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Does 3D Make Sense for Hollywood? The Economic Implications of Adding a Third Dimension to Hedonic Media Products

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This article examines the economic effect of the 3D feature on movie success by using secondary data from all movies released in digital 3D between 2004 and 2011, and a 2D control sample. Using propensity score matching, the authors provide evidence for a sample selection bias that leads to an overestimation of the 3D effect if not accounted for. Matching results show that 3D movies are, on average, not economically advantageous when compared with 2D "twins." However, subsequent weighted least squares regression analyses find that the impact of 3D on movie success varies in a non-linear, inverted U-shaped way with a "trend" variable that measures the point in time of a movie release and with a number of movie genres. A post-hoc analysis shows that a consumer's decision to attend a 3D screening of a 3D movie (instead of a 2D screening) is influenced by several factors, including whether the film is originally shot in 3D or the 3D element is added during postproduction.

In January 2011, *The Hollywood Reporter*, one of the film industry's leading trade magazines, claimed in a headline that the previous year "was saved by 3D" (McClintock, 2011a). Only 4 months later, however, the same outlet wrote: "'Pirates of the Caribbean's' low 3D numbers in U.S. could be a wake-up call to Hollywood" (McClintock, 2011b). This was followed shortly afterward by Hollywood mogul Jeffrey Katzenberg bemoaning "the 'heartbreaking' decline of 3D" (McClintock, 2011c).

These statements reflect the deep uncertainty media industries experience regarding the business potential of digitally adding a third dimension to hedonic media content for theater

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audiences, but also for consumers of home entertainment and electronic games. Although *Avatar*, the first hugely successful movie that used digital 3D technology (Boxofficemojo, 2013), has raised the hopes of a whole industry, there is no clarity yet on whether the new technology is friend or foe, blessing or curse.

Such uncertainty is typical for radical innovations such as digital 3D (Chandy & Tellis, 1998; Hoeffler, 2003), which has been called "the single most revolutionary change since color pictures" (Katzenberg, quoted in Copeland, 2008). Since its beginnings, the film industry has experienced several major innovations, including the introduction of sound, color, odor, and haptic sensations within a movie cinema. Whereas sound and color changed the movie industry forever, other sensory-focused formats such as Sensourround (an enhancement of the audio experience) and Smell-O-Vision/the Tingler (the use of odor and vibrating seats in the theater, respectively; Brooks, 2009) were flops. Also, nondigital versions of 3D were introduced to the film industry in the 1950s and also the 1980s, both times without long-term success.

The question we address in this research is whether digital 3D adds enough value to a movie to justify the multimillion-dollar investment its implementation requires over and above the already enormous production costs (Bowles, 2011). We aim to provide empirical insights into the economic processes surrounding this feature. First, we study the existence of a sample selection bias that might distort any comparison between digital 3D and 2D movies. Second, we investigate whether, and under what circumstances, 3D pays off for a producer of hedonic media content, specifically motion pictures, and identify a number of potential moderating forces of the 3D–success relationship.

We test the hypotheses using (a) all 73 digital 3D movies that were widely released in North American theaters between January 2004 and December 2011 and (b) a statistically matched sample of 1,082 movies in 2D, applying propensity score matching and weighted least squares (WLS) regression. Matching is a powerful approach to reduce a sample selection bias, which in the case of digital 3D movies might result from above-average production budgets and advertising spending allocated as a result of the industry's higher success expectations for these movies.

Our findings suggest that not accounting for this bias when comparing 2D and 3D movies leads to distorted results. When controlling for a "preferential treatment," we find that 3D movies are not advantageous on average, but that the economic effect of 3D varies with contingency factors, namely with a temporal "trend" variable that measures the point in time of a movie release and with a number of movie characteristics. A post-hoc analysis also sheds light on the conditions under which audiences prefer the 3D version of a movie to its 2D equivalent, again stressing the impact of the trend variable and movie characteristics, but also showing that audiences' adoption of a 3D movie depends on whether the movie was originally filmed in 3D or converted later on.

THEORETICAL BACKGROUND AND HYPOTHESES

Digital 3D as a New Element of Hedonic Products

The success of any innovation depends on the additional value it provides to consumers (Cooper, 1979). The incremental consumer value of the 3D element added to movies and other media

products is of a hedonic kind, measured in terms of the pleasure consumers derive from the consumption experience through the creation of consumer fantasies and emotions (Hirschman & Holbrook, 1982).

But does digital 3D lead to increased pleasure and does this increase in pleasure compensate for the higher price the industry charges consumers for 3D products? Empirical evidence for such an effect is limited. Regarding the link between 3D and pleasure, we are aware of only two studies that at least tangentially address it. Visch, Tan, and Molenaar (2010) showed that immersive formats can intensify the emotional response of consumers toward hedonic products. However, the authors use 3D viewing as the condition of low (rather than high) immersion and compare it to cave viewing instead of 2D viewing. Yim, Cicchirillo, and Drumwright (2012) showed that stereoscopic 3D viewing can result in higher enjoyment compared to a flat format, but study this effect in the context of 1-min advertisements, not full-length motion pictures. We are not aware of a single study that takes into account the sacrifices consumers have to make in order to view films in 3D.

For understanding the potential incremental value offered by 3D, some of the differences between hedonic and utilitarian products identified by previous research are important. Specifically, research has highlighted the existence of a satiation effect for hedonic products. Because of the experiential character of hedonic consumption and the pursuit of novel sensations, consumers tend to rather become satiated on sensory features than on nonsensory features (Inman, 2001; Sood & Drèze, 2006). Moreover, hedonic products differ from utilitarian ones in terms of consumers' price sensitivity, with consumers being less price sensitive when a product is of hedonic nature (Wakefield & Inman, 2003). This finding might be relevant in the context of 3D movies, as 3D-movie tickets are generally sold for a price premium.

The Effect of Digital 3D on Movie Success: Main Effect and Moderator Hypotheses

We now offer arguments on why digital 3D should increase the financial success of motion pictures. In addition, we draw on the particularities of hedonic consumption, namely sensation seeking, satiation effects, and low price sensitivity, and propose that a movie's genre, the temporal "trend" or point in time of its release, and whether it is an early or late sequel determine the amount of additional value of digital 3D for consumers, serving as moderators of the link between 3D and theatrical movie success. In line with movie industry economics (e.g., Vogel, 2011), we study the effect of digital 3D on three key facets of movie success, which serve as our dependent variables: (a) box office revenues, (b) attendance numbers (which account for the higher ticket prices of 3D movies), and (c) return on investment (which accounts for the additional production costs incurred due to the 3D element).

Main Effects Hypotheses

Based on the findings of Visch, Tan, and Molenaar (2010) and Yim, Cicchirillo, and Drumwright (2012), we expect digital 3D to increase the hedonic appeal of a movie. Such an effect is the logic underlying the approximately 40% price premium that has been charged for digital 3D movies by theaters in North America since the introduction of digital 3D in 2004. In a statement that is exemplary for the industry, Jeffrey Katzenberg, studio head and

producer, stressed the value-increasing character of digital 3D by arguing that it "present[s] an exceptional experience" (Bowles, 2011).

Linking this value-increasing character of 3D to our dependent variables results in the following arguments: First, we argue that any increase in appeal (or value) for consumers will result in a rise in demand. This rise is supposedly being captured by either a higher number of tickets sold for a movie or higher per-ticket revenues. The increase in ticket prices can thereby be interpreted as a proxy for a higher willingness to pay. Consequently, our first hypothesis is as follows:

H1a: The revenues generated by a digital 3D movie are higher than those of an otherwise equal 2D movie.

If the increase in appeal or value for consumers is higher than the increase in price, then the net benefit for consumers is positive and will result in higher numbers of attendance. Theaters cannot afford a reduction in attendance numbers, as the concession sales they generate from moviegoers constitute a substantial proportion of theater revenues (Gil & Hartmann, 2007). The importance of concessions has two reasons: First, they are very profitable offerings, with popcorn, for example, selling at a profit margin of up to 98% from material costs (McKenzie, 2008). Second, whereas earnings from admission sales have to be shared with movie studios, earnings from concession sales belong to the theaters alone (Epstein, 2006). Therefore, we assume theaters set the price premium for 3D tickets so that the net benefit of showing a film in 3D is positive. We offer our second hypothesis:

H1b: Attendance numbers of a digital 3D movie are higher than those of an otherwise equal 2D movie.

Finally, although the effect of digital 3D on a movie's revenues is assumed, its influence on the production costs is without question. Filming a movie in digital 3D or converting one that has been shot in 2D to 3D during postproduction requires a substantial financial investment. As the film industry aims to maximize profit, we expect the additional revenues generated by a digital 3D movie to exceed the additional costs of 3D, so that the return on investment is higher for digital 3D movies than for 2D movies:

H1c: A digital 3D movie has a higher return on investment than an otherwise equal 2D movie.

Moderation Effects Hypotheses

Based on sensation seeking, satiation effects, and low price sensitivity as particularities of hedonic consumption, we argue that the postulated effect of digital 3D on movie success is moderated by three factors: the temporal "trend" or point in time of the movie's release, the movie's genre, and the movie's cultural familiarity (i.e., whether it is an early/late sequel).

Trend. We expect the temporal trend, which we define as the point in time of a movie's release, to interact with the movie's 3D element in a non-linear way. The trend moderator is a

continuous variable that measures the difference in months between the release date of a movie and the most recent film in the dataset. It captures the changes over time that have affected both consumer preferences toward 3D and the exhibition infrastructure.

Specifically, we propose that, at the introduction of digital 3D, consumers were eager to experience its novel sensory sensations, which lead to an increase of its impact on all three facets of market success over time and also a rise in the number of theaters being able to show digital 3D movies. We expect the sensory stimulation value for consumers to have decreased over time (after having repeatedly experienced it) as a result of satiation regarding the sensory feature. Such satiation effects have been linked to a reduction of interest and an increase in price sensitivity ("buyer learning"; Day, 1981). As Hollywood director Roland Emmerich phrases it, "[P]eople will get tired of it" (quoted in Shaw-Williams, 2013).

As we study the impact of 3D on success on the product (i.e., aggregate) level and as every innovation requires a certain time to be adopted by the majority of consumers (Rogers, 2003), the moderating effect of the temporal trend should follow an inverted U-shaped function. Please note that this argument does not speculate on the absolute size of the 3D effect over time, but only states that demand should be relatively lower later in time compared to the peak it presumably reached after its introduction period. Thus, we offer our next hypothesis:

H2: The effect of digital 3D on movie success varies with the temporal trend in a non-linear way, with the interaction of 3D and trend affecting a movie's (a) revenues, (b) attendance numbers, and (c) return on investment following an inverted U-shaped function.

Genre. Because of the characteristics of hedonic consumption, some movie genres should be more suitable for digital 3D than others. Specifically, the potential of 3D to enhance fantasy and emotive sensations will be higher if a movie's value for consumers is primarily based on its visual attractiveness. Exemplary genres for which this applies include action and family movies (also of the animated type), which often feature rollercoaster rides, monsters, or other visual gimmickry. Similarly, horror movies should benefit strongly from digital 3D, as the consumers' benefits in this genre arise from shock and gore effects which become more realistic when shown in 3D.

In contrast, movies that are mostly dialogue-driven and feature everyday situations with "normal" people in ordinary settings, such as dramas and thrillers, provide fewer opportunities for the enhancement of hedonic consumer value. Thus, we expect the effect of 3D on movie success to be higher for visual-driven than dialogue-driven movie genres and propose the next hypothesis:

H3: The effect of digital 3D on movie success varies according to a movie's genre, with the effect of digital 3D on a movie's (a) revenues, (b) attendance numbers, and (c) return on investment being higher for visual-driven than for dialogue-driven movie genres.

Sequel. Movie sequels are a central component of the concept of cultural familiarity (Hennig-Thurau, Houston, & Sridhar, 2006) and are characterized by the use of "well-known ideas" (Litman & Kohl, 1989). A sequel is a type of hedonic brand extension for the evaluation

of which consumers use their brand knowledge of the original movie (e.g., Hennig-Thurau, Houston, & Heitjans, 2009).

Brand extension research generally finds this transfer of knowledge to be facilitated by the similarity between parent and extension (Völckner & Sattler, 2006). For sequels, we argue that using the same sensual format (i.e., 2D or 3D) as the predecessor movie increases similarity and should thus facilitate the sequel's success (Hennig-Thurau, Houston, & Heitjans, 2009). Christian Bale, lead actor of the most recent and very successful Batman trilogy, illustrates this logic: "It would have been inappropriate and somewhat gimmicky to have 'Dark Knight Rises' in 3-D. It seemed that we should continue in the vein that we had started" (Germain, 2012).

However, taking into account the particularities of hedonic consumption, Sood and Drèze (2006) find a satiation effect for movie sequels and suggest an audience preference for *dissimilar* hedonic extension products. Building on this finding, we propose that for a movie franchise that has been extended frequently, an enhancement of the brand knowledge transfer is of lesser importance, whereas adding digital 3D might help to avoid consumer satiation and could therefore be more economically sensible. Satiation occurs within the extended product line at any possible stage of the 3D life cycle and is independent of the trend moderator. In support of our reasoning, Subers (2010) argued that the filming of *Saw 7* in digital 3D followed the logic of adding new sensations to a worn-out movie brand, "[R]ecognizing that the formula had grown tired, producers decided to spice things up a bit for the seventh installment by adding 3D."

We thus expect that filming a sequel in digital 3D if the predecessor was in 2D has a negative impact on the success of early sequels (where high similarity is a "good thing" for audiences), but a positive impact for late sequels (where high similarity is a "bad thing" for audiences due to satiation). Thus:

H4: The effect of digital 3D on movie success varies with the sequel character of a movie, with the effect of 3D on a sequel's (a) revenues, (b) attendance numbers, and (c) return on investment being lower for an early sequel whose predecessor was released in 2D.

H5: The effect of digital 3D on movie success varies with the sequel character of a movie, with the effect of 3D on a sequel's (a) revenues, (b) attendance numbers, and (c) return on investment being higher for a late sequel whose predecessor was released in 2D.

METHODOLOGY

As numerous industry executives have expressed their belief that releasing a movie in 3D increases movie success, we expect 3D movies to systematically differ from 2D movies due to a "preferential treatment" by movie studios. Assuming this is the case, comparing the success of 3D and 2D films without making sample adjustments would systematically overestimate the impact of 3D and yield biased results. To make 3D and 2D movies comparable and to account for a preferential treatment, we employ statistical matching, which generates a pool of adequate substitutes out of a control sample and thus reduces a given sample selection bias. To further correct for the influence of control variables, we use matching weights when conducting WLS regression analyses.

Data

Our data set consists of all new feature-length digital 3D fiction movies given a wide theatrical release (i.e., 800 or more theaters on their opening weekend) in North America between January 2004—when *The Polar Express* marked the beginning of digital 3D movies—and December 2011. The resulting 3D sample consists of 73 movies. In addition, we use all 1,082 widely released 2D movies in the same time span as our control sample. A rich control sample is crucial for generating a valuable pool of adequate substitutes when applying statistical matching.

Analytical Model and Measures

Our analytical model reflects the previously stated hypotheses:

$$\begin{aligned}[lnMOVIESUCCESS]_i = {} & \alpha + \beta_1(3D_i) + \beta_2(TREND_i) + \beta_3[GENRE_i] \\ & + \beta_4(EARLYSEQUEL_i) + \beta_5(LATESEQUEL_i) + \beta_6(TRENDx3D)_i \\ & + \beta_7(TREND\_SQRx3D)_i + \beta_i[GENREx3D]_i \\ & + \beta_9(EARLYSEQUELx3D)_i + \beta_{10}(LATESEQUELx3D)_i \\ & + \beta_{11}[CONTROLS_i] + \varepsilon,\end{aligned}$$

where *MOVIESUCCESS* comprises three different success measures of a movie *i*, namely, *BOXOFFICE* (i.e., the total revenues of *i* in North American theaters over its life cycle), *ATTENDANCE* (i.e., the number of moviegoers of *i* in North American theaters over its life cycle), and *ROI* (i.e., the return on investment of *i* based on its production and marketing costs and North American theatrical revenues). *TREND* captures the temporal trend or point in time when movie *i* was released, measured as the difference in months of the release date of each movie to January 2012, which marks the end of our data period. *EARLYSEQUEL* and *LATESEQUEL* indicate whether a movie was the second or third entry in a movie series or the fourth or later entry, respectively.

The vector *GENRE* comprises the genre variables *ACTION*, *HORROR*, *THRILLER*, *COMEDY*, *DRAMA*, and *FAMILY*. The vector *CONTROLS* consists of additional movie success drivers, namely *BUDGET* (i.e., the production costs in US $ which we adjust for the extra costs of 3D, as described in detail below), *ADVERTISING* (i.e., the advertising spending for movie *i* before its theatrical release in US $), *SCREENS* (i.e., the number of theaters that showed the movie *i* on the opening weekend), *CRITICS* (i.e., a measure of professional critics' reactions to movie *i*), *STAR* (i.e., a dummy for the participation of at least one major star actor), *REMAKE* (i.e., a dummy for *i* being a remake of an original movie), and *MPAA* (i.e., a measure of the restrictiveness of *i*'s MPAA age rating for the US).

We adjusted all monetary variables for inflation. Published movie budgets always include the extra costs for either shooting a movie in digital 3D or converting it to 3D during postproduction, which would result in systematic budget differences between the 3D and the 2D group. We thus adjusted the budget variable by deducting these extra costs. Specifically, whereas we kept

budgets for 2D movies unchanged, we deducted 7.5% of the budget for an animated movie and 12.5% for a live-action movie that was filmed in digital 3D; these numbers are the arithmetic means of estimates by Sony Pictures Imageworks (Aubusson & Teulade, 2009). For movies filmed in 2D, but converted to digital 3D during postproduction, the costs of 3D are mainly a function of a film's runtime. We thus collected data on the movies' runtimes and multiplied it by 98,333, which is the arithmetic mean of several different estimations of conversion costs per minute (Bowles, 2011; Vlessing, 2011; Drawbaugh, 2010). We then deducted the product of runtime and 3D costs per minute from the total budget of converted 3D movie. Table 1 lists the definitions and sources of all variables used in this research.

To study the potential nonlinear effect of the trend variable, we used the second-degree polynomial in our regression models. To reduce multicollinearity problems often experienced in polynomial regressions of this kind, we transformed the trend variable into an interval ranging from −1 (=December 2011) to +1 (=January 2004). In addition, we used the logarithm of budget, advertising, and the dependent success measures to correct for skewed distribution (see, e.g., Gemser, Leenders, & Weinberg, 2012, for the same approach).

Propensity Score Matching

To address the expected sample selection bias (Heckman, 1979) for digital 3D movies as a result of their "preferential treatment" by Hollywood studios, we applied statistical matching (Rubin, 1973; Smith, 1997). The statistical matching procedure aims at comparing the difference of the expected outcome with the treatment (i.e., a digital 3D movie) to the expected outcome without the treatment (i.e., the same movie in 2D). As the latter is unobservable in reality, we used propensity score matching to build a set of "twin" movies out of the 2D control sample by applying the Kernel matching estimator (Epanechnikov kernel function with a bandwidth parameter of .06). Specifically, we estimated a binary logit model with the dependent variable being 1 for treated (i.e., 3D) and 0 for nontreated cases (i.e., 2D).

Matching is effective if the variables responsible for the selection bias are included in the logit model as regressors. Specifically, our selection of matching covariates was driven by the logic that movie producers do not make their fundamental decisions about whether to produce a movie or not (e.g., whether to opt for a sequel or bring a new idea to the big screen) dependent on 3D. Instead, we argue that films associated with certain characteristics have a higher probability to be produced in digital 3D, because the studios expect that 3D is economically feasible and/or will increase the movies' success potential. Support for this logic can be found in numerous statements by industry experts. For example, *Jackass 3D* star Johnny Knoxville commented on the 3D element of the third film of the *Jackass* series: "It was never our intention to do it in 3D. We just wanted to do another film" (quoted in Leupp, 2010). Similarly, *Pacific Rim*-director Guillermo del Toro stated that the decision to postconvert his film was made very late in the production process: "What can I tell you? I changed my mind" (quoted by Fischer, 2012).

Specific characteristics that influence the 2D/3D decision include the movie's production budget, pre-release advertising spending, and distribution intensity, but also the film's genre. The additional costs associated with producing a film in 3D pay off only for movies targeted at large audiences, so that movies with a high production budget, high advertising, and wide distribution have a higher probability to be produced in 3D. It should be noted that fundamental

TABLE 1
Definitions and Sources of Variables

Variable	*Description*	*Source*
3D	Binary variable taking the value of 1 if the movie was released in 3D	IMDb, Wikipedia
BUDGET	Logarithm of the 3D-modified budget of the movie (adjusted for inflation)	IMDb, Boxofficemojo
ADVERTISING	Logarithm of pre-release advertising spending (adjusted for inflation)	Kantar Media, TNS
SCREENS	Number of opening weekend theaters	Boxofficemojo
STAR	Binary variable taking the value of 1 if at least one actor participated in the movie who was included in the "Top 10 Money Making Stars" list prior to the respective release year	Quigley
CRITICS	Rating for the movie by professional movie critics, coded and aggregated by Metacritic	Metacritic
MPAA	Age restriction for US audiences by the Motion Picture Association of America (MPAA), with 1 = G, 2 = PG, 3 = PG-13, 4 = R	IMDb
REMAKE	Binary variable taking the value of 1 if the movie is a remake	IMDb
EARLYSEQUEL	Binary variable taking the value of 1 if a movie is the second or third installment of a movie series following a 2D predecessor	IMDb
LATESEQUEL	Binary variable taking the value of 1 if the movie is the fourth or later installment of a movie series following a 2D predecessor	IMDb
ACTION, DRAMA, COMEDY, HORROR, THRILLER, FAMILY	Binary variables taking the value of 1 if the movie belongs to the respective genre; one movie can belong to multiple genres	IMDb
TREND	Difference in months of the movie release to Jan 2012, rescaled to an interval ranging from −1 (Dec 2011) to +1 (Jan 2004)	Boxofficemojo
BOXOFFICE	Logarithm of box office gross revenue in North American theaters (adjusted for inflation)	Variety, Boxofficemojo
ATTENDANCE	Logarithm of the estimated number of tickets sold in North American theaters[a]	MPAA, Variety, Boxofficemojo
ROI	Logarithm of the quotient of North American box office revenues minus costs (pre-release advertising and total production costs) divided by costs[b]	Variety, IMDb, Boxofficemojo, Kantar, TNS

[a] We used the share of 3D revenues at the opening weekend and divided total North American box office revenues by that share. As no share was available for three movies, we used the average of the 3D share of the respective year to account for the availability of 3D screens at that time. We further divided these shares by estimated 2D and 3D ticket prices per year based on information from MPAA statistics.

[b] Please note that total costs include the extra 3D costs along with prerelease advertising spending and the modified production budget.

advertising and distribution decisions are made in conjunction with the production budget very early in the process: "[O]ur work really accelerates when a green light is given and the production process begins. [. . .] The marketing and releasing plans are coordinated together and marketing executives work very closely with distribution executives" (Fellman, 2006, pp. 364–365).[1] To rule out adjustments to distribution made after the 3D decision, we constructed a distribution variable that assigns each movie to one of four distribution intensity quartiles, ranging from 1 (*low distribution intensity*) to 4 (*high distribution intensity*). Following a similar logic, we argue that films featuring brands are targeted at larger audiences, so that investments associated with 3D can be justified more easily than for unbranded movies. Such brand elements that increase the probability of a movie being made in 3D include sequels, remakes, and movie stars.

In addition, visual-driven versus dialogue-driven genres will have a higher probability to be produced in 3D, as the presence of visual effects offers greater sensory opportunities for 3D. Tim Squyres, editor of *Life of Pi*, argued, "In deciding whether or not we should do the movie in 3D, we thought we have many, many scenes with a kid and a lifeboat on the ocean and a tiger and that's it" (quoted in Romanek, 2013). We included action, horror, and family (as visual-driven genres), and comedy, thriller, and drama (as dialogue-driven genres) in the statistical matching routine.

To avoid potential confounds, we did not consider variables in the matching for which decisions are predominantly made after the assignment of the treatment. Those variables include MPAA rating, professional critics, and adjustments to the distribution strategy, as argued above.

The procedure creates matching weights for each case that account for the comparability of the 3D and 2D movies. To generate unbiased results, these weights were subsequently used as regression weights when estimating the analytical model with WLS regression analysis (e.g., Linden & Adams, 2010).

RESULTS

Results of Statistical Matching

The results of the matching procedure strongly support our expectation that 3D movies systematically differ from 2D movies. For 10 of the 12 covariates used in the matching regression, a significant pre-matching difference between treated and control cases was found. All movies received "common support," which requires a substantial overlap in the characteristics of treated and control cases (Heckman, Ichimura, Smith, & Todd, 1996), so that we did not have to exclude any 3D movies from the analyses due to a lack of adequate 2D matches.

As a result of the matching, the mean standardized bias was reduced from 50.1 to 4.0, which is equivalent to a 92% bias reduction. Further, the pseudo-R^2 of the logit regression was .280 before the matching and only .006 after the matching. Most importantly, no significant differences between 3D and matched 2D movies remained for any of the matching variables after the matching, as shown in Table 2.

[1] Daniel R. Fellman, formerly a leading manager at Warner Bros. Pictures and former president of the American Theatre Management Corporation.

TABLE 2
Matching Results

	Mean Comparison (Pre/post Matching)			*Bias*	*t-test*	
	Treated	*Controls pre*	*Controls post*	*%reduction |bias|*	*p pre*	*p post*
LN BUDGET	4.3262	3.6218	4.2546	89.8	<.001	.603
LN ADVERTISING	9.9358	9.6597	9.9336	99.2	.003	.985
QUARTILE_SCREENS	3.3562	2.4399	3.3306	97.2	<.001	.863
SEQUEL	.28767	.14048	.29634	94.1	.001	.909
REMAKE	.17808	.10906	.16267	77.7	.072	.806
STAR	.08219	.29113	.09450	94.1	<.001	.795
ACTION	.46575	.26710	.42371	78.8	<.001	.612
HORROR	.15068	.10813	.15449	91.0	.263	.949
THRILLER	.17808	.36044	.18045	98.7	.002	.970
COMEDY	.50685	.44824	.47807	50.9	.331	.730
DRAMA	.13699	.46580	.16807	90.5	<.001	.604
FAMILY	.56164	.15619	.54551	96.0	<.001	.846

The sample selection bias of 3D becomes apparent when comparing unmatched and matched mean differences (without accounting for controls; back-transformed). 3D movies clearly outperform unmatched 2D movies with regard to box office revenues (3D = 82.76, 2D = 39.16, $p < .01$) and movie attendance (3D = 9.56, 2D = 5.65, $p < .01$), while no significant difference is found for ROI (3D = −.15, 2D = −.17, $p > .10$).[2] However, when comparing treated and matched control cases (i.e., correcting for the sample selection bias), no significant difference exists for any of the movie success variables (box office revenues: 3D = 82.76, 2D = 75.82, $p > .10$; attendance: 3D = 9.56, 2D = 10.64, $p > .10$; ROI: 3D = −.15, 2D = −.08, $p > .10$).

WLS Regression Results

To test our hypotheses, we then ran a number of WLS regressions, using the matching weights as regression weights. Every treated case received a weight of 1, so that the 73 movies in 3D added up to a cumulated weight of 73, and the individual weights of the 1,082 movies in 2D also added up to a cumulated weight of 73. We further included several control variables in the regression model to rule out an omitted variable bias when analyzing the link between 3D and movie success.

The regression procedure involved three steps. In the first step, we ran a WLS regression for each of the three dependent variables (*BOXOFFICE*, *ATTENDANCE*, *ROI*) which included only the 3D dummy and the control variables but no interactions. The results show no effect of digital 3D on box office revenues ($b = .048$, $p > .10$). However, the effects of 3D on attendance numbers ($b = -.132$, $p < .01$) and profitability ($b = -.029$, $p < .05$) are both

[2]Please note that actual industry ROI values would be significantly higher, as revenue sources other than theatrical US box office sales also contribute substantially to the return on investment.

TABLE 3
Summarized Results of Separate WLS Regression Analyses for Interaction Terms (Including Control Variables)

	Box Office		*Attendance*		*ROI*	
	B	*p*	*B*	*p*	*B*	*p*
3D × TREND	.259	<.001	.270	<.001	.071	.030
3D × TREND	−.060	.499	.024	.754	−.080	.058
3D × TREND SQR	−.583	<.001	−.449	<.001	−.276	<.001
3D × ACTION	.061	.327	.074	.170	.056	.053
3D × HORROR	−.220	.011	−.269	<.001	−.130	.001
3D × THRILLER	−.224	.006	−.165	.019	−.098	.009
3D × COMEDY	−.296	<.001	−.254	<.001	−.122	<.001
3D × DRAMA	−.151	.081	−.150	.046	−.078	.052
3D × FAMILY	.243	<.001	.224	<.001	.088	.002
3D × EARLYSEQUEL	−.083	.283	−.115	.087	−.037	.303
3D × LATESEQUEL	−.081	.489	−.106	.297	−.012	.827

negative. This means that, on average, a 3D movie attracts less consumers compared to its matched 2D counterpart and is less profitable. H1 is rejected.

In the second step, we ran separate WLS regressions, including one interaction at a time (and all control variables). We chose this approach over the simultaneous inclusion of all interaction terms because of the multicollinearity the latter would have caused and the limited number of available cases. The results reveal a significant polynomial interaction effect of 3D and *TREND* for all three dependent measures. Negative coefficients of the squared interaction term confirm the expected inverted U-shape proposed in H2.

Moderating effects for the genres *FAMILY* (a positive interaction) and *HORROR*, *COMEDY*, *DRAMA*, and *THRILLER* (negative interactions) are also significant for all three success measures; in addition, for *ACTION* the proposed positive interaction is only found to be marginally significant for the *ROI* measure. Because *FAMILY* and *ACTION* are mainly visual-driven genres and *COMEDY*, *THRILLER*, and *DRAMA* are primarily dialogue-driven genres, the direction of these effects is in line with H3. The negative interaction with *HORROR*, however, conflicts with H3; we address this finding later. Regarding the proposed sequel interactions, a negative interaction of 3D with *EARLYSEQUEL* is marginally significant for *ATTENDANCE* only, lending some support for H4. No significant interaction is found for 3D and *LATESEQUEL*, so that we have to reject H5. Table 3 overviews the different interaction regressions.

In the third and final step, we ran a joint regression including the interactions which were significant in the second step in addition to the controls. We used a blockwise approach, first entering the linear and then the squared interaction term of *TREND* into the model.[3] The

[3]We also added the main effect of *TREND* because this is methodologically required (please note that all monetary variables are adjusted for inflation).

addition of the squared term leads to a significant increase in R^2 for every success measure ($\Delta R^2_{\text{BOXOFFICE}} = .007$; $\Delta R^2_{\text{ATTENDANCE}} = .005$; $\Delta R^2_{\text{ROI}} = .015$; $p < .01$ in all cases). These results confirm the adequacy of the polynomial model.

Next, we added the significant genre and sequel interactions to the model, using a stepwise approach (critical F-score = .05). In the final model, the movie success measures *BOXOFFICE* and *ATTENDANCE* are well explained by the independent variables with R^2s of about .78, whereas the *ROI* measure is explained to a lesser, but still substantial degree ($R^2 = .49$). Variance inflation factors for this model peak at 7.0, without any erratic parameter changes occurring, which indicates that multicollinearity does not distort the polynomial model.

Table 4 shows that the effect of digital 3D varies strongly with regard to *TREND* in the theoretically argued non-linear, inverted U-shaped way for all three success measures. The interactions of 3D with the *FAMILY* (positive) and the *COMEDY* and *DRAMA* variables (both

TABLE 4
Stepwise Weighted Regression Analysis Results

	Box Office			*Attendance*			*ROI*		
	B	*p*	*VIF*	*B*	*p*	*VIF*	*B*	*p*	*VIF*
Intercept	−.867	<.001		−1.732	<.001		.402	.001	
LN BUDGET	.286	<.001	2.815	.247	<.001	2.793	−.207	<.001	2.793
LN ADVERTISING	.043	.093	1.551	.013	.542	1.553	−.040	.001	1.553
SCREENS	.001	<.001	2.641	.001	<.001	2.654	.000	<.001	2.654
EARLYSEQUEL	.169	<.001	1.235	.144	<.001	1.241	.098	<.001	1.241
LATESEQUEL	.178	.003	1.324	.219	<.001	1.340	.120	<.001	1.340
REMAKE	.013	.756	1.217	−.004	.919	1.211	.013	.506	1.211
STAR	−.009	.862	1.170	−.020	.667	1.159	−.009	.725	1.159
MPAA	.030	.337	3.951	−.004	.872	3.935	.034	.021	3.935
CRITICS	.125	<.001	1.465	.117	<.001	1.457	.057	<.001	1.457
ACTION	−.138	<.001	1.502	−.105	.001	1.531	−.056	.001	1.531
HORROR	−.019	.734	2.095	.017	.781	3.376	.027	.430	3.376
THRILLER	.031	.605	2.766	−.023	.545	1.485	−.047	.023	1.485
COMEDY	.148	.002	3.005	.129	.002	3.043	.072	.002	3.043
DRAMA	.138	.018	2.251	.120	.018	2.269	.060	.030	2.269
FAMILY	−.226	<.001	4.785	−.232	<.001	4.882	−.072	.014	4.882
3D	.455	<.001	6.778	.277	<.001	7.009	.160	<.001	7.009
TREND	.089	.020	2.803	.095	.004	2.853	.050	.007	2.853
3D × TREND	−.186	.035	6.813	−.066	.388	6.792	−.121	.004	6.792
3D × TREND SQR	−.626	<.001	5.813	−.471	<.001	5.777	−.286	<.001	5.777
3D × COMEDY	−.592	<.001	4.786	−.509	<.001	4.786	−.242	<.001	4.786
3D × FAMILY	.431	<.001	5.687	.350	<.001	5.965	.152	<.001	5.965
3D × DRAMA	−.188	.023	2.227	−.210	.004	2.324	−.118	.003	2.324
3D × THRILLER	−.188	.026	2.973						
3D × HORROR				−.212	.010	3.183	−.122	.006	3.183
R^2	.782			.785			.493		
F-statistic	176.904 (<.001)			18.029 (<.001)			47.834 (<.001)		

negative) also remain significant for all three success measures; *THRILLER* is significant in the box office equation and *HORROR* exerts a significant influence on attendance and return on investment. This illustrates that digital 3D is more advantageous for family movies, but less suitable for horror, comedy, drama, and thriller movies. The moderating effect of *EARLYSEQUEL* found in the separate regression for the attendance variable is crowded out by other model variables.

Post-Hoc Analyses

A Closer Understanding of Trend-Related Effects

To gain a better understanding of 3D's polynomial interaction with the temporal trend variable, we conducted two additional post-hoc analyses. We first ran subsample analyses, splitting the treated 3D cases into three terciles according to their release dates.[4] Specifically, we ran the control model, which comprises the 3D variable and all control variables, in the three subsamples, each consisting of the 3D movies of the respective time interval and all weighted 2D movies. The results reveal that 3D exerts a significant positive influence on all three success measures in the first tercile ($b = .292$, $p < .01$ for *BOXOFFICE*; $b = .132$, $p < .01$ for *ATTENDANCE*; $b = .073$, $p < .01$ for *ROI*). In the second tercile, 3D exerts no significant influence on *BOXOFFICE* ($b = .011$, $p > .10$) and a negative influence on both *ATTENDANCE* ($b = -.213$, $p < .01$) and *ROI* ($b = -.028$, $p < .10$). In the third tercile, 3D influences all three success measures negatively (*BOXOFFICE*: $b = -.153$, $p < .01$; *ATTENDANCE*: $b = -.304$, $p < .01$; *ROI*: $b = -.128$, $p < .01$). The inverted U-shape of the interaction of 3D with the trend variable is thus supported for all three success measures; the inversion of the effect begins at an earlier stage for those measures that carry the most immediate economic implications (i.e., attendance and ROI).

The second post-hoc analysis was a simulation to visualize the economic effect of 3D over time and to put it in relation to the effect of 2D. We employed the unstandardized coefficients of the weighted regression analysis to estimate the expected revenues for an "average" movie, which we constructed by defining the set of success drivers and only varying the *3D* and *TREND* variables. We set the values of the metric variables *BUDGET, ADVERTISING*, *SCREENS*, and *CRITICS* to their weighted data-set averages, held the binary measures constant (i.e., no sequel, no remake, no star, comedy) and chose a G-rating for the age-restriction.

Figure 1 demonstrates that the effect of 3D is not only nonlinear, but that the interaction with *TREND* is also disordinal in nature (Lubin, 1961), as the rank order of the treatment (i.e., 3D vs. 2D) changes with the value of another variable (i.e., *TREND*). Whereas in the early years of digital 3D technology, 2D movies scored higher on average, 3D movies outperformed 2D movies at the box office in the following years. More recently, however, 3D movies tended to generate less box office revenues than their matched 2D counterparts.

[4]The first tercile covered the 24 movies in 3D released from January 2004 to June 24, 2010, the second tercile covered the 24 movies in 3D released from June 25, 2010, to May 2, 2011, and the third tercile covered the 25 movies in 3D released from May 3, 2011, to December 2011. Detailed results of this test are available from the authors upon request.

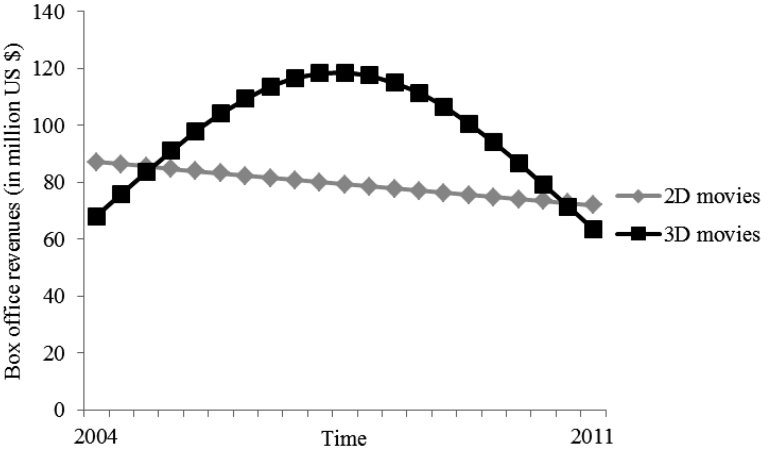

FIGURE 1 Post-hoc analysis: Non-linear interaction of *3D* and *TREND* on box office revenues. The same pattern is observable for attendance and ROI. The respective figures are available from the authors upon request.

Under Which Conditions Do Audiences Prefer the 3D Version of a Movie to its 2D Version?

In theaters, movies produced in digital 3D can often also be viewed in 2D while avoiding the 3D surcharge. For what kinds of movies does 3D constitute the "must-see" format favored by audiences? Because theater owners have to allocate movies to their 3D and 2D screens, this question is of particular relevance for them. We conducted an additional post-hoc analysis using the share of 3D revenues on the opening weekend as dependent variable and the moderators proposed previously in this research (i.e., trend, genres, sequel) as independent variables. We also added a new variable that reflects whether the movie was originally filmed in 3D (which has been associated with a higher 3D quality; Murphy, 2010) or whether 3D was added during postproduction. The share of 3D revenues was calculated as the 3D-related opening weekend revenues as published by the Boxofficemojo Weekend Report divided by the total opening weekend revenues. Information for the "filmed 3D" variable was collected from realorfake3d.com and Wikipedia. Table 5 presents the results of the analysis.

The results show that "filmed 3D" movies are associated with higher 3D shares. This indicates that audiences consider the value of 3D to be higher if filmed rather than added afterward; audiences avoid the price premium of 3D more often when a movie is postconverted into 3D. Moreover, the inverted U-shaped pattern is once more found for the trend variable, consistent with our previous results that linked 3D with movie success—at first, consumers' valuation of 3D increased over time, then it passed a certain threshold and has been declining afterwards. Interestingly, the (marginally) significant effects for family and horror movies show different directions compared to the main WLS analysis. Whereas for horror fans a 3D horror movie tends to be a "must see" movie in its 3D version, the contrary seems to be true for family films and families. This effect might be driven by the 3D price premium, which can build up to a hefty surcharge for the hypothetical family of four or more (Ebert, 2011). Consequently,

TABLE 5
Post-Hoc Regression Analysis Results

	3D share		
	B	*p*	*VIF*
Intercept	.478	<.001	
FILMED 3D	1.03	.005	1.166
EARLYSEQUEL	.051	.211	1.145
LATESEQUEL	−.066	.281	1.338
ACTION	−.019	.596	1.529
HORROR	.115	.062	2.089
THRILLER	.052	.284	1.422
COMEDY	−.046	.223	1.648
DRAMA	.036	.448	1.257
FAMILY	−.080	.074	2.180
TREND	−.443	<.001	2.499
TREND SQR	−.351	<.001	2.262
R^2		.635	
F-statistic		9.155 (<.001)	

Note. As the dependent variable is only specified for 3D movies, no 2D movies were used for this analysis. The share of 3D revenues was not available for three 3D movies, so the data set comprises at total of 70 movies in 3D.

theater owners should ensure that a cheaper 2D version is available for price-sensitive family audiences.

DISCUSSION AND IMPLICATIONS

This research provides initial evidence that, counter to widespread industry thinking in the global film industry, digital 3D movies do not enjoy a general advantage over 2D movies in terms of economic movie success when accounting for a sample selection bias. Although digital 3D movies clearly dominated 2D movies when an unmatched sample was used, no constant superior performance could be detected after propensity score matching, and both attendance numbers and films' ROI were even negatively affected by the 3D feature on average. Lower attendance numbers suggest additional losses for theater owners because of lower concession sales. These have important managerial implications, as a large proportion of theater profits results from popcorn and soft drinks (e.g., Epstein, 2006; Gil & Hartmann, 2007).

Although digital 3D was not found to be superior on average, our study shows the existence of contingency factors for the economic impact of 3D. This impact varies with the temporal trend into which a movie release falls along a nonlinear, inverted U-shaped pattern, but also with certain movie genres. Although the hypothesis that visual-driven genres are more suitable for 3D movies than dialogue-driven movie genres is generally supported, the genre horror runs counter to this pattern. A possible psychological explanation is that the prospect of a 3D

horror movie becoming too real for an inexperienced horror-movie consumer might scare away parts of the audience and thus lead, on average, to less tickets sold at the box office. This argument was also stated by an industry manager via personal communication. A post-hoc analysis further indicates that audiences consider movies which were originally filmed in 3D more valuable and their price premium therefore more justified in comparison to their converted counterparts. This analysis also provides additional support for the existence of nonlinear trend effects.

Concerning implications, our data suggests that releasing movies in digital 3D at the end of our data's time period does not generally offer a competitive edge in the market. Nevertheless, as the movie industry has invested heavily in the technology, it might not want to let go of the new format (Bowles, 2011). A recovery of 3D would be in line with Chandrasekaran and Tellis (2011), who reported empirical evidence for the existence of saddles for entertainment products. A *saddle* is defined as a sustained drop in sales after a preceding growth period which subsequently recovers to the former peak. Thus, it is still unclear whether the reported decline of 3D revenues is an indication of an innovation failure or a temporary saddle.

Regarding limitations, although we carefully selected the variables included in the statistical matching to parallel the industry routines in deciding whether a film is made in 2D or 3D, limited information was available to us about the decision processes for individual movie projects. Future research might extend our findings by adding such project-level information. A second limitation of this study is that our analysis focuses on the U.S. market. The entertainment business, however, has turned into a global industry (Walls & McKenzie, 2012). China, for instance, has reportedly experienced great resonance to the 3D format with enduring interest. With China in line to become the world's biggest film market by 2020 (Ernst & Young, 2012), forced cascade effects of the country's market demand to other countries are possible.

Finally, another limitation can be found in the operationalization of the estimated 3D cost and profitability measure. As no data for the 3D costs of each individual movie is available, we used an approximation based on generalized functions for live-action movies, animated movies and movies with 3D added during postproduction. Also, the profitability measure does not account for the home entertainment segment, where technology is still struggling to provide an experience of the same quality as in theaters. This could lead to a disadvantage of digital 3D movies in ancillary markets, as they might be evaluated as inferior products. At the same time, with an increasing number of 3D-capable television sets sold (Seals, 2013), consumers might become more interested in using the additional feature they have paid for and invest in 3D discs. The impact of 3D on home entertainment revenues remains an exciting open question for further research.

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