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## An Empirical Study of Factors Relating to the Success of Broadway Shows\*

### I. Introduction

The Broadway theater is one of the most important arts and entertainment industries in the world; indeed, the Broadway musical is commonly considered one of the few truly American art forms. Located in and around Times Square in New York City, the roughly 35 legitimate Broadway theaters form the backbone of one of the most highly concentrated entertainment districts in the world (along with London's West End).

Besides its cultural importance, the production of dramas, comedies, and musicals on Broadway is big business. According to data provided by the League of American Theatres and Producers given on the *Playbill* Web site (<http://www.playbill.com>), more than 11 million tickets were sold for Broadway shows in 1999, leading to more than \$550 million in gross revenues. This does not take into account ancillary revenues from souvenirs, cast albums, and so on, or the hundreds of millions of dollars in tourism revenue generated by the industry. While the payoff from a successful Broadway play can be high, so are the risks. A Broadway musical can cost as much as \$10 million to produce (according to Jujamcyn Theaters president

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This article uses the Cox proportional hazards model to analyze recent Broadway show data to investigate the factors that relate to the longevity of shows. The type of show, whether a show is a revival, and first-week attendance for the show are predictive for longevity. Favorable critic reviews in the *New York Daily News* are related to greater success, but reviews in the *New York Times* are not. Winning major Tony Awards is associated with a longer run for a show, but being nominated for Tonys and then losing is associated with a shorter postaward run.

Rocco Landesman, as quoted in the *New York Times* on April 29, 1999 [Pogrebin 1999]), with few guarantees of success. Many shows close after only a few performances, resulting in total losses for investors.

While the motion picture industry has been the subject of several empirical investigations recently, relatively little research has been done on the Broadway stage. The Broadway stage shares with the movie industry the atypical, but key, characteristic that demand is unpredictable, since audiences do not know if they will like a product until they actually experience it (as De Vany and Walls [1996, p. 1493] put it, “audiences make hits or flops, and they do it, not by revealing preferences they already have, but by discovering what they like”). For this reason, information transfer to the potential audience is crucial in the ultimate success of a show (or a film).

Several factors that represent potential information sources have been found to be associated with success in studies of the film industry. These include the genre (action, comedy, etc.) of the film (Wallace, Seigerman, and Holbrook 1993; Sawhney and Eliashberg 1996; Neelamegham and Chintagunta 1999; Ravid 1999; Simonoff and Sparrow 2000), the Motion Picture Association of America rating of the film (Wallace et al. 1993; Sawhney and Eliashberg 1996; Ravid 1999; Simonoff and Sparrow 2000), critical reviews (Hirschman and Pieros 1985; Sawhney and Eliashberg 1996; Eliashberg and Shugan 1997), Academy Award nominations and wins (Hirschman and Pieros 1985; Dodds and Holbrook 1988; Ravid 1999; Simonoff and Sparrow 2000), measures of “star power” (Wallace et al. 1993; Neelamegham and Chintagunta 1999; Ravid 1999; Simonoff and Sparrow 2000), whether or not the movie was a sequel (Sawhney and Eliashberg 1996; Ravid 1999), first week’s revenue (Sawhney and Eliashberg 1996; Simonoff and Sparrow 2000), and the budget for the film (Ravid 1999; Simonoff and Sparrow 2000).

There is also a key difference between the Broadway stage and film industry in that, for the former at any given time, supply is fixed and local rather than flexible and geographically diverse. Thus, recent research into the dynamics of movie success that is dependent on the supply of movie screens being flexible and adaptive (e.g., De Vany and Eckert 1991; De Vany and Walls 1996) is not relevant here.

Measuring success of a Broadway play is more difficult than for a movie, since potential revenues are very different for different types of shows (Broadway theaters range in size from 499 to almost 2,000 seats). In addition, while all movies close within a few months, some Broadway shows stay open for many years, making it difficult to measure ultimate success (some movies do, of course, have ongoing revenue streams from video sales and rentals and foreign release). The only systematic study of the determinants of success of Broadway shows is Reddy, Swaminathan, and Motley (1998). Two measures of success, the number of performances and cumulative attendance, were examined. They found that critic reviews (particularly those in the *Times*), preopening advertising in the *Times*, show type, and timing of the opening

of the show were significant predictors of the longevity (number of performances) of the show.

The study by Reddy et al. (1998) exhibits several weaknesses. The data are quite old, coming from 1980 to 1982; given the major changes in the entertainment industry in general, and in the Times Square area in particular, it is reasonable to suppose that determinants of Broadway success might have changed. Cumulative attendance was restricted to, at most, 26 weeks of data for each show, and the size of the theater was not taken into account. Longevity was modeled using ordinary linear regression, which is clearly inappropriate for this type of variable, as is discussed in the next section (one simple way to see this is that a linear regression model allows a negative predicted number of performances, which is, of course, impossible). Further, the effect of awards (such as the Antoinette Perry [Tony] Award) was not investigated.

This article is organized as follows. In Section II, the data are described, as are the survival analysis methods used to analyze them. Section III gives the results of the analyses. Section IV concludes the article.

## II. Data, Models, and Methodology

The data constitute a census of shows eligible for the Tony Awards opening on Broadway for a 3-year period (the 1996–97 through 1998–99 seasons), which are then followed until the end of the 1999–2000 season on May 3, 2000 (the traditional end of the season corresponds to the last day of eligibility of a show for the Tony Awards). The response variable of interest is the total number of performances of the show. Since seven of the shows had not closed by the end of the 1999–2000 season, the number of performances for these shows is censored (i.e., all that is known for these shows is that the number of performances is at least the observed value), which must be accounted for in the analysis (simply omitting the observations is inappropriate, since they contain partial information on longevity and are systematically relatively long-lived, having already survived at least one full Broadway season). The presence of censored values makes analysis of show longevity particularly natural, since there is a very well developed statistical machinery for modeling survival data with censored observations. Since a show's total revenue and its longevity are very strongly related (despite the differences in theater size and ticket prices between shows, the correlation of logged total revenue and logged total number of performances in these data is .943), all of the results reported here can be interpreted implicitly in terms of show revenues. Four shows ("Eugene Onegin," "Into the Whirlwind," "The Cherry Orchard," and one production of "The Three Sisters") were contractually limited to very few performances, and these are not included in the data analyses, resulting in data for 91 shows.

Critical opinion on the shows comes from reviews from the *New York Times* and the *New York Daily News*. Reddy et al. (1998) discussed the potential importance of critic reviews to consumers of a good such as a

Broadway show. The theater is an experiential good (one that people choose and use solely for the experience of pleasure). Since such an experience would typically be limited to one (or few) experiences, consumers seek to minimize risk by obtaining information from external sources. Critic reviews provide such information both experientially (conveying the feel of the theater-going experience) and objectively (information about the cast, plot, and genre of the show), and, if the critic is viewed as unbiased, his or her opinions can be persuasive. Further, a critic with tastes similar to those of the potential audience would tend to predict success or failure well, even if the reviews did not have a direct causal effect on that success or failure.

Since these reviews do not give numerical ratings of the shows, three doctoral students with an interest in the Broadway theater were used as judges to quantify the evaluations in the reviews. The judges read and rated each review independently on a scale from 1 (poor evaluation) to 5 (high evaluation). The instructions provided to the judges were identical to those used in Reddy et al. (1998). The correlations between the ratings of the three judges for the *Times* reviews ranged from .829 to .872, while those for the *Daily News* reviews ranged from .853 to .887. Given this high level of interrater reliability, the ratings for each newspaper are taken to be the average of the ratings for the three judges.

Following Reddy et al. (1998), the type of show is used as a potential predictor of show longevity. Shows were classified into the three broad categories used in the On Broadway Web site—play, musical, or musical revue—and were identified as a revival, or not. Such classifications are usually unambiguous, although in unusual circumstances the Tony Awards administration committee determines categories for Tony Award eligibility. Show type might be predictive for show success for several reasons. As noted earlier, many studies have found movie genre to be predictive of success. Musicals are considerably more expensive to produce than other shows, and such increased production values might appeal to consumers. Musicals also typically charge higher ticket prices than other types of shows, so a producer might keep a musical open longer to try to recover more of the initial fixed cost (if, e.g., weekly revenues are disappointing, but still exceed weekly costs).<sup>1</sup> By definition, a revival of a show gets a stamp of approval from having appeared on Broadway before, a potentially positive signal to consumers.

Initial audience reaction to the show was quantified using the percentage of available seats sold during the first week of the run, as reported by the League of American Theatres and Producers. Besides being a potential indicator to a show's producers of future revenues, first week's attendance is a

1. Musicals tend to be produced in larger theaters (averaging almost 1,400 available seats per performance vs. roughly 1,000 available seats per performance for other types of shows) and tend to earn higher revenues per seat (roughly \$36 per seat vs. roughly \$28 per seat), translating into much higher revenues per performance (roughly \$50,000 per performance vs. roughly \$27,000 per performance).

good indicator of the effectiveness of preopening publicity, since most Broadway show tickets are bought in advance.

The importance of awards' effect on the success of a show is assessed by Tony Award nominations and wins in the major categories of best musical and best play (revival and nonrevival), best director (musical and play), leading actor and actress (musical and play), and featured actor and actress (musical and play). In much the same way as critic reviews, winning or not winning the most important of Broadway theater awards is a powerful information source on the potential for customers to enjoy the show. Nominations and awards are also likely to be indicative of the overall talent level of the people involved in the show and, of course, of the quality of the show itself.

The nature of the Tony Awards—and their impact on Broadway productions—affects the way show success should be measured. Shows will often be kept open until Tony nominations are announced; troubled shows that are nominated benefit from related advertising, while those that are not nominated close quickly. In an extreme example, when the 1999 show “Rollin’ on the T.O.B.A.” lost its appeal even to be considered for the Tony Awards, it closed 3 days later (Pogrebin 1999). Shows that are nominated usually will be kept open until the awards are given; once again, while winners will often see increases in box office receipts and might benefit from awards-related advertising, losers often close almost immediately (McKinley 1999).

Thus, the total number of performances of a show can be related to its opening date in a way that has nothing to do with audience approval of the show. A troubled show that opens in February or March stays open several weeks (and dozens of performances) longer than one that opens in April, simply because it has longer to wait before Tony nominations or awards are announced. For this reason, longevity will be defined here in three distinct ways: total number of performances from opening night, total number of performances after the announcement of Tony Award nominations, and total number of performances after the announcement of Tony Award winners. For each of these targets, the connection with seasonal effects (time of year of opening) will also be investigated (Radas and Shugan [1998], Ravid [1999], and Simonoff and Sparrow [2000] found seasonal effects in movie success).

The longevity of a show can be viewed as its “survival time,” and statistical models and methods designed for such data should be used to study it. The data for each show are a triple,  $(t, c, \mathbf{x})$ . Here  $t$  is the number of performances until either the show closes or the end of the 1999–2000 season. The value  $c$  is an indicator of whether the observed value  $t$  is an actual survival time (because the show has closed;  $c = 1$ ) or is a censored value (because the show is still open at the end of the study;  $c = 0$ ). In the latter case only partial information is available (i.e., that the show's total number of performances is unknown but is at least  $t$ ). The values  $\mathbf{x}$  represent values of the predictor variables for the show.

Survival data of this type can be analyzed in nonparametric, semiparametric,

or fully parametric ways (for a full discussion of different methods, see Hosmer and Lemeshow [1999]). These methods are based on a few key properties of the survival process. The survival function  $S(t)$  satisfies

$$S(t) = P(T \geq t) = \int_t^{\infty} f(x)dx,$$

where  $f(\cdot)$  is the density function of the survival time. The hazard function  $h(t)$  is the instantaneous risk of failure (i.e., the show closing), given that it has survived to time  $t$  and satisfies

$$h(t) = f(t)/S(t).$$

A flexible approach to modeling survival as a function of covariates (and the most common approach) is the proportional hazards model, sometimes called the Cox model (Cox 1972). In this model the hazard function  $h(t, \mathbf{x}, \beta)$  is modeled as satisfying

$$h(t, \mathbf{x}, \beta) = h_0(t)e^{\mathbf{x}\beta}. \quad (1)$$

This is a semiparametric model in that the baseline hazard function  $h_0(t)$  is not specified, which allows for a wide variety of possible survival functions. This baseline hazard corresponds to that when each of the covariates equals zero, or equivalently (if the predictors are treated as centered in the analysis, as is typical) when they each equal their mean value. The model implies that hazard functions for different  $\mathbf{x}$  values are multiplicatively related, or equivalently that

$$S(t, \mathbf{x}, \beta) = [S_0(t)]^{\exp(\mathbf{x}\beta)},$$

where  $S_0(\cdot)$  is the baseline survival function. This model postulates an exponential effect of a covariate on the per show closing rate, holding all else in the model fixed (or, equivalently, a linear effect of a covariate on the logged closing rate). This exponential relationship is more reasonable than a linear one, given the nonnegativity of survival times and the typically observed right-tailedness of survival times. This is certainly true of Broadway show longevity; in the data set used here, more than half of the shows closed after 10 or fewer performances, while six had more than 800 performances. Figure 1 gives a histogram of the total number of performances for the shows. The values for the seven shows that had not closed by May 3, 2000, are marked with an X, so the actual total number of performances for those shows until closing is, in fact, larger than the recorded values. The long right tail in the histogram reflects the expected pattern for lifetime data.

Parameter estimates in the proportional hazards model are estimated by maximizing the partial likelihood function. Hypotheses regarding individual parameters are tested using Wald tests, while the overall significance of the regression relationship is tested using a (partial) likelihood ratio test (results using partial likelihood ratio tests for the individual parameters were similar

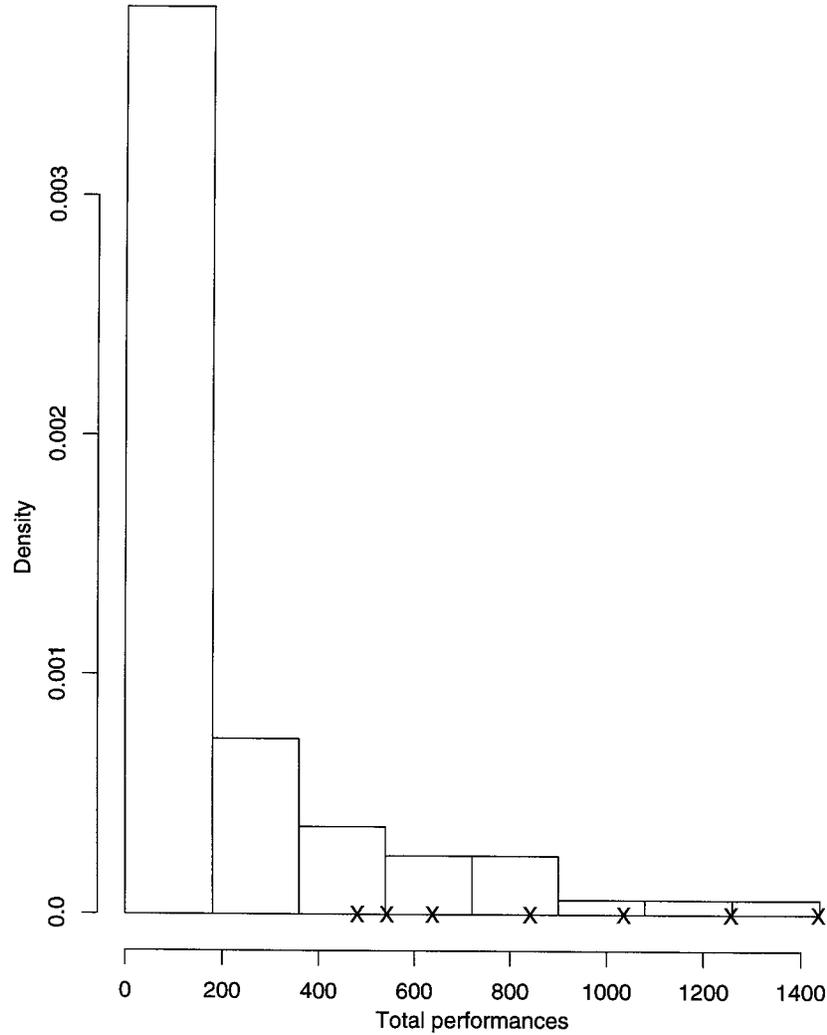


FIG. 1.—Histogram of observed total number of performances for each show. Numbers for shows that had not closed by May 3, 2000, are marked with an X.

to those using the Wald tests). The baseline survival function  $S_0(t)$  can be estimated using the partial likelihood, resulting in graphical representations of the regression relationship and estimated survival times for specific shows.

A useful generalization of the proportional hazards model (1) is the stratified proportional hazards model. Consider a show characteristic defined by a nominal variable, such as show type (i.e., musical, musical revue, or play). The model (1) assumes that, given the other covariates, the hazard function for, say, musicals is a constant multiple of that for, say, musical revues for all

TABLE 1 Results of Proportional Hazards Model Fit

Variable	Coefficient	exp(Coefficient)	$z$	$p$
Type of show:				
Musical	-.9747	.377	-3.12	.002
Musical revue	-.8568	.425	-1.72	.086
Revival	.2592	1.296	.98	.350
Opens in July	2.7227	15.221	3.16	.002
First-week attendance	-.0174	.983	-2.39	.017
<i>Daily News</i> review	-.2642	.768	-2.25	.025
<i>New York Times</i> review	.0482	1.049	.38	.700
Tony nominations	.0438	1.045	.47	.640
Tony Awards	-.5293	.589	-2.78	.005

NOTE.—Target variable is the total number of performances. Predictors include two indicator variables identifying the type of show (musical and musical revue), an indicator variable identifying if the show was a revival, a seasonality effect represented by an indicator variable identifying if the show opened in July (the only monthly indicator variable that was statistically significant), the percentage of seats sold in the first week, review ratings in the *New York Daily News* and the *New York Times*, the number of Tony nominations in the major categories, and the number of Tony Awards in the major categories. The entries under “exp(Coefficient)” are the multiplicative effect of a one-unit increase of the predictor on the hazard function given the other variables are held fixed.  $z$  refers to the Wald test of significance of the coefficient, with  $p$  the associated two-tailed significance level. The partial likelihood ratio test  $LR$  is compared with a  $\chi^2$  random variable on the appropriate number of degrees of freedom and tests the overall significance of the predictors. Overall significance:  $LR = 54.2$  on 9 degrees of freedom ( $p = 2 \times 10^{-8}$ ).

times  $t$ . This might not be the case, and the resultant nonproportionality of hazards means that the partial maximum likelihood estimates are no longer meaningful.

A simple way to address this nonproportionality is the stratified proportional hazards model, which postulates different baseline hazard functions for the different levels of the nominal variable (i.e., for each type of show). For this model, the hazard function satisfies

$$h_s(t, \mathbf{x}, \beta) = h_{s0}(t)e^{\mathbf{x}\beta}, \quad (2)$$

where  $h_{s0}(\cdot)$  is the baseline hazard for level  $s$ . Under this model, the effect of being in level  $s$  can be summarized using, for example, the median baseline survival time, while the regression coefficients are interpreted as multiplicative effects on the hazard as always.

### III. Results

#### A. Total Number of Performances

In this section we describe analysis of the total number of performances of the Broadway shows. Table 1 summarizes the results of the model fitting. First-week attendance was not available for two shows (“More to Love” and “Rollin’ on the T.O.B.A.”), and one show (“Summer and Smoke”) was not reviewed in the *Daily News*, leaving 88 shows in the sample. It should be remembered that it is hazard that is being modeled, so a positive coefficient implies an increased risk of a show closing and, hence, a shorter expected survival time.

The table shows that the model provides significant predictive power for

the risk of a show closing, as the partial likelihood ratio test of overall significance is highly significant. The type of show is significantly related to show survival, with (as expected) musical shows surviving longer than plays. Specifically, given the other variables, the hazard for a musical is 62.3% lower than for a play, and is 57.5% lower for a musical revue than for a play. This reflects the great success of shows such as “Cabaret,” “Chicago,” “Jekyll and Hyde,” “Ragtime,” “The Lion King,” and “Titanic,” each of which had more than 800 performances (no play had more than 600 performances). In contrast, whether or not a show is a revival is not a significant factor in survival, suggesting that this form of a stamp of approval does not influence consumer behavior.

The only component of the seasonal effect of opening month that is significantly associated with survival is whether or not the show opened in July, with a July opening increasing the hazard by a factor of more than 15. While this is not necessarily unexpected (the New York social scene moves to eastern Long Island during the summer, so shows with a high profile are unlikely to open in July), caution is warranted here, since only two shows in the sample opened in July (“A Thousand Clowns” and “Twelfth Night”), both of which closed quickly. A better indication of the feelings of Broadway producers about summer openings is that only nine shows opened on Broadway during the months May through September of 1997–99, an average of less than one show per month. Thus, it appears that producers consider seasonal patterns when deciding when to introduce a show, decreasing the likelihood of a strong seasonal effect on longevity.

Initial customer reaction to a show (perhaps driven by reaction to preopening publicity) is directly related to show success, as expected. Each additional percentage point of attendance (as a percent of total available seats) is associated with a 1.7% decrease in hazard, given the other variables. While initial success of the show is thus somewhat indicative of longevity of the show, it is far less important than the corresponding figures for movies were in Simonoff and Sparrow (2000), for example. The far more extensive (and expensive) advertising campaigns mounted for many movies compared with those for Broadway shows is an obvious potential explanation of this.

As expected from the arguments given earlier, critic reviews can be important in predicting longevity of a show, but the results here are different from those of Reddy et al. (1998) in an important way. A positive review in the *Daily News* is associated with a significantly more successful show, as a rating one point higher is associated with a 23.2% drop in the hazard, given the other variables. On the other hand, reviews in the *Times* are not at all related to show longevity.

Given that the *Times* review was the most important predictor of longevity found by Reddy et al. (1998) for the 1980–82 data, this result is worth further discussion. It is possible that this is merely reflecting a lack of power of the Wald test for the *Times* review, but this seems unlikely, given the strong statistical significance of the *Daily News* review (as was noted earlier, results

using the partial likelihood ratio test were similar). It is possible that the relationship between longevity and the *Times* review is too complex to be identified using model (1). Still, while there seems little doubt that in the past an unfavorable review in the *Times* was viewed as devastating to a show (Loney [1990] provides several examples of the tremendous influence of those reviews, referring to *Times* critics as “the Butchers of Broadway”), there were many shows in 1997–99 that got poor reviews in the *Times* but were very successful.<sup>2</sup> Similarly, several shows getting very positive reviews closed very quickly.<sup>3</sup> This result, seemingly surprising, given previous research, is actually not so surprising if recent popular press is examined. Consider the statement of author Alfred Uhry upon his Tony nomination for “The Last Night of Ballyhoo,” despite a mediocre review in the *Times*: “It’s nice to know that not getting a good review in the *New York Times* is not as awful as it once was” (Hulbert 1997). Reddy et al. (1998, p. 374) refer to this as evidence of celebrating an exception to “the awesome influence of the *New York Times* critic,” but, given the results we have found here for the same time period, it seems rather to support recognition among Broadway professionals that a negative review in the *Times* is no longer the kiss of death for their shows.<sup>4</sup>

Winning awards also seems to be associated with show longevity. Although the number of Tony Award nominations in major categories is not predictive for the risk of a show closing, the actual number of awards is, with each additional award associated with a 41.1% decrease in the hazard given the other variables. This might reflect the inherently higher quality of the show, greater opportunities for positive advertising, and/or the presence of a positive information source for potential attendees.

As is true for any statistical model, inferences from the proportional hazards model are valid only if the model assumptions hold. Two key tasks in fitting such models are to check if there are any outliers (shows whose longevity is strongly out of line with what is expected), and whether the proportional

2. Shows that received unfavorable reviews in the *Times* include “Footloose” (639+ performances), “Jekyll and Hyde” (1,257+ performances), “The Scarlet Pimpernel” (772+ performances), and “Titanic” (804 performances).

3. Shows that received favorable reviews in the *Times* include “Ah, Wilderness!” (40 performances), “Honour” (57 performances), “Hughie” (56 performances), “Ivanov” (51 performances), and “Juan Darién: A Carnival Mass” (41 performances).

4. Two quotes can illustrate the apparent disconnect between the views of *New York Times* critics and the public. *Times* critic Ben Brantley, in a June 6, 1999, article, lamented that “the suspicion has been hovering for several decades, now, that the once-sophisticated mecca of American theater is really just a mall in Squaresville: a forum for automated theme park shows, with doses of high culture provided by visitors from more adventurous places.” Contrast this with the observation of columnist Liz Smith in her March 26, 2000, column in *Newsday* that “theater critics like to tear apart the spectacular productions of Disney-on-Broadway (‘Beauty and the Beast’ and ‘The Lion King,’ for instance).” But “a powerful company, so rich in advertising bucks and so creative and market-wise, is able to override any negative slam those once-poor and ink-stained (now carpal-tunnel-syndromed) wretches can write, thus rendering the once all-powerful critics useless and anachronistic.” Whether in the past poor reviews in the *Times* caused the failure of a show (as was generally believed), or merely predicted it, it seems clear that now neither is the case.

hazards assumption holds. For these data, three shows show up as unusual, having greater longevity than expected, but removing the shows from the data set does not change the results in any important way.<sup>5</sup> There is also evidence of nonproportional hazards related to the type of show. A stratified proportional hazards model fit (stratified on type of show) yields results very similar to the unstratified analysis.<sup>6</sup>

### B. Number of Performances after Tony Nominations

In this section we examine longevity of a show after the announcement of Tony Award nominations. As was noted earlier, it is commonly believed that Tony nominations and Awards are crucial for the survival of Broadway shows (especially troubled shows), so some shows might survive longer than expected just to try to make it to the awards announcements. Postnomination and postawards analyses remove this potential source of bias.

Table 2 summarizes the results of a proportional hazards model fit. For these data there is no seasonal (opening month) effect included, since none of the underlying indicator variables were close to statistically significant. In addition, the show type effect is represented only by an indicator variable for musicals, thereby pooling musical revues and plays together. Audience re-

5. Since the target variable here includes censored observations, and the proportional hazards model attempts to fit the hazard function, rather than show longevity directly, there is no unambiguous definition of residuals for the model. One commonly used set of residuals is the martingale residuals,

$$e_i = c_i - \hat{H}(t_i, \mathbf{x}_i, \hat{\beta}),$$

where  $\hat{H}(t_i, \mathbf{x}_i, \hat{\beta})$  is the estimated cumulative hazard at time  $t_i$ . The martingale residual estimates a function that has mean zero if the model is correct, with positive values corresponding to shows that closed earlier than expected and negative values corresponding to shows that closed later than expected. Three shows had notable (negative) martingale residuals: “Footloose” (639+ performances for a musical with no Tony Awards, 70% first-week attendance, and a poor review in the *Daily News*, implying an expected longevity of 175 performances), “Jackie: An American Life” (128 performances for a play with no Tony Awards, 35% first-week attendance, and a poor review in the *Daily News*, implying an expected longevity of 59 performances), and “Jekyll and Hyde” (1,257+ performances for a musical with no Tony Awards, 68% first-week attendance, and a good review in the *Daily News*, implying an expected longevity of 310 performances). If these three shows are omitted from the sample, the effects that were statistically significant remain so (and become slightly stronger), while those that were not statistically significant remain insignificant. Thus, the three outliers do not substantively affect the implications of the analysis. The martingale residuals also do not exhibit any autocorrelation, supporting the assumption of independence of the survival observations in the sample.

6. The proportional hazards model (1) implies that the effect of a covariate on the hazard function is the same at all times. Grambsch and Therneau (1994) proposed testing this assumption via the specific form of time-varying coefficient

$$\beta_j(t) = \beta_j + \gamma_j g_j(t),$$

where  $g_j(t)$  is a specified function of time such as the identity, logs, or ranks. Proportional hazards correspond to  $\gamma_j = 0$  for all  $j$ , and each coefficient is tested using a score test. The score test here indicates nonproportionality linked to the type of show, which can be accounted for by fitting a model stratified on the type of show. The coefficients of the covariates in the stratified model are virtually identical to those for the unstratified model, and the model no longer exhibits significant nonproportionality of hazards.

TABLE 2 Results of Proportional Hazards Model Fit

Variable	Coefficient	exp(Coefficient)	<i>z</i>	<i>p</i>
Musical	-1.5750	.207	-3.85	<.001
Revival	.7106	2.035	2.09	.037
Attendance after nominations	-.0178	.982	-1.92	.055
<i>Daily News</i> review	-.3242	.723	-2.00	.046
<i>New York Times</i> review	.0018	1.002	.01	.990
Tony nominations	.1492	1.161	1.24	.210
Tony Awards	-.5052	.603	-2.41	.016

NOTE.—Target variable is the number of performances after the announcement of Tony Award nominations. Predictors include a show-type effect represented by an indicator variable identifying if the show was a musical (the only indicator needed to define the statistical extent of the effect), an indicator variable identifying if the show was a revival, the percentage of seats sold in the week after the announcement of nominations, review ratings in the *New York Daily News* and the *New York Times*, the number of Tony nominations in the major categories, and the number of Tony Awards in the major categories. Overall significance:  $LR = 42.1$  on 7 degrees of freedom ( $p = 5 \times 10^{-7}$ ).

action to the show and the effect of Tony nominations on attendance are quantified using the percentage of seats sold in the week after the announcement of the nominations.<sup>7</sup> There were a total of 57 shows open at the time of Tony Award nominations. The partial likelihood ratio test indicates strong predictive power of the covariates for hazard ( $p = 5 \times 10^{-7}$ ).<sup>8</sup>

The most striking pattern in table 2 is its similarity with table 1. Musicals are more successful than other shows, having a 79.3% lower risk of closing given the other variables. Attendance in the week after nominations are announced is predictive for survival, with an additional percentage point of seats filled associated with a 1.8% decrease in the hazard of closing holding all else fixed. Once again positive reviews in the *Daily News* are associated with increasing longevity, while reviews in the *Times* are not at all related to show success. Similarly, while the number of Tony nominations in major categories is unrelated to hazard, each additional Tony Award is associated with a 39.7% decrease in the risk of the show closing, given the other predictors.

Two differences between tables 1 and 2 are worth noting. First, there is no evidence of a seasonal (opening month) effect for postnomination longevity. This is actually not surprising, given that the only effect for total longevity was related to opening in July, and neither of the two shows that opened in July were still open at the time of Tony Award nominations, more than 8 months later. The other difference is that whether or not a show is a revival is a statistically significant predictor for hazard, with revivals having more than twice the risk of closing, given the other variables. Another way of

7. If first-week attendance is included in the model, it provides no additional predictive power, so attendance in the week after the nominations (reasonably) seems to be the appropriate attendance predictor for postnomination longevity.

8. None of the shows were outlying relative to the proportional hazards model for postnomination performances, according to the martingale residuals. The martingale residuals also do not exhibit any autocorrelation. Tests of nonproportionality of hazards also did not indicate any problems with model assumptions.

TABLE 3 Results of Proportional Hazards Model Fit

Variable	Coefficient	exp(Coefficient)	<i>z</i>	<i>p</i>
Musical	-1.8225	.162	-3.94	<.001
Revival	1.2494	3.488	2.86	.004
Attendance after nominations	-.0413	.960	-2.50	.012
Attendance after awards	.0254	1.026	1.40	.160
<i>Daily News</i> review	-.3167	.729	-1.73	.083
<i>New York Times</i> review	-.0132	.987	-.07	.950
Losing Tony nominations	.2586	1.295	1.81	.070
Tony Awards	-.3868	.679	-1.97	.048

NOTE.—Target variable is the number of performances after the announcement of Tony Award winners. Predictors include a show-type effect represented by an indicator variable identifying if the show was a musical (the only indicator needed to define the statistical extent of the effect), an indicator variable identifying if the show was a revival, the percentage of seats sold in the week after the announcement of nominations, the percentage of seats sold in the week after the announcement of winners, review ratings in the *New York Daily News* and the *New York Times*, the number of losing Tony nominations in the major categories, and the number of Tony Awards in the major categories. Overall significance:  $LR = 43.4$  on 8 degrees of freedom ( $p = 7 \times 10^{-7}$ ).

looking at this is that the expected number of postnomination performances for revivals, given average values of the other covariates, is 129 shows, while that for nonrevivals is 247 shows. The reason that the revival effect is not significant for total number of performances is that shows that were no longer open at the time of the Tony nominations (which are not used in the analysis in this section) had very short run times (an average of fewer than 65 performances), with little difference between revivals and nonrevivals (revivals averaging slightly longer runs). Shows that were still open when the Tony nominations were announced were (not surprisingly) generally longer-lived, but, among this group, revivals were less successful. Presumably the familiarity of the material in a revival to the potential audience is one reason why shows are revived, but it appears that this does not translate into a longer run (perhaps that familiarity is ultimately viewed as a lack of novelty, keeping audiences away).

### C. Number of Performances after Tony Awards

In this section we examine longevity of a show after the announcement of Tony Award winners. Table 3 summarizes the results of a proportional hazards model fit. For these data there is no seasonal (opening month) effect included, since none of the underlying indicator variables were close to statistically significant. In addition, the show type effect is represented only by an indicator variable for musicals, thereby pooling musical revues and plays together. Audience reaction to the show, and the effect of Tony nominations and Awards on attendance, is quantified using the percentage of seats sold in the week after the announcement of the nominations and percentage of seats sold in the week after the announcement of the awards. There were a total of 50

shows open at the time of Tony Award winners announcement. The partial likelihood ratio test indicates strong predictive power of the covariates for hazard ( $p = 7 \times 10^{-7}$ ).<sup>9</sup>

Several covariate relationships are consistent with earlier results. Once again musicals run longer than other types of shows, having 83.8% lower risk of closing given the other variables. The relative benefit of a show not being a revival is even stronger here, with revivals having 3.5 times the risk of closing, holding all else fixed. Once again, reviews in the *Times* are unrelated to show longevity, but now the favorable nature of a positive review in the *Daily News* is only marginally significant. This is actually not surprising, since one would expect that Tony Awards and nominations would provide important “official” information for potential customers over and above reviews (note also that all shows had been open at least 4 weeks by the time of the Tony Awards ceremony, so a weakening of the effect of an opening-night review would be expected). Interestingly, while higher attendance in the week after announcement of nominations is significantly associated with postaward longevity (one additional percentage point of attendance reducing the risk of closing by 4% holding all else fixed), attendance in the week after announcement of the awards is not. It is not clear why this would be the case.

The relationship of postaward longevity to Tony nominations and Awards is particularly interesting. For the first time, the number of Tony nominations is (marginally) associated with survival. In order to make clearer the implications of the model, Tony nominations are now divided into two parts: winning nominations (Tony Awards) and losing nominations (i.e., the number of Tony Awards subtracted from the number of nominations). As would be expected, and consistent with the earlier analyses, receiving more Tony Awards is associated with longer survival, with an additional award associated with a 32.1% decrease in the risk of closing given the other variables.<sup>10</sup> The number of losing Tony nominations is inversely related to postaward longevity, which might seem counterintuitive but is actually reasonable. Each additional losing Tony Award nomination is associated with a 29.5% increase in the risk of

9. None of the shows were outlying relative to the proportional hazards model for postaward performances, according to the martingale residuals. The martingale residuals also do not exhibit any autocorrelation. The score test for proportionality of hazards indicates nonproportionality linked to several variables. A model stratifying on the number of Tony nominations and whether or not a show is a musical no longer exhibits significant nonproportionality of hazards. The coefficients of the covariates in the stratified model are similar to those for the unstratified model, and the resultant inferences are also very similar.

10. Changing the predictors in the proportional hazards model from total nominations and Tony Awards to losing nominations and Tony Awards does not affect the fit of the model in any way. The only change is to the coefficient for Tony Awards, since it now represents something slightly different than before; it is now an estimate of the exponential effect on survival of one additional award, given that the total number of losing nominations (and other predictors) is kept fixed, rather than an estimate of the exponential effect on survival of one additional award, given that the total number of nominations (and other predictors) is kept fixed. The coefficient for the number of Tony Awards, if the number of nominations is used in the model (rather than number of losing nominations), is  $-0.6454$ , corresponding to a 47.6% decrease in the risk of closing, given the other variables.

closing, but this is given that all else is held fixed, including the number of Tony Awards. Thus, losing nominations (additional nominations without additional wins) are apparently viewed as negative information by the public (or by the show's producer)<sup>11</sup> and are associated with increased risk of the show closing.<sup>12</sup>

#### IV. Conclusion

In this article, we have used the proportional hazards model to investigate the factors relating to the longevity of Broadway shows. The type of show is an important predictor for show longevity, with musicals having longer run times than other shows. Critic reviews in the *Daily News* are related to longevity, as would be expected, but, in contrast to earlier investigations (but not, perhaps, to current views in the industry), reviews in the *New York Times* are unrelated to the success of a show. Winning major Tony Awards is associated with greater success, but being nominated and then losing is negatively related to postaward longevity. Rather than being a positively viewed stamp of approval, the status of a show as a revival is inversely related to show success, at least after the Tony Award nominations have been announced. As expected, increased early attendance is associated with greater success of a show.

This research could be extended in several ways. It would be interesting to see how the lessons learned here apply in London's West End. Show longevity is only one possible measure of a show's success, and it would be worthwhile to study other measures, such as attendance (as in Reddy et al. 1998) and gross revenues. Obtaining and using expenditure and budget information (such as salaries and advertising costs) could help explain not only longevity and revenue, but (perhaps) even more interestingly, profit or return on investment. It would also be interesting to see if the star power of leading or featured actors and actresses in Broadway shows is related to show success, as it seems to be for movies. The availability of weekly data on revenues and

11. The negative impact of losing Tony nominations was seen again in the 1999–2000 season, when the musical "The Wild Party" was nominated for four awards in the major categories but won none. The show closed 1 week after the awards announcements.

12. The proportional hazards model has the great advantage of not requiring specification of a parametric form for the baseline hazard function, but the price paid for this flexibility is that survival can be modeled only indirectly (through the hazard function) rather than directly (through the expected logged survival time). Parametric survival models that assume a parametric distribution for the error term in a regression of logged survival time on covariates, while still allowing for censoring, are called accelerated failure time models. Typical error distributions are an extreme value distribution (implying Weibull survival times; Walls [1998], used such a model to examine survival of movies in Hong Kong as a function of type of movie [English or Chinese language] and initial box office revenue) or a Gaussian distribution (implying lognormal survival times). In order to investigate the sensitivity of the results presented here to the proportional hazards formulation, all of the regression models were refit based on accelerated failure time models and Weibull or lognormal assumed survival distributions. In all cases, the parametric accelerated failure time results were very similar to the semiparametric proportional hazards results. That the significance and interpretation of the variables in the proportional hazards and accelerated failure time formulations are so similar is strong evidence that the observed effects are real.

attendance for shows means that it would be possible to try to model the attendance or revenue process of Broadway shows longitudinally (following the figures through time), along the lines of what Sawhney and Eliashberg (1996) did for movie revenues.

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