investment window makes a difference. Prior studies have likely overstated angel returns by assuming all investments are made simultaneously. Second, we show that patient angel investing may not be significantly suboptimal, but possibly only because angels generally make investments during an extended window. Third, we extend existing literature by hypothesizing and demonstrating empirically that re-investment appears to be a signal for low returns investments by angels in groups; suggesting negative rather than positive escalation effects.

Our findings have important implications for practice. For angel investors, the results are clearly a cautionary tale about re-investment, which appears to be a signal for low return investments. Angels should treat each investment *de novo* and strive to avoid the sunk cost fallacy. Further, angels may secure better returns by supporting their portfolio companies to get to breakeven and exit quickly rather than patiently seeking long-term growth. Angel investing may be an inherently inefficient investment class, where success is idiosyncratically driven

by unique expertise, connections, or blind luck. Achieving above-average risk-adjusted returns from angel investments likely stems from not having to hold very many for very long, and possibly folding them if you do.

Our findings also offer a cautionary message for policy. On the one hand, angels are an important source of local funding and non-financial support for entrepreneurs and have become ‘cradle to grave’ investors with the withdrawal of VC from the early-stage risk capital market. On the other, the poor overall prospect for returns, as suggested in this study and others, highlights the need for rethinking the role of policy in the angel investment market.

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