# No News is News: Do Markets Underreact to Nothing?*

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**Abstract**

As illustrated in the tale of "the dog that did not bark," the absence of news and the pure passage of time often contain information. We test whether markets fully incorporate the information content of "no news" using the empirical context of mergers. Following the initial merger announcement, uncertainty relating to merger completion can take many months to be resolved. In the interim, the pure passage of time is informative about the probability of merger completion. For example, once six months have passed after announcement, the probability that the merger will ever complete falls rapidly. We show empirically that the variation in hazard rates of completion during the 12 months after announcement strongly predicts returns. This contradicts a model of rational markets, and supports a limited attention model in which markets underreact to no news. We also show that our findings cannot be explained by event time variation in systematic risk, downside risk, or idiosyncratic risk. Specifically, we use an underreaction model to construct a trading strategy that invests in deals during event windows when completion hazard rates are high. Controlling for risk, our strategy outperforms a strategy that invests in deals when completion hazard rates are low by 100 basis points per month.

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# 1 Introduction

*"The dog did nothing in the night-time ... that was the curious incident."*
- Sir Arthur Conan Doyle

The absence of news reports and the pure passage of time often contain important information. For example, a citizen who lives through a sustained period without terrorist attacks should update positively on the effectiveness of the government's anti-terrorism programs. A manager who observes that an employee has executed a difficult task without incident should update positively on the employee's quality.

"No news" is also news in many financial contexts. For example, if a firm does not lay off workers or declare bankruptcy after a macroeconomic shock, investors should update positively on the firm's underlying strength. On the other hand, if an otherwise healthy firm repeatedly fails to announce new investment projects, rational investors may be justified in updating negatively on the firm's growth prospects. Finally, investment return patterns that seldom display news-worthy variation can reveal information about the underlying investment decisions. For example, overly-consistent returns may be suggestive of fraud, as in the case of Bernie Madoff's investment fund.

Rational agents should perform Bayesian updating on the passage of time. In efficient financial markets with rational investors, the passage of time can lead to price movements even in the absence of explicit news. Alternatively, agents may be boundedly rational and imperfectly update on no news. In particular, agents may suffer from limited attention and underreact to the absence of news, which, by definition, is less salient and vivid than the events covered by news stories (Tversky and Kahneman, 1973, Slovic, Fischhoff and Lichtenstein, 1979). Understanding how agents process the absence of news is important because the passage of time often contains information that can reduce asymmetric information problems between voters and politicians, employers and employees, and investors and managers. Underreaction to no news can lead to misallocation of resources. This may be particularly distortionary because no news tends to be slow-moving and persistent.

In this paper we explore how markets react to no news, i.e., the pure passage of time. The main empirical challenge lies in the construction of a counterfactual: how *should* agents behave if they were to update rationally on the passage of time? We focus our attention on a financial context that allows for the construction of such a counterfactual: mergers.

Mergers offer a convenient empirical setting for several reasons. First, each merger has a clear starting point: the announcement of the intention to merge. Second, the returns of merger investment strategies depend heavily on a well-defined and stochastic ending point: the merger either completes, or the parties withdraw for reasons such as loss of financing, antitrust rulings, or target shareholder resistance. To best capture this uncertainty, we focus on mergers without known expiration dates, so that both the timing and outcome of merger resolution are stochastic. Between merger announcement and resolution, there exists an interim period, usually lasting several months to a year, during which little or scattered news is released about the probability of completion. We show empirically that the pure passage of time during this interim period contains information about whether the deal will ultimately complete. We then compute how prices should move during this interim period in the cases of full rationality and underreaction to the passage of time.

Using a sample of over 5000 mergers, we estimate the hazard rate of merger completion, defined as the probability that a merger will complete in event week $n$ conditional on it not completing nor withdrawing prior to week $n$. If the hazard rate of completion is non-constant over the event life of a merger, then the passage of time contains information about merger completion. We find that hazard rates of completion do indeed vary strongly over event time and are hump shaped. Hazard rates rise from zero in the first weeks after announcement, peak around event week 20, and then decline to zero one year after announcement. In contrast, hazard rates of withdrawal are essentially flat. These patterns hold throughout the calendar time period of our sample, 1970 to 2010. They also hold after accounting for potential heterogeneity, such as the form of merger financing (cash- or equity-financed) or the size of the deal.[1]

What happens to prices during this interim period? We empirically document a strong positive correlation between hazard rates and returns in the year following merger announce-

[1] We focus on event time variation in hazard rates to provide *one* motivating reason why the passage of time should contain information. There may be other reasons why the passage of time contains information (e.g., the arrival rate of competing bids may vary over the event life of mergers). See Section 5.3 for a discussion of why these other potential explanations do not conflict with with our underreaction hypothesis.

ment.[2] In other words, returns are predictable and they move with the hump-shaped hazard rates. For example, a strategy that invests in equity-financed mergers experiences a mean return of around 15 basis points per week in the first few weeks after merger announcement. Returns peak at nearly 50 basis points per week around event week 20 and then decline as more time passes after announcement.

What explains the strong predictability of returns by hazard rates? In the remainder of the paper, we explore two possible explanations: underreaction to the passage of time (the behavioral explanation) and changes in risk over the event life of mergers (the rational explanation).

First, we examine the behavioral explanation. To develop the main intuition, we construct a simple model of underreaction to the passage of time. The model links movements in the target's price to market beliefs about event-time variation in hazard rates. According to the model, if agents correctly update and systematic risk does not change over the event life of mergers, then mean weekly returns should be constant over the event life of a merger. Returns should not vary systematically with the passage of time and they should not be predicted by changes in the hazard rate.

However, if agents underreact to the information contained in the passage of time, they will behave as though they believe that the underlying hazard rate of completion does not change as much as the true hazard rate. This implies that agents will tend to *under*estimate the completion hazard rate when hazard rates are high and *over*estimate it when hazard rates have fallen.

Underreaction to the passage of time further implies that mean returns should be high when hazard rates are high (since markets underestimate merger completion probabilities and receive positive surprises on average) and low when hazard rates are low (since markets overestimate merger completion probabilities and are disappointed on average). In other words, hazard rates and mean returns should be positively correlated. This matches what we observe in the data: mean returns are significantly non-constant over the event life of a merger and the pattern in returns is aligned with movements in aggregate hazard rates.

[2] For cash-financed mergers, the relevant return is the return from holding the target. For equity-financed mergers, the relevant return is that from a strategy in which one takes a long position in the target and a short position in the acquirer.

Importantly, these predictions hold even if investors observe explicit news prior to formal merger resolution, such as mandated corporate disclosure of shareholder voting or insider information leaks about merger completion probability. If investors are rational and update on intermediate bits of news as well as the passage of time, that should make the passage of time even less predictive of returns.

Using our simple model, we estimate the beliefs about completion hazard rates that generate the observed average returns in each event week. The implied beliefs track empirically measured hazard rates but display less variation over time (12 percent and 46 percent less variation in the cases of cash- and equity-financed mergers, respectively). This is consistent with an underreaction hypothesis in which agents only partially incorporate the information content of the passage of time when setting prices.

While our results are consistent with the behavioral model of underreaction to no news, the positive relationship between returns and hazard rates could also reflect compensation for risk (the rational explanation). We begin by noting that the positive correlation between predicted hazard rates and returns is a phenomenon measured over the event life of the merger, and therefore cannot be explained by changes in risk or risk premia over calendar time.[3] Next, we explicitly test whether our results can be explained by event-time variation in risk. We consider three types of risk: (1) systematic risk as captured by the Fama-French factors, (2) downside risk, in which returns covary more with the market during market downturns, and (3) idiosyncratic risk. To measure risk, we examine the returns of trading strategies that only invest in deals during certain event windows. Using a modification of the common merger arbitrage strategy described in Mitchell and Pulvino (2001), for each calendar month between 1970 and 2010 we invest in all mergers active between certain event windows. By only investing in available deals, we limit our analysis to strategies that would have been feasible for investors at each point in calendar time. We test whether a trading strategy that invests in deals when hazard rates are high (estimated from the aggregate sample of mergers in a preceding period) delivers a higher alpha than a strategy that invests in deals in event weeks when the hazard rates are low, as well as a Buy and Hold strategy

[3] Because mergers occur in waves, we may be concerned that event time is correlated with calendar time, and therefore, changes in risk or risk premia over calendar time may matter. However, in a regression of returns on hazard rates, the results remain similar after we control for calendar time (year x month) fixed effects, which removes all calendar time variation in risk and risk premia.

that invests in deals for their entire event life.

Our High Hazard trading strategy delivers a significant monthly alpha (relative to the three Fama-French factors) of around 63 basis points for cash deals and 147 basis points for equity deals. This is significantly higher than the -3 basis points and 16 basis points respectively of strategies that buy deals in the Low Hazard weeks, and is also significantly higher than the 39 basis points and 109 basis points respectively of the traditional Buy and Hold strategy commonly used in merger arbitrage. These alphas are informative for two reasons. First, they show that there exists significant predictable variation in returns that cannot be explained by variation in systematic risk as captured by the Fama-French factors. Second, the alphas represent the economic magnitude of potential mispricing: variation in hazard rates predicts a substantial difference in alpha of 66 basis points (cash mergers) and 131 basis points (equity mergers) per month between the High and Low Hazard strategies.

In general, our strategies have very low exposure to the three Fama-French factors, with all betas under 0.3. We also show that High Hazard event weeks do not have, on average, higher betas then Low Hazard weeks. In addition, our results are substantively unchanged if we account for an additional factor capturing momentum. Finally, we compute event-week-specific betas, and show that they do not change significantly in event time. Over the course of the calendar period during which we execute our trading strategy, we observe many mergers in each stage of deal life. We estimate the risk properties for strategies that only invest in deals during each event week separately. We show that the exposures to the three Fama-French factors do not change observably in event time, and if anything are weakly negatively correlated with hazard rates.

Next, we test whether the positive relationship between hazard rates and returns can be explained by exposure to downside risk which varies in event time. In general, as with all merger arbitrage strategies (see Mitchell and Pulvino, 2001), our strategies are slightly more risky during down markets than in regular markets (the market beta of our High Hazard strategy increases from 0.3 to around 0.4 when the market monthly return is less than -3%). However, we show empirically that downside beta does not vary significantly over event time and is not correlated with hazard rates. The betas with respect to factors that capture option-like payoffs as described in Agarwal and Naik (2004) are very low and do not covary with hazard rates in event time. Moreover, our High Hazard strategy returns actually decline by less than market returns on average during major downturns. Therefore, while downside risk is a potential contributor to the positive returns in the traditional Buy and Hold merger arbitrage strategy, it cannot explain why returns covary with hazard rates over the event life of a merger.

Finally, we test whether the positive relationship between hazard rates and returns can be explained by higher return volatility during event windows when hazard rates are high. In cases when merger completion comes as a surprise, prices should jump. Therefore, we may expect higher return volatility when hazard rates of completion are high. Diversified investors should be indifferent to changes in idiosyncratic risk. However, merger arbitrageurs may be constrained to hold portfolios that consist only of mergers, and therefore may demand compensation even for idiosyncratic risk. We find that the standard deviation of our High Hazard strategy is indeed slightly higher than the standard deviation of returns for our Low Hazard strategies. However, the difference in volatility is too small to explain the variation in returns. Moreover, the volatility of our High Hazard strategy is modest and *less* than the volatility of the market portfolio, because our portfolio is usually diversified across at least 20 active deals.

We conclude that changes in risk and risk premia in event time are unlikely to drive the relationship between hazard rates and returns. Rather, the empirical evidence supports the hypothesis that markets fail to incorporate all information contained in the passage of time while waiting for merger resolution. We also find evidence consistent with the presence of sophisticated investors who correctly update on the passage of time: the relation between hazard rates and returns is twice as strong for the smaller half of deals (by market capitalization of the target) than for the larger half of deals. This suggests a limits to arbitrage story in which sophisticated investors are unable to fully arbitrage away mispricing due to transaction costs or price-impact costs, which may be higher for smaller deals.

To the best of our knowledge, this is the first paper to empirically investigate market underreaction to no news and the passage of time. However, our findings build upon and complement related findings in behavioral finance. For example, Da, Gurun and Warachka (2012) show that markets underreact to the slow release of news. Corwin and Coughenour

(2008) and Barber and Odean (2008) show that investors focus on familiar or attention-grabbing stocks, while Hirshleifer and Teoh (2003), Hirshleifer et al. (2004) and DellaVigna and Pollet (2009) study limited attention in the context of information disclosure by firms. Cohen and Frazzini (2008) show the effects of limited attention in learning about firms' economic linkages. Finally Gur and Regev (2001), Chan (2003), Hirshleifer, Lim and Teoh (2009) and Tetlock (2011) study under- and over-reaction to explicit news in different financial settings. Overall, the existing literature argues that investors exhibit limited attention when sifting through a set of news stories. This paper shows that investors also underreact to the *absence* of news, which itself can contain valuable information.

The remainder of this paper is organized as follows. Section 2 describes our data. Section 3 describes event time variation in hazard rates. Section 4 describes the relationship between hazard rates and returns. Section 5 describes the behavioral model of underreaction. Section 6 tests whether our results can be explained by variation in risk. Section 7 presents supplementary results and robustness and Section 8 concludes.

# 2 Data

We combine data on merger activity from two sources. The first data source, generously shared by Mark Mitchell and Todd Pulvino (MP), covers merger activity from 1965 to 2009. It is an updated version of the data described in Mitchell and Pulvino (2001). The second data source is Thomson One (TO), which covers merger activity from 1985 to 2010 and was formerly known as the SDC database. Because MP covers a longer time series while TO offers more comprehensive coverage over recent years, we combine the two datasets as follows: we use the MP dataset for years up to and including 1995 and the TO dataset afterwards. The exact year of the split is determined through a comparison of the relative coverage of the two datasets in each year. Our results are robust to using only MP or only TO data.

We define the initial takeover premium for cash deals as the ratio of the initial offer price at deal announcement to the price of the target two days before deal announcement. For equity-financed deals, the takeover premium is defined as $\Delta * P^A_{t=-2}/P^T_{t=-2}$, where $\Delta$ is the exchange ratio, defined as the number of acquirer shares offered for each share of the target, and $P^A$ and $P^T$ are the the acquirer's and target's share prices, respectively.

We apply the following filters to our initial sample of mergers.

1. The merger is all cash-financed or all equity-financed. We exclude hybrid forms of financing or deals with contingency terms (e.g., collar agreements) because they are more difficult to price using the available data on equity prices. For equity-financed deals, we require that there exists data on the exchange ratio for the deal.

2. The merger takes the form of a simple one-step merger without a known expiration date or anticipated date of completion. We exclude tender offers, which have known expiration dates, because the information content of the passage of time near and beyond the expiration date is likely to be obvious to market participants.

3. For cash-financed mergers, equity price data is available for the target from The Center for Research in Security Prices (CRSP). For equity financed mergers, equity price data for both the target and acquirer is available from CRSP.

4. We exclude deals for which the typical hazard rates of completion or withdrawal are less applicable. First, we exclude deals that compete with a previous bid for the same target that was announced within the past three years because competing bids are relatively more likely to withdraw and follow more deal-specific heterogeneity in timing. Second, we exclude deals in which the initial takeover premium is less than one. As we execute our trading strategy (see Section 6.1), we also exit out of a deal if the target price rises above the acquirer offer price (or the imputed offer price, defined as the exchange ratio multiplied by the acquirer stock price, in the case of an equity-financed merger). In these cases the market expects either a competing offer or a favorable revision of deal terms and deal completion is less likely to be the primary form of uncertainty.

Note that these filters only exclude deals from the sample or investment strategy based upon information that was publicly available at the time of the deal. After applying these filters, we are left with 3385 cash financed deals and 1955 equity financed deals, which are summarized in Table 1. If a deal does not complete, it can either be formally withdrawn on a particular date or remain pending. 70 percent of cash-financed deals complete with a median time to completion of 83 days. 76 percent of equity-financed deals complete with a median time to completion 97 days.

# 3 Hazard Rates

In this section, we document how the hazard rate of completion varies over the event lives of mergers. Time variation in hazard rates represents one important reason why the passage of time after merger announcement should contain information about whether the deal will ultimately complete. Other reasons why the passage of time may contain information are discussed in Section 5.3.

## 3.1 Empirical Hazard Rates

Let $t$ refer to the number of weeks after the merger announcement. In other words, $t$ refers to event time rather than calendar time. Let $S(t)$ be the probability that the merger survives up to event time $t$, i.e., it has not completed or been withdrawn prior to $t$. Let $h(t)$ be the hazard rate of completion at time $t$, i.e., the probability that the merger completes during period $t$ conditional on surviving up to $t$. We also estimate a separate hazard rate of withdrawal $w(t)$, although we will later show that this hazard rate remains roughly constant over time.

We use the standard Kaplan-Meyer estimator, which constructs the hazard rates of completion (withdrawal) as the fraction of deals that complete (fail) during each period $t$ among those that have survived until time $t$. The Kaplan-Meyer estimator assumes that all merger completion and withdrawal events are drawn from the *same* underlying distribution and provides an estimate of such a distribution at each point in event time. In reality, it is reasonable to think that deal completions and withdrawals might follow different hazard processes depending on observable or unobservable characteristics of each deal. We explicitly account for one major source of heterogeneity: the financing of the deal. A large literature has explored the differences between cash- and equity-financed deals, and we allow the two to have different hazard rates curves for completion and withdrawal. Another dimension of heterogeneity is whether the deal is a tender offer or not. As noted previously, we exclude tender offers from our analysis because they tend to complete quickly and have known expiration dates. We leave a discussion of other potential sources of heterogeneity for the next subsection.

Figures 1 and 2 show the estimated hazard rates of completion and withdrawal for cash and equity mergers. The figures report estimates computed using the full sample of mergers (1963-2010), and separately over the early and late parts of the sample (1963-1990 and 1991-2010, respectively).

Three main results emerge from these figures. First, the hazard rates of completion are strongly non-constant. For cash deals, they start at around zero during the first weeks, then rise to about 5 percent per week around week 15, and gradually decline to zero by the end of the first year after announcement. A similar pattern is observed for equity deals, for which the hazard rate reaches 9 percent per week at the peak in week 23. Second, hazard rates of withdrawal are essentially constant for both cash and equity deals. Third, hazard rate patterns estimated using the early and late calendar time samples are similar, suggesting that hazard rate patterns have not changed significantly over the past several decades.

## 3.2 Unobserved Heterogeneity

Within the categories of cash and equity mergers, the hazard rate for any specific merger may differ from the hazard rate we estimate using aggregate data because of other observed and unobserved heterogeneity. While it is impossible to fully account for other unobserved heterogeneity in hazard rates, our results are robust to unobserved heterogeneity for two reasons.

First, we test a behavioral hypothesis that predicts a positive relationship between each individual merger's latent hazard rate and returns. To the extent that our measured hazard rate approximates each merger's individual hazard rate with noise, this is a bias *against* our empirical findings in support of the behavioral hypothesis.

Second, we can prove that under commonly used assumptions about the nature of the unobserved heterogeneity, the mean individual latent hazard rate is non-constant over a merger's event life if the *measured* hazard rate (which ignores the heterogeneity) is non-constant. In other words, given that we measure a strongly hump-shaped pattern in empirical hazard rates, the true hazard rate will necessarily display even more time variation. This implies that even if unobserved heterogeneity is present, there is, on average, information content in the passage of time. In particular, we prove the following proposition in the Appendix:

**Proposition 1.** *Suppose that the true hazard rate for merger $i$ is $h_i(t) = \alpha_i h(t)$, where $h(t)$ is an unobserved common component and $\alpha_i$ is a merger-specific unobservable parameter distributed in the cross-section according to the distribution function $G(\alpha)$ with mean 1. Then, we have*

$$h(t) \geq h_\theta(t) \ \ \forall t$$

*where $h_\theta(t)$ is the measured hazard rates that ignores the unobserved heterogeneity.*

Proposition 1 shows that the mean of the latent individual hazard rates must always lie weakly above the estimated hazard rate. We also know that individual hazard rates are zero at the very beginning of event time (because a merger cannot complete immediately after announcement due to regulatory restrictions) and zero at the very end of event time (some period $T$). This, combined with Proposition 1, shows that the mean individual latent hazard rates much have at least as much time variation as the estimated hazard rate $h_\theta(t)$, and therefore, the passage of time contains information about merger resolution.

In the Appendix, we account for another explicit source of observed heterogeneity: the merger arbitrage spread, as measured by the relative difference between the effective offer price and the target price two days after merger announcement. A large merger arbitrage spread often reflects market beliefs that the merger is unlikely to complete, and vice versa. As expected, we find that a larger merger arbitrage spread tends to shift the overall hazard rate curve down proportionally, but the overall hump-shape of the hazard rate curve remains the same. Since our analysis focuses on event-time variation in hazard rates rather than the mean level of hazard rates, we abstract away from this source of heterogeneity in future analysis. In unreported results, we also check for heterogeneity by size of the target, and find similarly shaped hazard curves across size categories.

Armed with the result that hazard rates of completion vary significantly over the event lives of mergers, we now study the implications for returns.

# 4 Returns and Hazard Rates

In this section, we document a surprising positive correlation between hazard rates (as estimated from an aggregate sample) and average returns over event time. For cash mergers, the relevant return is the weekly return from investing in the target. For equity mergers, the relevant return is the weekly return from going long the target and shorting $\Delta$ shares of the acquirer. Importantly, each week's return includes the gains from any delisting, i.e., the upside from attaining the acquirer's offer price if the merger completes in that week. We start by plotting the series of hazard rates and average returns across deals in event time for cash and equity mergers. Because very few deals survive until one full year after announcement, and returns are very noisy, we focus on event weeks 1 through 45 in all subsequent analysis.[4]

Figure 3 plots completion and withdrawal hazard rates in the top panel and mean weekly returns in the bottom panel. Because of noise in returns data, we plot returns over event time by fitting a smoothed local mean to the panel series of returns for each deal in each event week. The figure shows smoothed returns using the optimal bandwidth. In unreported results, we also plot the curve using 0.5 and 1.5 times the optimal bandwidth, as well as fitting a local linear regression, and find qualitatively similar results. The figures show that the hazard rate of completion and weekly returns tend to move together. In the first weeks after the announcement and towards the end of the first year after announcement, completion hazards are below the average and returns are below the average as well. In the intermediate weeks, hazard rates are high and returns are high as well. Finally, returns revert to the average by the end of the last event week (week 45) – this nuance is discussed in detail in Section 5.2

In Figure 3, we also plot 90 percent pointwise confidence bands for each point in the returns curve. These confidence bands grow wider as we approach one year after merger announcement because fewer deals survive as time passes after announcement. Because these confidence intervals are pointwise estimates, and therefore overly conservative for understanding whether returns are constant over event time, we turn to a more formal test of whether returns are constant over event time. We estimate a regression of returns on indica-

[4]All results in the paper are substantively unchanged if we include returns after week 45, although the confidence intervals for average returns (as plotted in Figure 3) are very wide for all weeks after week 45.

tors for each event week following deal announcement, with controls for calendar year-month fixed effects and with standard errors clustered by calendar year-month. We can reject that the coefficients on the event-month indicators are jointly equal to one another with p-values of 0.07 and 0.02 respectively for cash and equity deals.

Next, we test the strength of the relationship between returns and completion hazard rates. For each merger type and for each event week, we compute a time series of returns over calendar time obtained by only investing in deals during that specific event week. These returns will therefore be averages across deals which are active during each event week in each calendar month.

In Table 2, we regress returns on hazard rates, controlling for calendar year-month fixed effects. The fixed effects control for possible calendar time variation in unobservables that might affect returns (for example, calendar-time variation in risk or risk premia). We cluster standard errors at the calendar year-month level. For both cash and equity deals, we find that hazard rates (estimated from the aggregate sample) significantly predict returns over event time. We further split the sample by the size of the target. We classify half of the deals as large and half as small, based upon the market capitalization of the target at the time of announcement relative to the mean target value in each calendar year. We find a positive correlation between hazard rates and returns for both small and large deals. However, the relationship is more than twice as strong for the smaller half of deals than for the larger half. We will return to this point in the next sections.

Overall, we find that returns following merger announcement are predictable using aggregate hazard rates. What explains this return predictability? In the remainder of the paper, we explore two possible explanations: underreaction to the passage of time (the behavioral explanation) and changes in risk over the event life of mergers (the rational explanation).

# 5 A Simple Behavioral Model of Underreaction

To understand what time variation in hazards implies for returns when markets imperfectly update on the passage of time, consider the following parsimonious pricing model for the returns of the target of a cash merger after the announcement of the intention to merge.

## 5.1 The Model

Let $t$ represent the number of weeks after merger announcement, as measured in event time. Let $\hat{P}(t)$ be the price of the target's shares after the announcement has been made, but before the deal has completed or withdrawn. Even in the absence of specific news about the deal, $\hat{P}(t)$ can change over time if investors use the passage of time to update on the probability that the deal will complete. If at any point the deal completes, the value of the target jumps to $P_C$, the amount of cash per share promised to the target's equity holders. If at any point the deal is withdrawn, the price jumps to $P_0(t)$, where $P_0(t)$ is some latent process.[5] We model $P_0(t)$ as follows:

$$dP_0(t) = \mu P_0(t)dt + \sigma P_0(t)dZ(t)$$

where $Z(t)$ is a standard Brownian motion. We assume that there is an end time, $T$, such that any deal that does not complete by time $T$ is assumed to never complete (in accordance with the empirical evidence that shows that hazard rates of completion fall to zero approximately one year after merger announcement).

If the merger has not completed or withdrawn prior to time $t$, the price of the target $\hat{P}(t)$ is determined as follows:

$$\begin{aligned}
\hat{P}(t) &= E_t\{\textstyle\int_t^T e^{-r(z-t)} e^{-\int_t^z [\hat{h}(k)+\hat{w}(k)]dk} \hat{h}(z) P_C dz \\
&+ \textstyle\int_t^T e^{-r(z-t)} e^{-\int_t^z [\hat{h}(k)+\hat{w}(k)]dk} \hat{w}(z) P_0(z) dz \\
&+ e^{-r(T-t)} e^{-\int_t^T [\hat{h}(k)+\hat{w}(k)]dk} P_0(T)\}
\end{aligned}$$

where $\hat{h}(t)$ and $\hat{w}(t)$ are risk-neutral hazard rates.

Because we wish to focus on a possible behavioral explanation, assume for now that all risk is idiosyncratic and the market believes that all risk is idiosyncratic. This means that we can interpret $\hat{h}(t)$ and $\hat{w}(t)$ as market beliefs about the actual hazard rates, as opposed to the risk-neutral hazard rates that also reflect the risk attitude of the market (we postpone

[5] Using the insight from Malmendier, Opp and Saidi (2011) which shows that merger announcements can change the underlying value of the target even if the merger never completes, we do not constrain $P_0(t)$ to represent the value of the target if the merger had never been announced. Rather, $P_0(t)$ represents the value that the target share price would revert to if the acquirer were to withdraw at time $t$.

a thorough discussion of risk to a later section).

Under these modeling assumptions, it is easy to show that the expected one-period return at time $t$ can be decomposed as follows:

$$\begin{aligned} E\left[ret_t\right] &= rdt \\ &+ \left(\frac{P_C}{\hat{P}(t)} - 1\right)\left[h(t) - \hat{h}(t)\right]dt \\ &+ \left(\frac{P_0(t)}{\hat{P}(t)} - 1\right)\left[w(t) - \hat{w}(t)\right]dt \end{aligned}$$

where $h$ and $w$ are the *true* hazard rates (as opposed to the market beliefs represented by $\hat{h}$ and $\hat{w}$). Note that

$$\left(\frac{P_C}{\hat{P}(t)} - 1\right) > 0 \;\; and \;\; \left(\frac{P_0(t)}{\hat{P}(t)} - 1\right) < 0$$

The model generates simple testable predictions concerning the relationship between hazard rates and mean returns at each event time $t$. First, if markets have correct beliefs about hazard rates ($h(t) = \hat{h}(t)$, $w(t) = \hat{w}(t)$), the mean target return will always equal the risk free rate $r$ (since all risk is assumed to be idiosyncratic). Second, if the market underestimates completion hazard rates ($\hat{h}(t) < h(t)$), mean returns will be higher than the risk free rate $r$. This occurs because the market, underestimating the probability of completion, will receive positive surprises on average, generating abnormally high returns. Finally, if the market overestimates the completion probability ($\hat{h}(t) > h(t)$), the target's stock will be overvalued at time $t$ and experience a return lower than the risk-free rate. Note that returns in each period depend only on the difference between beliefs and true hazard rates in that period and not on future differences between beliefs and true hazard rates.

These predictions directly map to the behavioral hypothesis of market underreaction to no news. Suppose that markets fail to use the passage of time to update on changes to the hazard rate, but have correct beliefs on average over the event life of a merger. In other words, the market believes that $\hat{h}(t) = \hat{h}$ and $\hat{w}(t) = \hat{w}$, where $\hat{h}$ and $\hat{w}$ represent the average of the *true* hazard rates. This implies that the market will have approximately correct beliefs about the hazard rate of withdrawal because $w(t)$ is approximately constant over time. However, the market will underestimate the completion hazard rate during event weeks in which the true hazard rate is high. During these times, the model predicts that we should observe particularly high returns for the target's stock. In contrast, in event periods in which the true completion hazard rate is particularly low, markets, by underreacting to this variation, will overestimate the hazard rate, and the model tells us we should expect to see particularly low returns for the target. In other words, underreaction to the passage of time implies that mean returns should be positively correlated with true hazard rates, exactly as we observe in the data.

Figure 4 shows an example of how the relationship between hazard rates and returns varies depending on whether beliefs are correct. The top panel shows the completion and withdrawals hazard rates (solid lines), estimated for cash deals. It also plots a sample set of beliefs in which the market holds correct beliefs about hazard rates for the first several weeks after deal announcement (the dotted line and the solid lines coincide). After a certain number of weeks, and up to a year after announcement, agents fail to use the passage of time to update on changes in the hazard rate. The beliefs about the completion hazard rate are constant but correct on average. As a consequence, in this example, markets underestimate the true completion hazard rate between weeks 10 and 37 and overestimate the hazard rate from week 37 onwards.

The lower panel of Figure 4 shows the model predictions for average returns in each event week, assuming that the deal has not yet completed or withdrawn. During event periods in which beliefs are correct, mean excess returns are zero (the return is equal to the risk-free rate). When markets underreact to no news but have correct beliefs on average about hazard rates, the return curve follows the shape of the hazard rate of completion: returns are positively correlated with hazard rates.

These predictions extend to a model in which merger returns contain risk that is systematic and in which risk and risk premia are allowed to be non-constant in calendar time. As long as risk and risk premia do not vary on average over event time, rational updating on the passage of time implies that merger returns should be constant over the event life of the merger (although mean returns may exceed the risk free rate). Underreaction to no news still implies a positive relationship between hazard rates and returns. These predictions also extend to a model of equity-financed deals: returns for these deals are those from a portfolio in which investors long the target and short the acquirer. Finally, these predictions hold even if agents *also* have incorrect beliefs about the average completion rate over the merger's event life. As long as hazard rate beliefs exhibit *flatter* event time variation than true hazard rates, the model predicts a positive relationship between hazard rates and mean returns.

This simple model is meant to illustrate the behavioral hypothesis's predictions and does not capture all aspects of reality. In particular, the market may observe news (e.g., deal-specific news about a competing bidder or rumors about completion probability) prior to merger resolution, which can lead to jumps in $\hat{P}(t)$ or $P_0(t)$. The release of explicit news is a bias against the behavioral prediction that hazard rates (as estimated from an aggregate sample) should predict returns. If investors are rational and update on intermediate bits of news as well as the passage of time, that should make the passage of time even less predictive of returns.

## 5.2 Estimating Market Beliefs about Hazard Rates

In addition to predicting a relationship between hazard rates and returns that matches the data, we can use the model to estimate the market's beliefs with regard to completion hazard rates that are implied by the observed returns. We parametrize the model using the main sample moments of the data: $P_c = 1.3P_0(0)$, corresponding to an approximately 30% takeover premium as shown in Table 1, and $r = 2\%$ per year. We numerically estimate the values for beliefs $\hat{h}(t)$ such that the model-implied returns match the observed average return in each event week:

$$\begin{aligned} E\left[ret_t\right] &= rdt \\ &+ \left(\frac{P_C}{\hat{P}(t)} - 1\right)\left[h(t) - \hat{h}(t)\right]dt \\ &+ \left(\frac{P_0(t)}{\hat{P}(t)} - 1\right)\left[w(t) - \hat{w}(t)\right]dt \end{aligned}$$

with $h(t)$ and $w(t)$ representing the estimated hazard rates in the data, and $\hat{P}(t)$ computed using the beliefs $\hat{h}(t)$ and $\hat{w}(t)$. In order to focus on implied beliefs concerning the completion hazard rate, we also impose that beliefs about the withdrawal hazard rate are correct, $\hat{w}(t) = w(t)$. Given that $w(t)$ is approximately constant, the results are robust to relaxing this assumption. To focus on the time variation of implied beliefs concerning hazard rates, we also adjust the average return across all event weeks to be equal to the risk-free rate, as assumed in the model (in practice, as shown by Mitchell and Pulvino, 2001, the *average* return for a Buy and Hold strategy exceeds the risk free rate mainly due to transaction costs in operating the arbitrage strategy – these are constant in event time).

Figure 5 compares the estimates of true hazard rates with the beliefs implied by fitting the model to the observed returns. As predicted by the underreaction model, we find that implied beliefs of completion hazard rates are flatter than estimates of true hazard rates for both cash and for equity deals. Hazards are overestimated at the beginning and the end of the event period, and underestimated in the intermediate period. This implies that markets only partially incorporate the information content of the passage of time. We can also estimate the extent of the underreaction: the implied beliefs display 12 and 46 percent less variation over event time than the estimates of true hazard rates for cash and equity mergers, respectively.[6]

Figure 5 also shows an interesting convergence between beliefs and true hazard rates as the time after merger announcement approaches one year. While returns one year after announcement are relatively noisy, this is consistent with a story in which agents are slow to react to changes in the hazard rate. However, after sufficient time has passed, agents eventually hold correct beliefs and realize that the merger is unlikely to ever complete. Once agents hold correct beliefs, returns revert to zero (in the model) or to their mean (once we account for constant systematic risk). This explains why returns display a small upward swing toward the mean near the end of the event period as shown in Figure 3.

[6] We measure the total variation in true hazard rates as $TV = \sum_{t=1}^{T} \left(h(t) - \bar{h}\right)^2$. The sum of squared errors between the true hazard rate and implied beliefs is $SE = \sum_{t=1}^{T} \left(h(t) - \hat{h}(t)\right)^2$. Therefore, $SE/TV$ offers an estimate of the event time variation in true hazard rates that is not captured by implied beliefs. If beliefs are correct, $SE/TV = 0$, and if beliefs are completely flat, then $SE/TV = 1$. We find that implied beliefs for cash deals capture relatively more variation in true hazard rates than implied beliefs for equity deals. While it is difficult to pinpoint the exact reason, it may be more difficult to arbitrage mispricing in equity deals because the arbitrageur must take a short position in the acquirer.

## 5.3 Other Information Content in the Passage of Time

In this paper, we focus on the hazard rates of merger completion because they are easily measured and clearly non-constant over event time. However, event time variation in hazard rates need not be the *only* reason why the passage of time after merger announcement contains information. The value of the target, acquirer, or combined entity may change systematically with the passage of time for other reasons. For example, the arrival rate of receiving competing bids from other potential acquirers may be non-constant over event time. In Appendix Figure 12, we show that the hazard rate of receiving competing bids is slightly higher in the weeks immediately following merger announcement than in later weeks (although it is relatively flat compared to hazard rates of completion). In addition, the expected value of merger synergies may vary over the event lives of mergers. For example, mergers that complete within certain event windows may generate more synergy value than mergers that complete within other event windows.

It is possible that these other real changes to merger value tend to vary systematically with hazard rates. Therefore, we cannot distinguish between the following:

1. Markets underreact to the event time variation in hazard rates of completion

2. Markets have correct beliefs about the event time variation in the hazard rate of merger completion but underreact to other changes to merger or target value that move in event time with hazard rates.

Importantly, both interpretations are consistent with the behavioral hypothesis in implying that hazard rates (and the real events correlated with hazard rates) predict returns because markets underreact to the information content of the passage of time.

# 6 Risk

In this section, we study the possibility that risk varies in event time with hazard rates. If this is the case, the pattern in returns documented in Section 4 could reflect compensation for risk within a rational framework. We focus on event-time variation in risk because the positive correlation between hazard rates and returns is a phenomenon measured in event time rather than calendar time. Moreover, we observe over 5,000 mergers staggered across calendar time and control for all calendar time variation in risk or risk premia through the use of calendar year-month fixed effects in all regressions. Since we do not observe event-time variation in risk premia, we will focus on event-time variation in *risk*.[7]

We explore three types of risk which may vary in event time and affect returns. First, we study whether systematic risk as captured by the Fama-French factors varies over event time. We do this by constructing feasible trading strategies that invest in deals only in specific event-time windows. This allows us to not only to capture potential event-time variation in systematic risk, but also to estimate the economic magnitude of the variation in returns not explained by systematic risk (the alphas of the trading strategies). Second, we consider downside risk, i.e., the possibility that high average returns are explained by the possibility of severely negative returns concentrated in bad times. Third, we investigate whether idiosyncratic risk can explain the observed relation between hazards and returns. Idiosyncratic risk may matter if the investors that operate in these markets are undiversified and therefore require compensation for exposure to volatility. Overall, we find that the event-time variation in systematic risk, downside risk, and idiosyncratic risk cannot explain the strong empirical correlation between hazard rates and returns.

## 6.1 Event-time Variation in Systematic Risk

To understand how the risk exposures of deals vary over event time, we construct calendar-time returns for a set of portfolio strategies, each of which is exposed only to deals active during specific event windows. We construct our strategies by modifying the traditional Buy and Hold merger arbitrage strategy described in Mitchell and Pulvino (2001), which buys deals after announcement and holds until either completion or withdrawal.

The first step in the construction of these portfolio strategies is to identify three event-time windows based *only* on the behavior of the completion hazard rate as estimated from an aggregate sample: a first period in which the hazard rate is below its mean (Low Hazard 1 period), a second period in which the hazard rate is above its mean (High Hazard period),

[7] Although we can never observe changes in risk premia over event time, it is not easy to justify why risk premia should change over event time if risk does not also change.

and a third period later in a merger's event life when the hazard is again below its mean (Low Hazard 2 period). We estimate these event windows separately for cash and equity deals. The cutoff points are event weeks 11 and 40 for cash deals and 14 and 41 for equity deals.

Given these cutoff weeks, we construct a series of monthly returns for each of the three strategies as follows. In each calendar month, we invest in all deals that, at the beginning of the month, happen to be active in the relevant event weeks for each of the three strategies. To distinguish the three strategies more sharply, we leave 2 weeks around each cutoff point, and we do not invest in deals that are active in those event weeks.

As an example, consider equity deals. Since the cutoffs are 14 and 41, we construct the Low Hazard 1 strategy by only investing in deals that, at the beginning of each calendar month month, are active in event weeks 1 through 12.[8] We construct the High Hazard strategy by investing only in deals that, that at the beginning of each calendar month, are active in event weeks 16 to 39. Finally, deals active in event weeks 43 to 45 are selected by our Low Hazard 2 strategy. Note that all the results that follow are very robust to the exact choice of the cutoffs, as discussed in Section 7.

For each calendar month, we construct an equal-weighted return using all selected deals. If no deals are active in the relevant event window in a given calendar month, the strategy invests in the risk-free rate for that month. Following standard merger arbitrage strategy, we go long the target for cash deals. For equity deals, we buy the target and sell short $\Delta$ shares of the acquirer for each share of the target bought. This ensures that the return following deal completion does not depend on the price of the acquirer at the time of completion and makes the return series comparable to that of a cash deal. Note that while all the deals are equally weighted, we separately explore the returns of strategies that only invest in large or small deals, as measured by target market capitalization.

[8]In the middle of a calendar month, if a deal falls out of the relevant event window (e.g. the deal approaches event week 13 and the relevant event window is weeks 1 through 12), we exit out of the deal and invest the proceeds in the risk free rate. Similarly, if the deal completes in the middle of a calendar month, we capture the gains from completion and invest the proceeds in the risk free rate.

### 6.1.1 Alphas over Event Time

We begin by testing whether event windows covered by the High Hazard strategy still experience higher returns that the periods covered by the Low Hazard 1 and 2 strategies, after controlling for systematic risk. The top panel of Table 3 shows the Fama-French alphas of the three strategies for both cash and equity deals using the full sample. We find that average returns in excess of the risk-free rate, after controlling for risk, are much higher for event weeks corresponding to high hazards than for those corresponding to low hazards. For example, for cash deals, the alphas of the two Low Hazard strategies are 1bp and -6bp per month and statistically insignificant, while that of the High Hazard strategy is 63bp per month (7.5% per year). Similarly, for equity deals the alpha of the High Hazard strategy is 147bp per month (17.5% per year), much higher than both Low Hazard strategies, respectively 68bp and -35bp a year.

Using these estimates, we can formally test a crucial prediction of the underreaction hypothesis: after controlling for risk, returns and hazards are correlated in event time. The corresponding test in terms of the three strategies presented above is that the alpha of the High Hazard strategy should be significantly greater than the alpha of both Low Hazard strategies. In the central column of Table 3 we test the hypothesis that $\alpha_{high} > \alpha_{low_1}$ and $\alpha_{high} > \alpha_{low_2}$ by computing the test for the linear combination:

$$T_{rel} = (\alpha_{high} - \alpha_{low_1}) + (\alpha_{high} - \alpha_{low_2}) \leq 0$$

versus the alternative $(\alpha_{high} - \alpha_{low_1}) + (\alpha_{high} - \alpha_{low_2}) > 0$. In other words, we reject the hypothesis of rational markets only if $\alpha_{high}$ is *sufficiently higher* than the average of two $\alpha_{low}$ coefficients. As shown in the third column of Table 3, the alpha in the High Hazard region are significantly higher than the alphas of the Low Hazard strategy, and the p-value of the corresponding test is less than 0.01 for both equity and cash deals.

The underreaction hypothesis centers on predictions for event-time variation of average returns, but does not have direct predictions about the average return over the life of the merger. Starting with Mitchell and Pulvino (2001), the risk arbitrage literature has shown that the average return of a Buy and Hold strategy (which invests in deals from announcement until completion or withdrawal) is higher than the risk-free rate even after controlling for the standard risk factors and downside risk. Within our framework, this is equivalent to saying that the average return around which we expect event-time variation under the underreaction hypothesis is not the risk-free rate $r$, but some higher value $\mu > r$. The difference between $\mu$ and $r$ will be captured by the alpha of a Buy and Hold strategy.

In the last column of Table 3, we compare the alphas of our High and Low Hazard strategies to the alpha from the Buy and Hold strategy. Our model predicts that the alpha of the High Hazard strategy should be higher than the Buy and Hold alpha, and that the alpha from the Buy and Hold strategy will, in turn, be larger than the alphas for our Low Hazard strategies. Again, we test the hypothesis by looking at the sum of the differences, $T_b = (\alpha_{high} - \alpha_{bh}) + (\alpha_{bh} - \alpha_{low_1}) + (\alpha_{bh} - \alpha_{low_2})$. The statistic $T_b$ will be positive if the underreaction theory is correct and negative if it fails.

The first column of Table 3 also reports the alpha of the Buy and Hold strategy. Consistent with the findings in the merger arbitrage literature, it is positive and significant at 39bp per month for cash deals and 109bp per month for equity deals. We perform the test for $T_b$ in the last column of the table, rejecting the null hypothesis that $T_b \leq 0$ with a p-value of less than 0.01 for both cash and equity deals. In other words, the test confirms that, while the Buy and Hold strategy delivers a positive alpha, there is significant event-time variation of returns, and a High Hazard (Low Hazard) strategy significantly outperforms (underperforms) the Buy and Hold strategy. Finally, the last line of the top panel shows that the results are similar and more significant using a combined test that looks at the joint significance across cash and equity strategies.

The remainder of Table 3 explores how the results depend on the calendar time horizon in which the estimation is performed. The second panel only uses data for the first half of the sample (1970-1990) while the third panel looks at the second half of the sample (1991-2010). All the main results hold in these sub-periods; the test for cash deals in the late sample is the only one that is not significant, but the joint test across cash and equity deals is still strongly significant.

In the first three panels of Table 3, we use the same sample to estimate the hazard rates (from which the cutoffs for the trading strategies are based) that we use to evaluate the trading strategies and construct the alphas. In the last panel of Table 4, we report the returns for portfolio strategies that only use information about hazard rates already available at the time of the investment. We choose the event window cutoffs for the High and Low Hazard Strategies based upon hazard rates estimated using the earlier 1970-1990 data, but only invest in deals active during the later 1991-2010 sample. Given that Figures 1 and 2 show that the shape of the hazard rate curves remained stable for the past four decades for both cash and equity deals, it is not surprising that all results remain similar when performing the test using the early hazard rates and later returns.

Finally, we note that we adopted a conservative approach in constructing the return series used to compute the alphas of the various strategies presented in Table 3. Since fewer deals survive into the event window covered by the Low Hazard 2 strategy (many deals have withdrawn or completed before then), it is more likely to find months with no active deals for the Low Hazard 2 strategy than it is for the High Hazard strategy. Since the return of a month with no active deals is set equal to the risk-free rate, this may artificially bias the alpha and betas of the Low Hazard 2 strategy towards zero, thus hiding the true risk and return properties of deals during their last event weeks. To avoid this problem, in Table 3 we only included returns from calendar months in which active deals were available for investment. This, while more conservative for tests of event time variation in strategy alphas, does not represent the returns of a more realistic trading strategy that must invest in the risk free rate during calendar months in which no deals are active. For completeness, in the top panel of Table 4 we repeat the exercise including *all months* for all strategies, thus forming a tradable portfolio strategy. All the previous results hold.

The second and third panels of Table 4 explore heterogeneity in strategy returns across the smaller and larger halves of deals (the split is based upon the market equity of the target at the time of announcement relative to the mean target value in each calendar year). We find that the High Hazard strategy delivers higher alphas than the two Low Hazard strategies as well as the Buy and Hold strategy for both large and small deals (with the exception of insignificant alphas for cash deals involving large targets). However, the difference in alphas is much more dramatic for the sample of smaller targets. This supports the evidence presented earlier in Table 2 showing that the correlation between hazard rates and returns is more than twice as strong for the smaller half of deals. Table 4 confirms that these patterns persist after controlling for systematic risk. Overall, the stronger return predictability in the sample of smaller deals is suggestive of a limits to arbitrage view in conjunction with the underreaction hypothesis: many, but not all, investors underreact to the information content in the passage of time. Sophisticated investors may be unable to arbitrage away mispricing in the sample of smaller deals due to the higher transaction costs and potential price impact associated with smaller deals.

#### 6.1.2 Betas over Event Time

In the previous section, we showed that hazard rates predict returns even after controlling for exposure to the Fama-French risk factors. We now directly explore event time variation in risk by looking at the betas of the various strategies. Table 5 reports the strategy betas with respect to the three Fama-French factors. Panel A shows that the betas are all quite small, between -0.1 and 0.3. We also check whether returns might be related to exposure to a momentum factor, but Panel D of the same table (third column) shows that betas with respect to UMD are also very small.

Panel B of Table 5 tests whether the betas for the High Hazard strategy are different from the betas for the two Low Hazard strategies. We cannot reject the hypothesis that the betas of the Low Hazard strategies are at least as high as the betas of the High Hazard strategy. In fact, not only is the difference statistically insignificant, the magnitude of this difference is also extremely small in economic terms, always less than 0.15.

To capture event-time variation in risk exposures in greater detail, we also look directly at the variation in the betas across each event-time week (as opposed to dividing the one-year event window into three hazard regions). For each of the 45 possible event weeks in a deal's event life, we construct a calendar-time series of returns of a portfolio that buys deals that are active in that event week only (separately for cash and equity deals). We then construct a panel of calendar time returns for each of the 45 event-week portfolios. We plot the estimates of the betas in Figure 6, with cash mergers in the top panel and equity mergers in the bottom panel.

Figure 6 points to two important features of these portfolio returns. First, the betas with respect to *all* the Fama-French factors are again generally very small (the market beta is usually less than 0.2). The magnitude of the betas cannot account for the difference in the alphas we observe in our High Hazard period (between the green bars) and the Low Hazard periods (the far left and right regions). Second, there does not seem to be significant time variation in any of the betas over event time (although estimation of the betas becomes more noisy as we move from left to right, since fewer deals survive as event time passes).

In Table 6 we formally test whether betas vary in a systematic way with hazard rates over event time. We find that the relationship between betas and hazard rates is a well-estimated zero for all three Fama-French factors. The point estimates of the relationship are, in fact, negative with small standard errors. The economic magnitude of the estimated relation is also extremely small: one standard deviation increase in the hazard rate corresponds to a reduction in each of the betas of around of 0.01.

Overall, the results obtained so far indicate that that there is no significant event-time variation in systematic risk as captured by the Fama-French factors.

## 6.2 Event-time Variation in Downside Risk

An alternative explanation of the observed event-time relation between hazard rates and returns is variation in downside risk. It is possible that the high returns of the High Hazard strategy reflect compensation for the risk of experiencing particularly bad returns in bad times (i.e., when the market is particularly low), in a way that is not captured by the standard risk factors. This exposure to downside risk, similar to an exposure to a short position in a put on the market portfolio, has been studied in previous research focusing on Buy and Hold arbitrage strategies. For example, Mitchell and Pulvino (2001) find that their Buy and Hold strategy is indeed exposed to downside risk, although the magnitude of the exposure is small and insufficient to explain the Buy and Hold alpha.

In this section we ask whether the higher alpha of the High Hazard strategy relative to the alphas of the Low Hazard strategies could be explained by *differential* exposure to downside risk in event time. We start by calculating the raw performance of each strategy in periods in which the market return is low, defined as all months in which the market portfolio experiences a monthly return below $-3\%$. Panel C of Table 5 reports the average return of each strategy as well as their alphas and Fama-French betas during this subset of calendar months. While the table shows that betas increase slightly across the board (for example, the market beta of the High Hazard strategies for cash deals goes up by 0.14, from 0.29 to 0.43), the magnitude of all the betas remains quite low. Moreover, the betas of the High Hazard strategy do not significantly differ from the betas of the two Low Hazard strategies. In addition, the average returns of the three strategies are not particularly low: in months when the market loses more than 3%, no strategy loses on average more than 1.4%.

In Panel D of Table 5, we directly measure exposure to downside risk by adding the out-of-the-money Put and Call factors constructed by Agarwal and Naik (2004) to the standard set of to Fama-French factors. These factors capture the components of the average return that can be attributed to exposure to out of the money options on the market. We find that the exposure of all strategies to these factors are extremely small and do not vary significantly across high and low hazard rate periods.[9]

We conclude our analysis of downside risk by presenting graphical evidence that the strategy with the highest returns (High Hazard) does not seem to owe its high return to high exposure to downside risk. In the top panels of Figures 7 and 8 we plot the cumulative log returns of the High Hazard strategy against the Buy and Hold strategy. The figures show that the High Hazard strategy strongly outperforms the Buy and Hold strategy by at least three fold over the calendar window shown (the y-scale is in terms of log cumulative returns), without any higher exposure to downside risk. This is true for both cash and equity deals. The bottom panels of the two figures show the simple returns of the High Hazard strategy against the returns of the market portfolio. We estimate that the returns of the High Hazard strategy are about as volatile as the market. Further, the downward spikes of the strategy (months with particularly low returns) are not strongly aligned with market downturns, and in fact the High Hazard strategy never experiences a monthly return below 22 percent in any month in the four decades covered by the data sample. To summarize, Figures 7 and 8 confirm that the High Hazard strategy yields a high return without high downside risk.

[9]In unreported results, we also estimate similarly low exposures to the *in-the-money* Put and Call factors constructed by Agarwal and Naik (2004).

## 6.3 Event-time Variation in Idiosyncratic Risk

A final potential explanation for the correlation between hazard rates and returns is event-time variation in idiosyncratic risk. In cases when merger completion comes as a surprise, prices should jump. Therefore, we may expect higher return volatility during event windows when hazard rates of completion are high. Why should idiosyncratic risk be priced at all? It's possible that the arbitrageurs that operate in merger markets are underdiversified, and require compensation for holding a particularly volatile portfolio.

We find that variation in idiosyncratic risk cannot explain the correlation between hazard rates and returns. Our High Hazard strategy does indeed experience greater volatility than our Low Hazard strategies, but the volatilities for all our strategies are relatively low and the differences are insignificant. The low volatilities reflect the fact that jumps in prices associated with individual mergers are diversified through portfolio strategies that invest in multiple deals simultaneously. Panel D of Table 5 (first columns) shows that the volatilities of all strategies are in fact lower than that of the market portfolio (0.055), as visible also from Figures 7 and 8 for the High Hazard case. Therefore, we do not attribute the returns of our High and Low Hazard strategies to compensation for idiosyncratic risk.

Finally, it is worth noting that we present conservative estimates of the return volatility that merger arbitrageurs are likely to experiment. Our High Hazard strategy holds an average of approximately 20 deals in each calendar month, which is already sufficient to obtain large diversification benefits in terms of smoothing returns volatility. However, our sample of deals is artificially limited because we restrict our analysis to pure cash- and equity-financed deals. A merger arbitrageur would likely be able to invest in a much wider set of deals, such as mergers in which the financing consists of a mix of cash and stock.

Overall, we have shown in this section that the empirical correlation between hazard rates and returns cannot be well explained by event-time variation in systematic risk, downside risk, or idiosyncratic risk.

## 7 Robustness

The regression results in Table 3 derive from trading strategies that uses precise event window cutoffs based upon the estimated hazard rates presented in Figures 1 and 2. In this section we show that these results are extremely robust to perturbations to the timing of the event window cutoffs.

Figures 9 and 10 report the *difference* between the alpha of a strategy that only invests in deals active between event weeks $t_1$ to $t_2$, and the alpha of the Buy and Hold strategy. $t_1$ can be read on the vertical axis, and $t_2$ on the horizontal axis.

For example, consider cash deals in Figure 9. The Low Hazard 1 strategy invests in deals active between event weeks 1 and 9, so its alpha can be read as $(t_1 = 1, t_2 = 9)$: the circle at the bottom left. The circle in the middle corresponds to the High Hazard strategy and the circle on the top right corresponds to the Low Hazard 2 trading strategy. The bottom-right corner $(t_1 = 1, t_2 = 45)$ corresponds to the Buy and Hold strategy. Since the graph reports the alphas of the strategies relative to the Buy and Hold strategy, it is not surprising to find exactly 0 at (1,45), negative numbers for the Low Hazard strategies, and a positive number for the High Hazard strategy.

Starting from the circles representing the cutoffs for our three trading strategies, it is straightforward to see that perturbations to the cutoff points in all directions do not dramatically affect the alphas. The Low Hazard strategies lie in an area with negative alphas (relative to the Buy and Hold strategy). Meanwhile, the High Hazard strategy lies in an area with all positive alphas (relative to the Buy and Hold strategy). This shows that the strategy alphas do not strictly depend on the cutoff points, but more generally align well with the high- and low- return areas predicted by the underreaction hypothesis.

## 8 Conclusion

The absence of news and the pure passage of time often contain important information. However, no news, by definition, tends to be less salient and vivid than traditional news stories. This, combined with limited attention, may lead boundedly rational investors to underreact to the passage of time.

In this paper, we test how markets react to the pure passage of time using the empirical context of mergers. Following the initial merger announcement, uncertainty relating to merger completion can take several months to a year to be resolved. We find that hazard rates of merger completion vary strongly over time after the merger announcement, implying that the passage of time can predict merger completion. If markets are rational, prices should correctly incorporate this information. When we examine target return patterns, we find that the aggregate merger completion hazard rates are positively correlated with target returns.

We then investigate two possible explanations for this return predictability. We first show that the positive correlation over event time between returns and hazards is consistent with a limited attention model in which the agents underreact to the passage of time. When agents underreact to no news, they do not fully appreciate the event-time variation of hazard rates, and behave as if hazard rates were less time-varying (flatter) than in reality. This leads to periods in which agents over- or under-estimate the true hazard rates of completion. When true hazards are high, they will be underestimated by the agents and returns will be too high. When true hazards are low, they will be overestimated by the agents, producing low returns. This underreaction can explain the observed correlation of hazards and returns.

While the positive relationship between returns and hazard rates is consistent with underreaction to no news, it could also be explained by changes in risk over the event lives of mergers. We find that, after controlling for systematic risk as captured by the Fama-French factors, the alpha for a strategy that invests in deals during high-hazard event weeks are significantly larger than the alphas for strategies that invests in deals during low-hazard event weeks. In addition, using a multiple portfolios strategy that invest only in deals active in each event week, we estimate the systematic risk associated with each week in a merger's event life. We find that merger returns have low betas in general, and systematic risk does not vary with hazard rates over the event lives of mergers. We also show that neither downside risk nor idiosyncratic risk can explain the observed pattern in returns and its relation with hazard rates. We conclude that aggregate hazard rates of merger completion predict merger returns because markets underreact to the passage of time.

Using the empirical context of mergers, we demonstrate that even a fairly sophisticated market can underreact to the passage of time. This underreaction can be costly, resulting in excess returns of up to 100 basis points per month after controlling for risk. Of course, not all market participants underreact, and we find that the extent of underreaction is smaller for larger merger deals, where the most sophisticated merger arbitrageurs are likely to be present.

Evidence of underreaction in mergers markets is also suggestive of a more general phenomenon, in which agents underreact to the passage of time because it is often less salient than explicit news stories. Underreaction to no news can be persistent, and can exacerbate asymmetric information problems in other contexts, such as the interactions between voters and politicians or managers and employees. We leave an exploration of the extent to which underreaction to no news pervades other contexts to future research.

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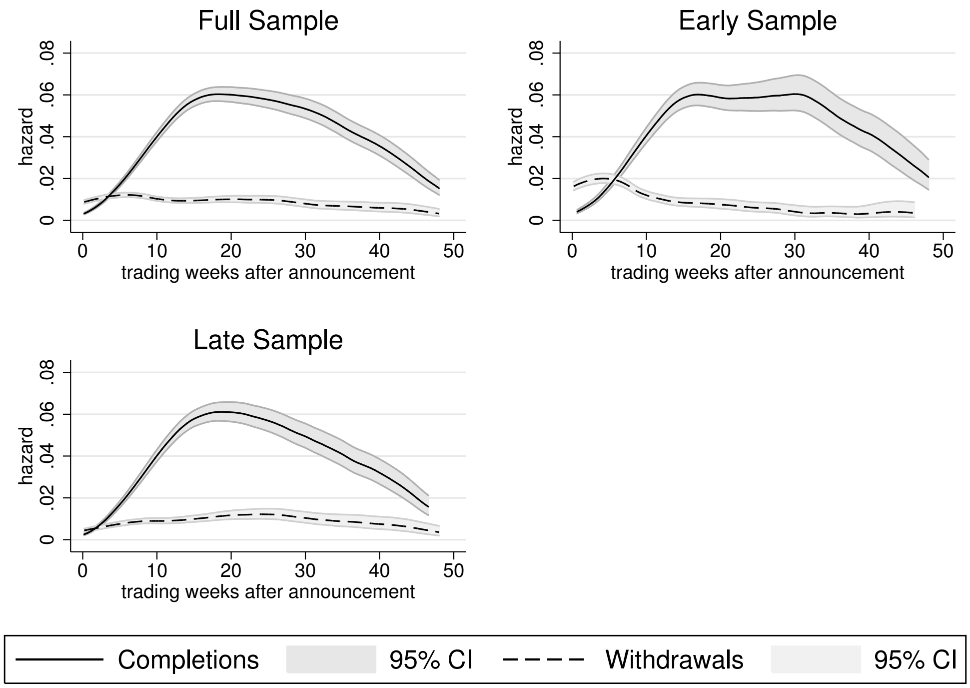


**Figure 1:** Cash Mergers: Hazard Rates

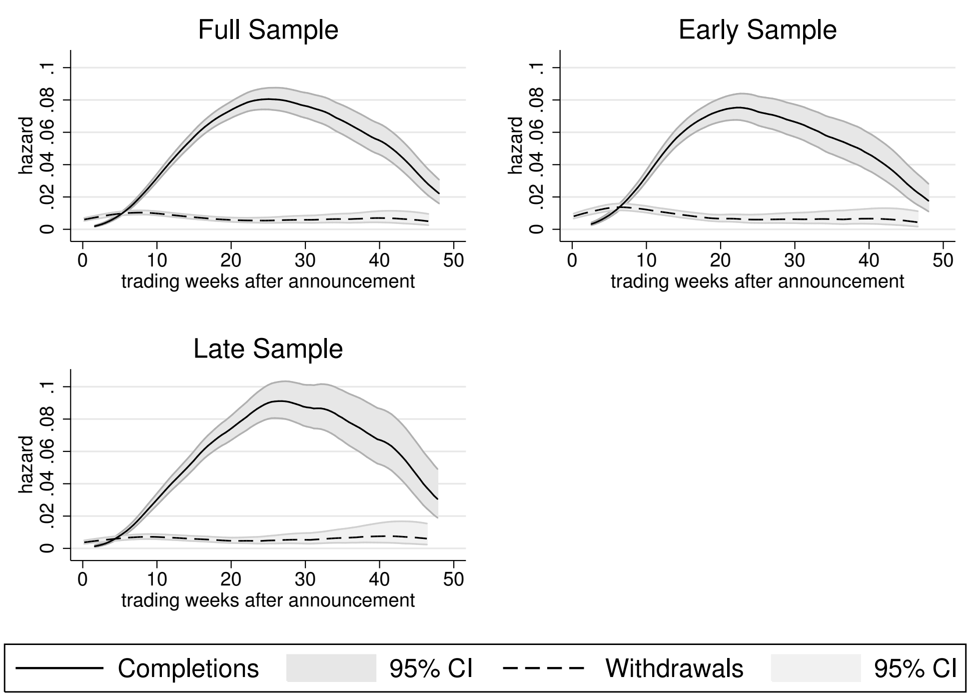


**Figure 2:** Equity Mergers: Hazard Rates

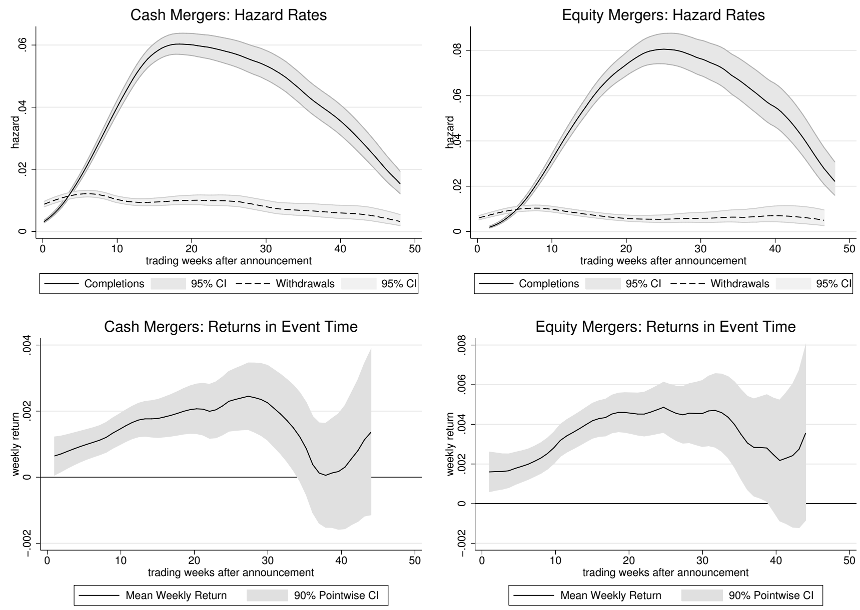


**Figure 3:** Hazard Rates and Mean Weekly Returns

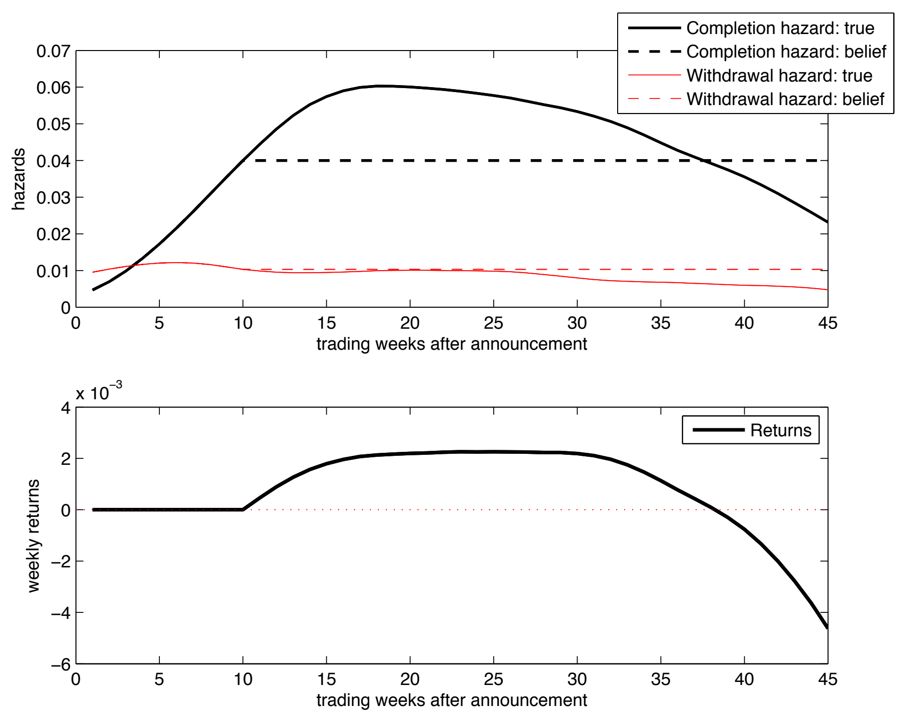


**Figure 4:** Model Predictions of Returns Given Beliefs

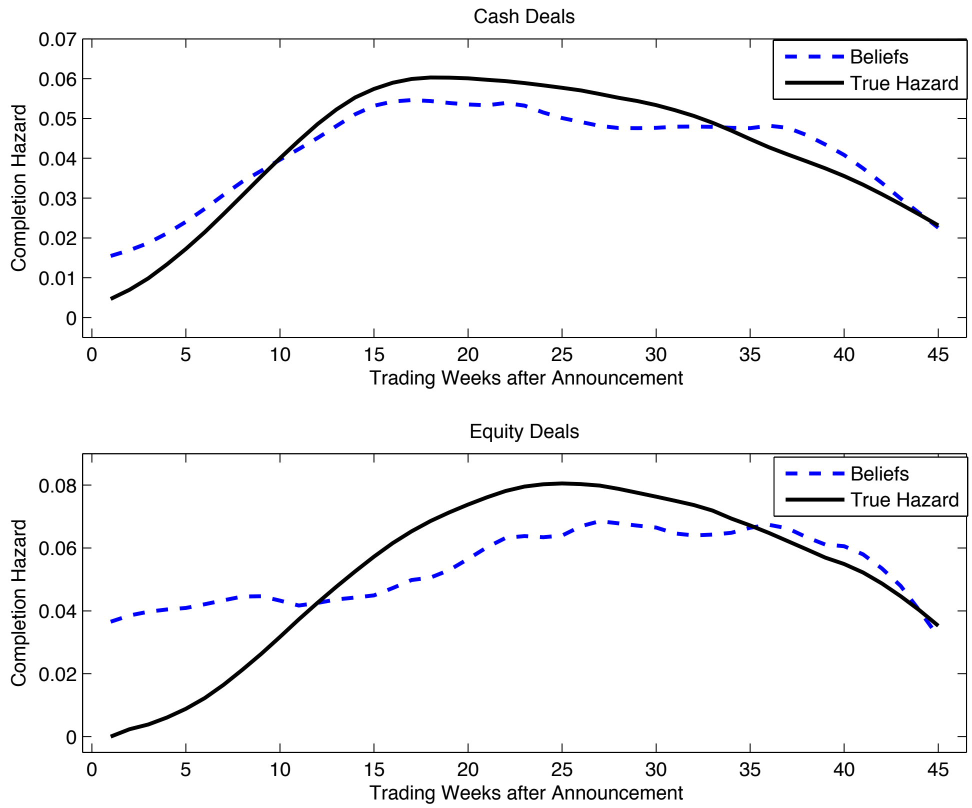


**Figure 5:** Implied Hazard Rates Beliefs

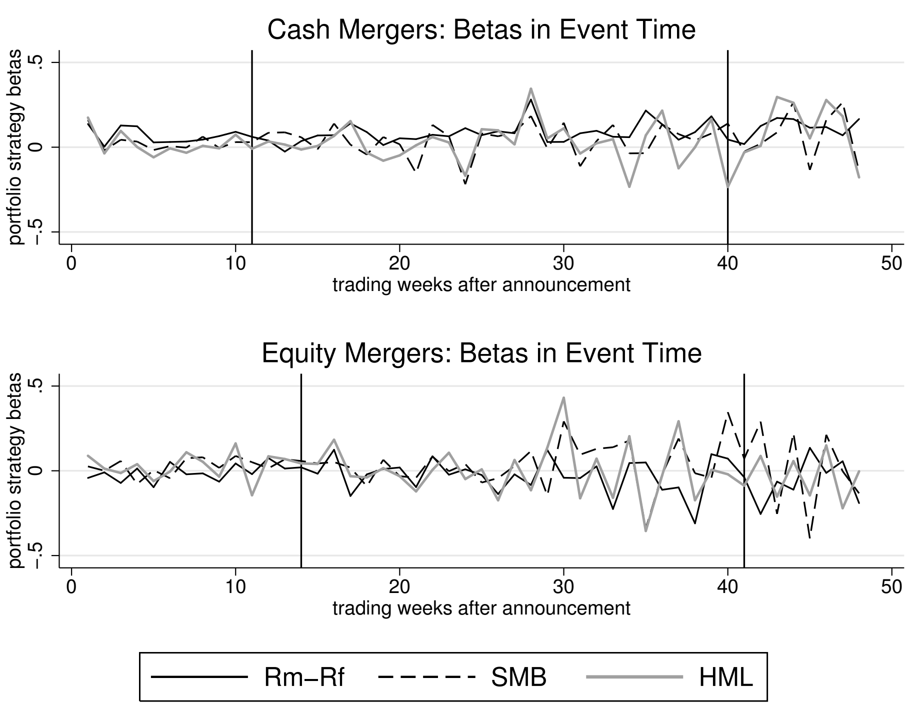


**Figure 6:** Event-time Variation in Risk

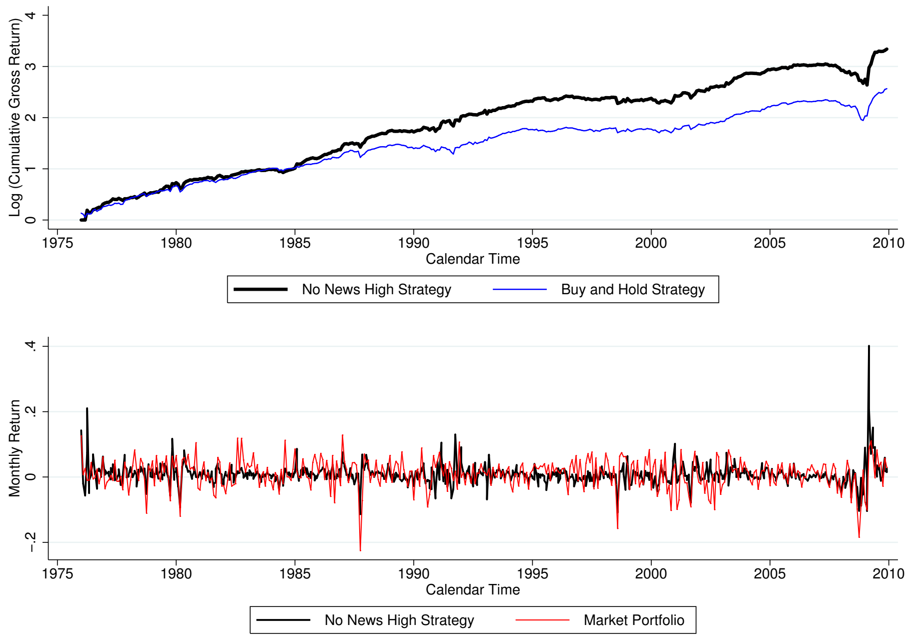


**Figure 7:** Cash Mergers: Portfolio Returns Comparisons

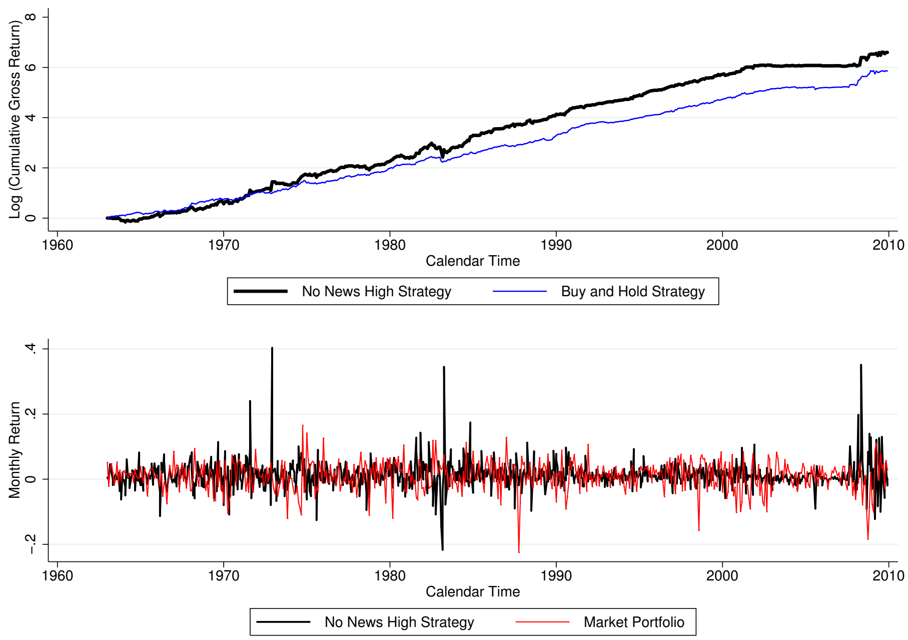


**Figure 8:** Equity Mergers: Portfolio Returns Comparisons

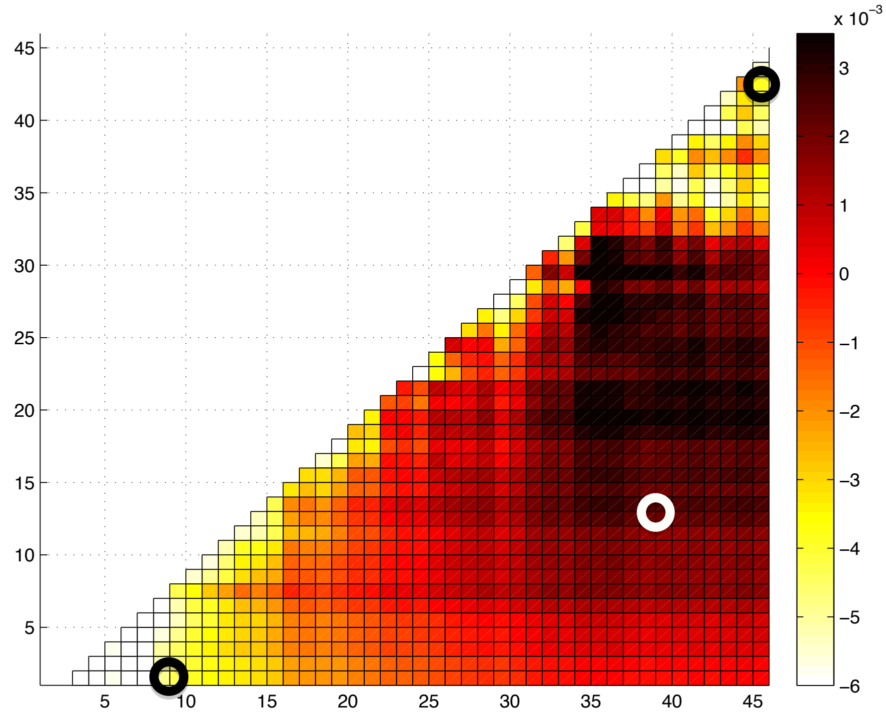


**Figure 9:** Cash Mergers: Hazard Rates vs. Returns

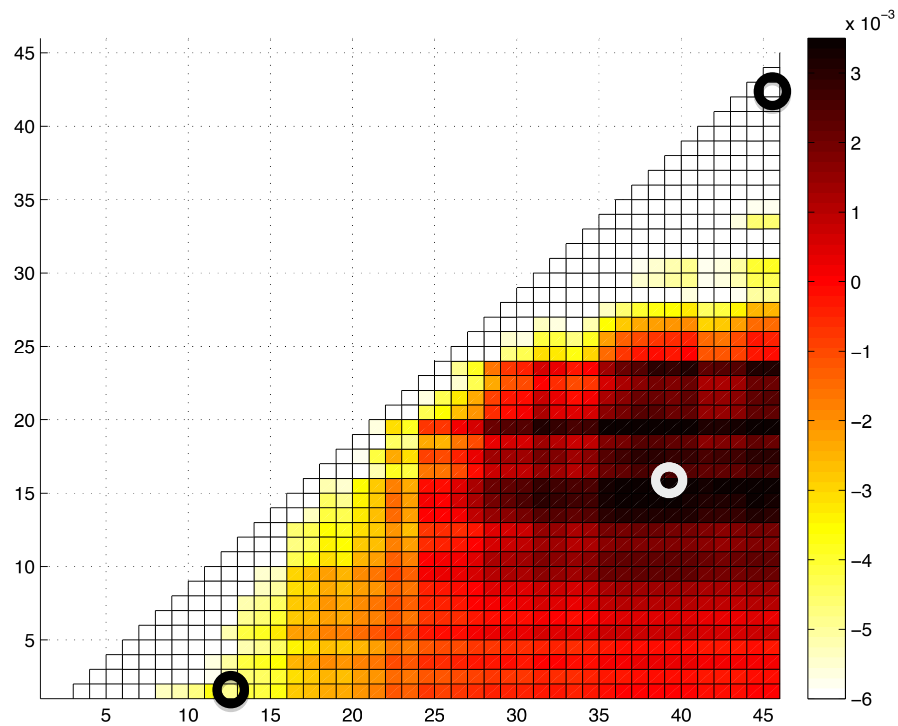


**Figure 10:** Equity Mergers: Hazard Rates vs. Returns

| | Cash Mergers | | | Equity Mergers | | |
|---|---|---|---|---|---|---|
| | Mean | Median | Stdev | Mean | Median | Stdev |
| Number of deals | 3385 | | | 1955 | | |
| Time to completion | 99.2 | 83.0 | 60.8 | 110.1 | 97.0 | 57.7 |
| Time to withdrawal | 66.0 | 40.0 | 85.7 | 66.0 | 44.0 | 94.0 |
| % Completed | 70.5 | | | 76.4 | | |
| % Withdrawn | 22.2 | | | 18.8 | | |
| % Pending | 7.3 | | | 4.8 | | |
| Premium | 1.33 | 1.26 | 0.40 | 1.33 | 1.23 | 1.22 |
| Size 1960-1979 | 54.4 | 19.3 | 959.7 | 67.9 | 27.5 | 146.4 |
| Size 1980s | 228.5 | 50.8 | 762.9 | 241.2 | 51.4 | 742.3 |
| Size 1990s | 269.8 | 70.1 | 673.7 | 687.4 | 144.0 | 2886.0 |
| Size 2000s | 1017.8 | 191.8 | 3157.1 | 1147.1 | 166.0 | 4344.5 |

**Table 1:** Summary Statistics

| **Dep Var: Weekly Returns** | Full sample | | Small Targets | | Large Targets | |
|---|---|---|---|---|---|---|
| | Cash | Equity | Cash | Equity | Cash | Equity |
| Weekly hazard | 0.0327 *** | 0.0486 *** | 0.058 *** | 0.0673 *** | 0.0103 | 0.0372 *** |
| | (0.011) | (0.011) | (0.017) | (0.018) | (0.013) | (0.014) |
| Calendar year x month FE | Y | Y | Y | Y | Y | Y |
| Obs | 62685 | 27506 | 31052 | 14092 | 31633 | 13414 |
| R2 | 0.0197 | 0.0171 | 0.0227 | 0.029 | 0.0331 | 0.0371 |

**Table 2:** Hazard Rates vs. Returns

| Sample | Type | Strategy | Individual Strategies: alpha | | Individual Strategies: stderr | Tests: P-values: High > Low | Tests: P-values: High > Buy and Hold > Low |
|---|---|---|---|---|---|---|---|
| **Full Sample** | Cash | Low hazard 1 | 0.0001 | | 0.0015 | | |
| | Cash | High hazard | 0.0063 | *** | 0.0017 | 0.0054 | 0.0067 |
| | Cash | Low hazard 2 | -0.0006 | | 0.0037 | | |
| | | Buy and hold | 0.0039 | *** | 0.0013 | | |
| | Equity | Low hazard 1 | 0.0068 | *** | 0.0015 | | |
| | Equity | High hazard | 0.0147 | *** | 0.0023 | 0.0003 | 0.0002 |
| | Equity | Low hazard 2 | -0.0035 | | 0.0055 | | |
| | | Buy and hold | 0.0109 | *** | 0.0012 | | |
| | | Obs | 3164 | | | Joint test | Joint test |
| | | R2 | 0.082 | | | 0.0000 | 0.0230 |
| **Early Sample** | Cash | Low hazard 1 | -0.0010 | | 0.0017 | | |
| | Cash | High hazard | 0.0078 | *** | 0.0022 | 0.0023 | 0.0032 |
| | Cash | Low hazard 2 | -0.0031 | | 0.0050 | | |
| | | Buy and hold | 0.0043 | *** | 0.0014 | | |
| | Equity | Low hazard 1 | 0.0048 | *** | 0.0018 | | |
| | Equity | High hazard | 0.0166 | *** | 0.0030 | 0.0003 | 0.0004 |
| | Equity | Low hazard 2 | -0.0097 | | 0.0086 | | |
| | | Buy and hold | 0.0111 | *** | 0.0016 | | |
| | | Obs | 1655 | | | Joint test | Joint test |
| | | R2 | 0.104 | | | 0.0000 | 0.0000 |
| **Late Sample** | Cash | Low hazard 1 | -0.0002 | | 0.0022 | | |
| | Cash | High hazard | 0.0045 | * | 0.0024 | 0.1530 | 0.1468 |
| | Cash | Low hazard 2 | 0.0038 | | 0.0065 | | |
| | | Buy and hold | 0.0035 | * | 0.0019 | | |
| | Equity | Low hazard 1 | 0.0088 | *** | 0.0022 | | |
| | Equity | High hazard | 0.0153 | *** | 0.0031 | 0.0190 | 0.0237 |
| | Equity | Low hazard 2 | 0.0036 | | 0.0054 | | |
| | | Buy and hold | 0.0107 | *** | 0.0019 | | |
| | | Obs | 1507 | | | Joint test | Joint test |
| | | R2 | 0.086 | | | 0.0230 | 0.0239 |
| **Late Sample, Early Hazards** | Cash | Low hazard 1 | 0.0007 | | 0.0022 | | |
| | Cash | High hazard | 0.0052 | ** | 0.0024 | 0.1001 | 0.1114 |
| | Cash | Low hazard 2 | -0.0004 | | 0.0059 | | |
| | | Buy and hold | 0.0035 | * | 0.0019 | | |
| | Equity | Low hazard 1 | 0.0082 | *** | 0.0024 | | |
| | Equity | High hazard | 0.0139 | *** | 0.0029 | 0.0270 | 0.0282 |
| | Equity | Low hazard 2 | 0.0036 | | 0.0054 | | |
| | | Buy and hold | 0.0107 | *** | 0.0019 | | |
| | | Obs | 1476 | | | Joint test | Joint test |
| | | R2 | 0.1079 | | | 0.0177 | 0.0169 |

**Table 3:** Strategy Alphas. The "High > Low" column reports p-values for the null hypothesis that $(\alpha_{high} - \alpha_{low_1}) + (\alpha_{high} - \alpha_{low_2}) \leq 0$. The "High > Buy and Hold > Low" column reports p-values for the null hypothesis that $(\alpha_{high} - \alpha_{bh}) + (\alpha_{bh} - \alpha_{low_1}) + (\alpha_{bh} - \alpha_{low_2}) \leq 0$.

| **Tradable - Full Sample** | | Individual Strategies | | Tests: P-values | |
|---|---|---|---|---|---|
| | | alpha | stderr | High > Low | High > Buy and Hold > Low |
| Cash | Low hazard 1 | 0.0001 | 0.0015 | | |
| | High hazard | 0.0063 *** | 0.0017 | 0.0014 | 0.0011 |
| | Low hazard 2 | -0.0006 | 0.0027 | | |
| | Buy and hold | 0.0039 *** | 0.0013 | | |
| Equity | Low hazard 1 | 0.0067 *** | 0.0014 | | |
| | High hazard | 0.0131 *** | 0.0020 | 0.0000 | 0.0000 |
| | Low hazard 2 | -0.0030 | 0.0008 | | |
| | Buy and hold | 0.0109 *** | 0.0012 | | |
| | Obs | 3748 | | Joint test | Joint test |
| | R2 | 0.0832 | | 0.0000 | 0.0000 |

| **Small Targets (Lower 50%)** | | Individual Strategies | | Tests: P-values | |
|---|---|---|---|---|---|
| | | alpha | stderr | High > Low | High > Buy and Hold > Low |
| Cash | Low hazard 1 | 0.0013 | 0.0021 | | |
| | High hazard | 0.0115 *** | 0.0024 | 0.0062 | 0.0024 |
| | Low hazard 2 | -0.0040 | 0.0067 | | |
| | Buy and hold | 0.0071 *** | 0.0018 | | |
| Equity | Low hazard 1 | 0.0061 *** | 0.0023 | | |
| | High hazard | 0.0176 *** | 0.0036 | 0.0000 | 0.0646 |
| | Low hazard 2 | 0.0002 | 0.0144 | | |
| | Buy and hold | 0.0123 *** | 0.0021 | | |
| | Obs | 2921 | | Joint test | Joint test |
| | R2 | 0.0483 | | 0.0025 | 0.0051 |

| **Large Targets (Upper 50%)** | | Individual Strategies | | Tests: P-values | |
|---|---|---|---|---|---|
| | | alpha | stderr | High > Low | High > Buy and Hold > Low |
| Cash | Low hazard 1 | -0.0017 | 0.0015 | | |
| | High hazard | 0.0011 | 0.0023 | 0.9743 | 0.9460 |
| | Low hazard 2 | 0.0034 | 0.0040 | | |
| | Buy and hold | -0.0001 | 0.0014 | | |
| Equity | Low hazard 1 | 0.0060 *** | 0.0020 | | |
| | High hazard | 0.0105 *** | 0.0021 | 0.0033 | 0.0022 |
| | Low hazard 2 | -0.0075 | 0.0062 | | |
| | Buy and hold | 0.0084 *** | 0.0014 | | |
| | Obs | 2951 | | Joint test | Joint test |
| | R2 | 0.0771 | | 0.0168 | 0.0158 |

**Table 4:** Strategy Alphas - Robustness

| **Panel A: Betas** | | Alpha | Rm-Rf | SMB | HML | Obs | R2 |
|---|---|---|---|---|---|---|---|
| Cash | Low 1 | 0.0001 | 0.2209 *** | 0.1594 *** | 0.0862 | | |
| | | (0.002) | (0.046) | (0.039) | (0.073) | | |
| | High | 0.0063 *** | 0.2935 *** | 0.2096 *** | 0.1565 * | | |
| | | (0.002) | (0.066) | (0.059) | (0.086) | | |
| | Low 2 | -0.0006 | 0.1516 | 0.1472 | 0.0607 | | |
| | | (0.004) | (0.115) | (0.123) | (0.152) | | |
| Equity | Low 1 | 0.0068 *** | -0.1046 *** | 0.0954 ** | 0.0146 | 2194 | 0.0675 |
| | | (0.002) | (0.034) | (0.043) | (0.051) | | |
| | High | 0.0147 *** | -0.1179 * | 0.0805 | -0.0224 | | |
| | | (0.002) | (0.059) | (0.061) | (0.080) | | |
| | Low 2 | -0.0035 | -0.0123 | 0.0236 | 0.0720 | | |
| | | (0.006) | (0.013) | (0.017) | (0.159) | | |

| **Panel B: Tests on Betas** | | Rm-Rf | SMB | HML |
|---|---|---|---|---|
| Cash | High > Low 1 | 0.1639 | 0.2000 | 0.2245 |
| | High > Low 2 | 0.1468 | 0.3016 | 0.2926 |
| Equit | High > Low 1 | 0.9229 | 0.9170 | 0.8429 |
| | High > Low 2 | 0.9847 | 0.1963 | 0.7990 |

| **Panel C: Rm-Rf < -3%** | | Avg. Ret. | Alpha | Rm-Rf | SMB | HML | Obs | R2 |
|---|---|---|---|---|---|---|---|---|
| Cash | Low 1 | -0.0141 | 0.0148 * | 0.3835 *** | 0.2356 ** | -0.0782 | | |
| | | (0.004) | (0.008) | (0.095) | (0.101) | (0.176) | | |
| | High | -0.0108 | 0.0188 *** | 0.4281 *** | 0.2493 ** | 0.034 | | |
| | | (0.004) | (0.007) | (0.119) | (0.110) | (0.167) | | |
| | Low 2 | -0.0109 | 0.0209 | 0.4345 | -0.1421 | -0.2636 | | |
| | | (0.011) | (0.024) | (0.357) | (0.336) | (0.275) | | |
| Equity | Low 1 | 0.0149 | 0.0122 * | -0.0491 | 0.3149 *** | 0.2067 ** | 405 | 0.2093 |
| | | (0.003) | (0.006) | (0.107) | (0.095) | (0.095) | | |
| | High | 0.0226 | 0.0204 ** | -0.0906 | 0.1904 | -0.0546 | | |
| | | (0.005) | (0.008) | (0.149) | (0.148) | (0.156) | | |
| | Low 2 | -0.0122 | -0.0855 | -1.2620 * | 0.1672 | -0.0236 | | |
| | | (0.015) | (0.057) | (0.755) | (0.308) | (0.345) | | |

| **Panel D: Other Risk Factors** | | Stdev returns | Alphas | UMD | OTM Call | OTM Put | Min return | Max return |
|---|---|---|---|---|---|---|---|---|
| Cash | Low 1 | 0.0279 | -0.0008 | -0.0174 | -0.0066 *** | -0.0039 | -0.132 | 0.220 |
| | | | (0.002) | (0.030) | (0.002) | (0.003) | | |
| | High | 0.0365 | 0.0067 *** | -0.1447 ** | -0.0054 | 0.001 | -0.109 | 0.401 |
| | | | (0.002) | (0.062) | (0.004) | (0.004) | | |
| | Low 2 | 0.0550 | -0.0009 | -0.0589 | -0.0001 | -0.0053 | -0.247 | 0.240 |
| | | | (0.005) | (0.108) | (0.007) | (0.007) | | |
| Equity | Low 1 | 0.0335 | 0.0085 *** | -0.0069 | -0.0009 | 0.0000 | -0.137 | 0.346 |
| | | | (0.002) | (0.049) | (0.003) | (0.004) | | |
| | High | 0.0496 | 0.0154 *** | 0.0447 | 0.0032 | -0.0022 | -0.217 | 0.403 |
| | | | (0.003) | (0.049) | (0.006) | (0.004) | | |
| | Low 2 | 0.0420 | -0.0046 | 0.0508 | 0.0016 | -0.0066 | -0.169 | 0.096 |
| | | | (0.007) | (0.111) | (0.009) | (0.006) | | |
| | Market | 0.0545 | | | | | -0.231 | 0.124 |

**Table 5:** Strategy Betas

| **Dep Var: Betas** | Rm - Rf | SMB | HML |
|---|---|---|---|
| Weekly hazard x Cash | -0.454 | -0.488 | -0.676 |
| | (0.687) | (1.056) | (1.139) |
| Weekly hazard x Equity | -0.039 | 0.425 | -0.128 |
| | (0.460) | (0.062) | (0.066) |
| Merger type dummies | Y | Y | Y |
| Obs | 96 | 96 | 96 |
| R2 | 0.35 | 0.01 | 0.02 |

**Table 6:** Time-varying Betas

# Appendix

## Proof of Proposition 1

*Suppose that the true hazard rate of completion for firm $i$ is $h_i(t) = \alpha_i h(t)$, where $h(t)$ is the common component and $\alpha_i$ is a firm-specific unobservable parameter distributed in the cross-section according to the distribution function $G(\alpha)$ with mean 1. Suppose also that $h(0) = h(T) = 0$. Then, we have*

$$E_\alpha[\alpha h(t)] = h(t) > h_\theta(t)$$

*where $h_\theta(t)$ is the* measured *hazard rates ignoring the unobserved heterogeneity. Since $h(0) = h(T) = 0$, $h(t)$ has to be more time-varying than $h_\theta(t)$.*

Proof: Write

$$h_\theta(t) = \frac{\int_0^\infty -\alpha S(t)^{\alpha-1} S'(t) g(\alpha) d\alpha}{\int_0^\infty S(t)^\alpha g(\alpha) d\alpha}$$

and

$$h(t) = E_\alpha(\alpha h(t)) = \int_0^\infty -\alpha S(t)^{-1} S'(t) g(\alpha) d\alpha$$

Now,

$$E_\alpha(\alpha h(t)) = \int_0^\infty -\alpha S(t)^{-1} S'(t) g(\alpha) d\alpha = \int_0^\infty \frac{-\alpha S(t)^{\alpha-1} S'(t)}{S(t)^\alpha} g(\alpha) d\alpha$$

For ease of notation call

$$X = -\alpha S(t)^{\alpha-1} S'(t)$$

$$Y = S(t)^\alpha$$

with $E[Y] > 0$ since $S(t) > 0$ and $\alpha > 0$. We have:

$$E_\alpha(\alpha h(t)) = E[\frac{X}{Y}]$$

$$h_\theta(t) = \frac{E[X]}{E[Y]}$$

Now define $Cov(\frac{X}{Y}, Y) = E[X] - E[\frac{X}{Y}]E[Y]$.

$$Cov(\frac{X}{Y}, Y) = Cov(-\alpha S(t)^{-1}S'(t), S(t)^{\alpha}) < 0$$

since: $S(t)^{-1} > 0$, $S'(t) < 0$ and $Cov(\alpha, S(t)^{\alpha}) < 0$ ($S(t)^{\alpha}$ is decreasing in $\alpha$ since $S(t) < 1$).

So this implies

$$E[\frac{X}{Y}]E[Y] > E[X]$$

and since $E[Y] > 0$ we can write:

$$E[\frac{X}{Y}] > \frac{E[X]}{E[Y]}$$

or:

$$E_{\alpha}(\alpha h(t)) > h_{\theta}(t)$$

# Appendix Figures

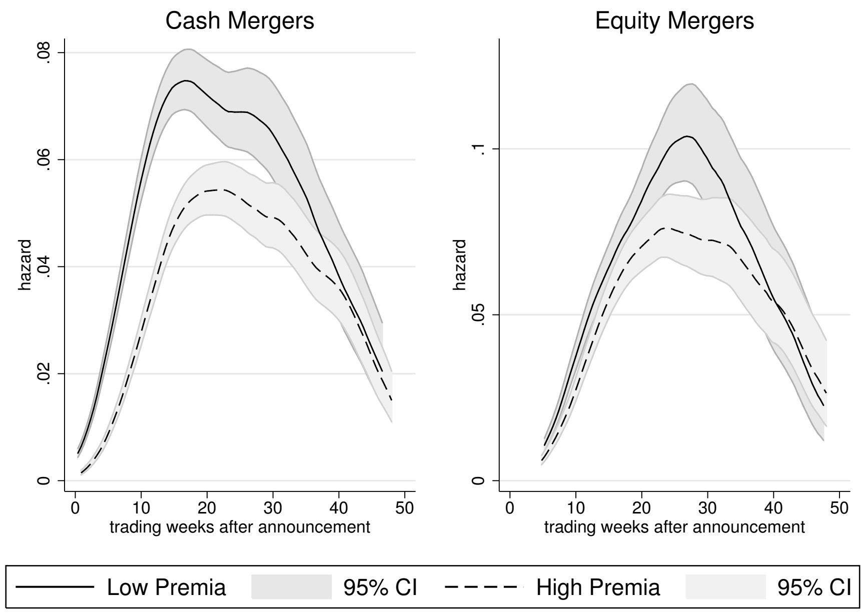


**Figure 11:** Hazard Rates by Premia (2 Days After Announcement)

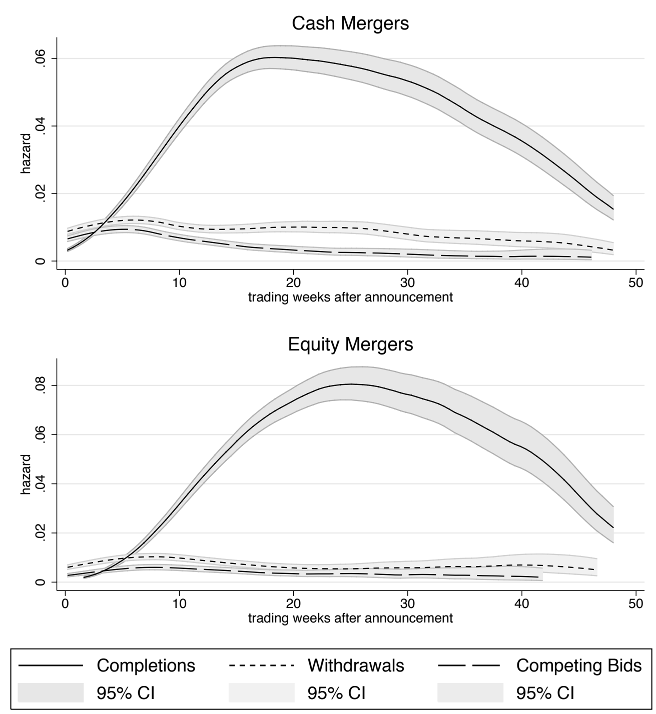


**Figure 12:** Hazard Rates of Completion, Withdrawal, and Competing Bids