DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 22-08

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Depar men of Economics

Uni ersi   of Colorado Bo lder
Bo lder, Colorado 80309

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What is the e ect of the corporate marriage of Disney and Pixar on their lms' image quality?

Youngeun Choi

October 26, 2022

Abstract

This paper estimates the impact of Disney's acquisition of Pixar on the image quality of Disney's animated feature lms. Image quality is one of the explicit mea-

1 Introduction

The entertainment and media industries have actively increased mergers and acquisitions (M&A), which have become an important industry growth strategy over two decades. The purposes of business acquisition are an integration and expansion strategy of the industry, either vertically or horizontally. Companies want to consolidate their market positions and intensify their competitiveness not only in their domains but also in other domains. In the case of Disney, mega mergers were with Pixar (7.4 billion USD, 2006), Marvel (4.4 billion USD, 2009), Lucas lm (4.05 billion USD, 2012), and 21st Century Fox (71.3 billion USD, 2019). The acquisitions of each company have somewhat di erent rationales. For instance, Disney bought Lucas lm to gain the copyrights of the Star Wars series, and the purchase of 21st Century Fox was to enter the streaming service market. These colossal mergers have impacted its nancial performance (Korenkova (2019)). Beyond the nancial performance, the e ect of M&A on product quality is still an unanswered question.

This paper estimates the impact of the Disney acquisition of Pixar on the image quality of their animated feature lms. Image quality is one of the explicit measurements for a product's key attributes. Visual attributes, such as images or texts, are the consumer's recognition of objects, where producers take them as primary variables for their decision making. Bajari and Benkard (2005) take the quality as endogenous choice of the producer, and assume that all charateristics are perfectly observed in the analysis even though it is unobservable. It is hard to quantify those visual attributes, because of the in nite amount of information contained in images. A few papers use the number of patents to measure the product quality improvement from M&A (Ahuja and Katila (2001); Cloodt, Hagedoorn and Van Kranenburg (2006); Giovanni (2012)), but patents are the second-best solution to capture the quality of products. After application for patents, it usually takes up to 18 months for them to be approved. It is hard to claim that the quality of lms is based on the growth in the number of patents. Not all companies pursue acquisition to exploit the increase in patents. Some rms are involved in M&A to increase market power, or gain entry into new markets, not for technological innovation only (Zhao (2009)). Once we quantify unstructured data, in this paper visual attributes, it is possible to know the e ect of the merger on quality improvement.

Today Disney's animated lms are highly acclaimed in outstanding storytelling and emotional resonance. As they release a new animated lm, it consistently ranks at the top ten highest-grossing movies. However, Disney faced increasing competition, when in the late 1990s, their box o ce performances were not always stellar. For example, Pixar and DreamWorks incorporated their developed technology such as computer-generated sequences into their lms. Disney had no striking computer graphics technology compared to other companies, but they had pro ciency in the movie industry. While Pixar had an innovative software program, for example RenderMan, they had no distribution channel. From this acquisition, Disney expected to reboot their image quality and take back the throne, whereas Pixar anticipated expanding their market power or reducing nancial risk. The reason to improve image quality is not only to provide a better product to consumers, but also companies want to reduce their costs. The technical director of Pixar once said in the VentureBeat's Transform 2020 conference that the modern digital animation industry faces time-consuming and high cost in rendering animation. They try to improve the image quality to reduce the workload and costs[1]. Better image quality means creating another innovation to make technology cheaper and more e cient.

This paper conducts a causal analysis of how the acquisition a ected Disney's animation quality improvement before and after the merger using the Synthetic Control Method (SCM). Disney only acquired Pixar among animated studios between 1996 to 2016. The SCM is the perfect method to estimate the e ect of a single aggregate unit that is exposed to a interest of event at period T_0. However, it is always an unclear question which variables should be included to nd the synthetic controls. This paper adopts the model selection method in the SCM, which uses out-of-sample techniques. From the candidate non-nested models, one model is selected based on the lowest root mean squared prediction error (RMSPE). This is the rst empirical paper using the model selection method in this SCM literature.

Another main challenge is quantifying the image quality. No other paper measures the e ect on the image quality from the acquisition. Instead, Zhang et al. (2017) estimate the e ects of property images on demand for AirBnb. They brought up the word \image quality" but only used the number of images posted on the website as an indicator. This indicator is not an appropriate measurement for image quality. This paper uses a di erent method to measure the explanatory variable (image quality), which is the Blind Referenceless Image Spatial Quality Evaluator (BRISQUE) techniques developed by Anish, Moorthy and Bovik (2012). The BRISQUE is a highly cited method in the computer and engineering elds. This distinguishing method requires no reference image[2] where it evaluates an image as it is distorted. To illustrate a new practical application of the BRISQUE in economics, this paper describes the process and how the quality is measured. The Support Vector Machine

[1]In the conference, he said that \at least 50 CPU hours to render one frame at 2K resolution." Those companies try to make rendering cheaper through innovation for the high rendering times in the digital animation industry. Pixar adopted Generative Adversariaxplaof 88.6S(or)-25817.91(f 8831(TGANualit)27auo.halit)29t

Mouse. Disney's studio relocated from Kansas City to Hollywood with the rest of the movie industry in 1930. Disney's core competency was making characters express emotion and working with detailed realism. Disney Studio released the rst feature length animation movie, Snow White and the Seven Dwarfs, in 1937. This lm used the traditional animation process, which included rendering two-dimensional visuals on a transparent sheet of celluloid (this technique is called a cel animation process). The cel animation is known as 2D, paper-drawn, or traditional animation technique. Animators produce a sequence of drawings in celluloid, which are photographed sequentially over a background by a movie camera. Using cel animation transfers illustration between frames rather than redrawing from scratch each time. Snow White was a monumental success around the world in that period, and became the highest grossing lm that year.

Disney's main competitor was Fleischer Studios in the 1930s. Fleischer Studios was an American animation studio founded in 1929 by brothers Max and Dave Fleischer. The Fleischers invented the rotoscoping process, still in use today. The rotoscope process is creating animated sequences by tracing over live-action footage frame by frame. This technique allows animators to create realistic characters, but is time consuming. The Fleischers were a premier producer of animated cartoons with Disney Studio in the 1930s until Paramount Pictures acquired ownership in late 1941. The other Disney competitor was Warner Bros. Warner Bros. movie studio was founded in 1921, and its animation studio was opened in 1928. Warner Bros. developed characters in zany, exaggerated, and extreme styles. They created enduring cartoon characters, such as Bugs Bunny, and Road Runner

A rising production costs delayed the investment in the feature-length animation until two developments boosted in the 1980s. Disney Studio discovered the musical could be revived in the cartoon form, when they released The Little Marmaid in 1989. The second was the development of computer animation technology. The cel animation had developed inside a computing environment in the digital age, but cel animation was superseded by computer graphics. Editing, compositing, and motion tracking had been prohibitively expensive, but the advent of the new technology in the animation industry greatly reduced costs.

As 1940s, scientist and researcher implemented the computer graphics. In 1940s, John Whitney built a custom computer device, producing precise lines and shapes. Saul Bass, with the assistance of the Whitney, animated the opening title sequence of Vertigo using this device. Vertigo is the movie from Alfred Hitchcock in 1958, considered to be one of the rst live-action lms using computer animation. By the 1980s, many people began using computer graphics as an art form, and graphic design tools had evolved dramatically. From 2D images to virtual 3D objects, animators had gured out how to move, shade and light to objects before rendering them as animation frames. Superior software compressed the

From M&A, one could expect that the merger of Disney and Pixar would further strengthen the capability of technology and innovation for both companies. If the purpose of M&A were to find a way to reboot Disney's image, one should look on whether the transaction of those companies was successful or not by looking over the image quality improvement.

3 Literature Review

3.1 The merger and acquisition in economies

In the former strand of economics and business literature, Andrade et al. (2001) answer why M&A occur, for the economies of scale or synergies. The activity was held near the industry cluster to foster economies during the 1990s. In order to explain the economic development resulting from M&A, many papers have looked at the impact on the financial performances. Bennett and Dam (2018) estimate significant embedded merger premiums in stock prices using both the logit regression and the two-stage fixed effect method. Dranev, Frolova and Ochirova (2019) narrow down to see the effect of the fintech industry M&A on the financial sector stock returns. Bhagwat, Dam and Harford (2016) find the activity decreases market volatility at the interim period. Not only considering the firm's performance, Smeets, Ierulli and Gibbs (2016) study the impact on employment with robust matched employer-employee data.

Previous papers use various methods to find the effect of M&A. Especially for comparative case studies, Kessler and McClellan (2000), Lehto and Böckerman (2008), and Di Guardo, Harrigan and Marku (2016) analyze the firm's employment and the performance from M&A using difference-in-difference. Giovanni (2012) first used the synthetic control method (SCM) to explore the effect of M&A on the patenting quantity. Zohrehvand, Doshi and Vanneste (2021) exploit the synthetic control method to find the effect of Dollar Tree-Family Dollar acquisition on shareholder returns. Berger et al. (2021) study deregulation, which allows the transaction between companies using SCM. They argue mergers create value for the firm and its shareholders.

In the entertainment sector, Sweeting (2010) applies the fixed effect to find the product positioning of the music radio industry post M&A. For the effect of Disney's acquisition of 20th Century-Fox, Sergi, Owers and Alexander (2019), Korenkova (2019) and Agnihotri and Bhattacharya (2021) provide case studies by comparing the revenue before and after the merger. Still, few papers ask whether the transaction between companies directly improves the quality of their product.

For the assessment of the firm's quality improvement, previous literature, in contrast to this analysis, mostly uses the number of patents in their portfolios to measure knowledge and show the increase of the number of patents (Ahuja and Katila (2001); Cloodt, Hage-

since $T_0 + 1$, hence $Y_{jt} = Y^1_{1t}; t > T_0$ and $Y_{jt} = Y^0_{jt}$ for $j = 2; ...; J + 1$ and $t = 1; \cdots; T$. Y^1_{1t} is observable so that the challenge is to predict the counterfactual outcome Y^0_{1t}.

Abadie and Gardeazabal (2003) introduce the weights that characterize the synthetic controls to build a counterfactual outcomes for the treated unit in the absence of treatment with the combination of weighted control units. To choose weights $W = (w_2; \cdots; w_J)$, first let X_1 be a $(k \times 1)$ vector of pre-intervention characteristics (predictors) of the treated unit, where k is the number of predictors. Let X_0 be $(k \times J)$ matrix of containing the same variables for the untreated units. Abadie and Gardeazabal (2003) and Abadie, Diamond and Hainmueller (2010) propose to minimize the distance between the characteristics of untreated (X_0) and the characteristics of treated (X_1),

$$||X_1 - X_0W||_V = \sqrt{(X_1 - X_0W)'V(X_1 - X_0W)} \quad (1)$$

subject to the restriction with the sum of weights to one and weights to be non-negative. W denotes weights for a potential synthetic controls and V is weights of predictors (relative importance of obtaining a good match between X_1 and X_0) given by the nonnegative diagonal matrix. The question still remains how to select V. Abadie, Diamond and Hainmueller (2010) choose V by minimizing the mean squared prediction error (MSPE) of treated outcome to the MSPE of the synthetic control outcomes prior to the treatment. In this paper, we also adopt the method that Abadie, Diamond and Hainmueller (2010) provide.

There is no consensus about which variables should be included in predictors. Instead of using unobserved factors to predict the counterfactual outcome, previous applied papers use the simple average of the outcome variable for the pre-treatment periods, or include covariates for the precise estimation. For instance, Abadie and Gardeazabal (2003); Abadie, Diamond and Hainmueller (2015) use the mean of all pre-treatment outcome values and additional covariates, Abadie, Diamond and Hainmueller (2010) pick $Y_{j;T_0}; Y_{j;T_0-8}$ and $Y_{j;T_0-13}$, and Bohn, Lofstrom and Raphael (2014); Gobillon and Magnac (2016) use all pre-treatment outcome values only. Abadie, Diamond and Hainmueller (2010) claim the way of using the pre-treatment outcomes should depend on the results to provide a good fit for the treatment outcome. In practice, however, Ferman, Pinto and Possebom (2020) pose a problem of a lack of guidance on the selection of matching variables used in the synthetic control estimator; the lack of guidance would create specification-searching opportunities. Researchers will look for specifications that yield better results including or excluding some values from its specification.

Choi (2022) proposes using the out-of-sample forecasting technique to find the best set of predictors for the synthetic control method setting. This paper finds the synthetic controls from the first set of samples and evaluates the predictive power of each candidate model from the rest set of samples to find the best set of predictors. The out-of-sample forecasting technique is conducted by splitting the pre-treatment period into two parts: 1) the initial 70% for the training set and 2) the subsequent 30% period for the testing set. As the time period is yearly based, so I drop the decimal places and stick to 70:30 ratio. The training set is used to build the synthetic controls in each candidate model. Afterwards, the testing set is used to evaluate the predictive power of each model by minimizing the root mean squared prediction error (RMSPE) of the outcome. The number of candidates model is non-nested $2^K - 1 = 2^9 - 1 = 511$, where the number of plausible predictors is k=9. The case where all predictors are not included is excluded. Finally, the smallest RMSPE among all possible models is selected as the optima model for the estimation.

4.2 Blind/Referenceless Image Spatial Quality Evaluator

Human beings can capture the image as it is, but a computer needs the value to perceive it is an image. As we input an original image into the computer, the computer starts to segment the image into the smallest indivisible segments unit, a pixel. Pixel intensity is the first collection of information of pixels. Since a few metrics have been developed to measure specific regular statistical properties, whereas the distorted image deviates from the regular statistical properties. Distribution of the natural image's pixel intensity differs from the distribution of the distorted image's pixel intensity. As we normalize the pixel intensities and compute the distribution over these normalized intensities, the resulting discrepancy from the regularity of natural statistics helps to design the image quality assessment without needing any reference image. The pixel intensity is represented by height $i \in 1, \ldots, M$ and width $j \in 1, \ldots, N$, $I(i,j)$.

$$\hat{I}(i,j) = \frac{I(i,j) - \mu(i,j)}{\sigma(i,j) + C} \tag{2}$$

$$\mu(i,j) = \sum_{k=-K}^{K} \sum_{l=-L}^{L} w_{k,l} I_{k,l}(i,j) \tag{3}$$

$$\sigma(i,j) = \sqrt{\sum_{k=-K}^{K} \sum_{l=-L}^{L} w_{k,l} (I_{k,l}(i,j) - \mu(i,j))^2} \tag{4}$$

where K, L is the maximum value of height and width[4]. Eq. (2) is the formula of MSCN where Eq. (3) and (4) are local mean and local deviation, and $C = 1$ is a constant value to avoid the denominator to be zero. Here $w_{k,l}$ is a Gaussian filter of size (K,L) to apply the Gaussian filter to the image. In order to extract features from the image, we use filter technique where we call filter as window, mask, or kernel. Gaussian filter is used to blur images and reduce noise, which uses Gaussian function.

After normalization, pixel intensities of natural images follow a Gaussian Distribution, while pixel intensities of unnatural or distorted images do not. MSCN provides a suitable normalization for pixel intensities. As we compute MSCN, it is possible to know the relationship of the pixel since it is smoothly connected with neighboring pixels. Even though MSCN coefficients are definitely homogenous for pristine images, there would be disturbance from the distortion to the sign of the adjacent coefficients. The BRISQUE technique provides a model to capture the properties of neighboring pixels; it is called the empirical distribution of pair-wise products of neighboring MSCN coefficientsxelhe BRISQUE technique provides a

Bovik (2012) nd that the MSCN coe cients are distributed as a Generalized Gaussian Distribution (GGD) and the pairwise products of neighboring coe cients are distributed as technique, see Anish, Moorthy and Bovik (2012).

In the merger analysis, the outcome of interest is the image quality. The goal of using BRISQUE in this paper is to extract the information of image quality of animation rms' to measure the e ect of M&A on image quality. We aggregate each IQA for all movies created by companies j in period t.

5 Data

To estimate the e ect of M&A on image quality, this paper considers 12 samples, where the treated unit is \Disney" and the control units are the animation studios that produced animations from 1996 to 2016: Shin-Ei, Asatsu, Toei, Ghibli, 20th Century, DreamWorks, Paramount, TMS, OLM, Universal, Sony. When one studio produced at least more than two animated lms, we take the average of those lms. For the case where one rm did not produce in a given year, the average between before and after is taken. Starting point is 1996, ten years prior to the 2006 merger, and the impact up to ten years later (2016) is measured.

This paper collects the images of the animations in the Internet Movie Database, IMDb. IMDB is the world's most popular online database of information about lms. They provide the lm's related features and still cuts of lm. For IQA, the rst steel cut image of the feature-length movie is chosen provided by IMDb. The candidates for predictors were all collected manually from IMDb and Anime News Network. Anime News Network is a number of English language news source that provides information of Japanese animation.

Possible variables used for predictors are the pre-treatment period of IQA, country of origin (dummy variable whether it is produced in the United States or Not), budget (measured in 2006 dollars), length of the lm (minutes), the number of producers, the number of lm editors, the number of sta of the art, visual, and animation department. The number of sta involved in the production line provides a solid indicator of how the company focuses on image quality.

From the storyboard to the nal frame of animated lms, each lm takes an average of three to ve years to create (WaltDisney (2022)). The duration of the creation of each animated lm is a possible variable to consider. However, some famous movies were possible to obtain this information, but it is hard to obtain data for all movies that I consider in this analysis. Thus, the duration of the creation period is excluded as predictor.

6 Results

Directly comparing the dynamic of IQA between Disney and other companies could produce disparities in their e ect if the treated outcome and the counterfactual outcome di er before the event of interest. Figure 2 plots trends of IQA of Disney and the average of the rest of the animation companies. As the gure shows, the rest of the companies may not provide a suitable comparison group to study the e ects of M&A on image quality. Before M&A between Disney and Pixar, Disney and other companies show di erent trajectories in image quality. Levels of the image quality in Disney start to diverge with the advent of technology of 3D animation in 2005, the period where Chicken Little was released. In 2006, the year M&A was accomplished, Disney adapted to the technology change and acquired new 3D animation techniques to improve the image quality.

companies in 2006.

Figure 6 illustrates the IQA gaps between Disney and synthetic Disney under the selected and full model. The degree of the estimated effect after Disney's acquisition of Pixar shows the 20 point of increase in IQA under the full model (all predictors are included). Interestingly, the full model captures more treatment effects, which leads to misjudgment of the findings. It is highly recommended to conduct model selection to avoid excessively or minorly the treatment effect.

These findings are highly related to the rank of the highest-grossing film in Disney. Figure 7 plots the rank of the highest-grossing film for Disney and other four representative studios in a given year. Animation movies from Dream Works, Paramount, or Pixar used to seize the market power of the animation industry between 2006 and 2012. Although Disney struggled to be the highest-grossing film after the merger, they took back the throne in 2013 from *Frozen*. Disney finally knew how to create hits on their hands by mixing their hand-drawn method with computer-animated techniques. *Frozen*, released in 2013, is the perfect blend of these techniques that Disney admitted. They also knew that their animation quality was finally back on track (Kara (2019)).

7 Inference about M&A

To assess the significance of our estimates, we conduct the same placebo studies that Abadie, Diamond and Hainmueller (2010) used in previous studies. The treatment of interest is reassigned to companies different from Disney. Other companies are being reassigned as treated and Disney is shifted to the donor pool. The synthetic control method is used iteratively to estimate the effect of M&A and to check estimated gaps for other companies where no intervention took place. If the effect of M&A on image quality shows a large difference relative to the distribution of placebo effects, then we will consider the effect to be significant.

Figure 8 represents the results for the placebo test. The dashed gray lines are the gap associated with each of the 11 runs of the test. This denotes IQA difference between mock treated companies and their respective synthetic versions. The bold blue line emphasizes the gap estimated for Disney. Before the merger, gaps between each mock company and its synthetic counterpart show a larger gap, whereas change in Disney is nearly zero which doesn't show much change. That is, our placebo Disney has no noticeable effect in contrast to the actual Disney. As Figure 6 exhibits, the estimated gap for Disney over the post-treatment period is large relative to the distribution of the gaps for the companies in the donor pool.

Figure 9 reports the ratios between the post M&A RMSPE ($R_j(T_0+1;T)$) and the pre M&A RMSPE ($R_j(1;T_0)$) for Disney and for all the companies in the donor pool. The ratio is

$$r_j = \frac{R_j(T_0+1;T)}{R_j(1;T_0)} \tag{9}$$

which measures the quality of the t of synthetic control for unit j in the post-treatment period, relative to the quality of the t for unit j in the pre-treatment period. Disney is prominent as the company with the highest ratio between post and pre treatment period. The post-treatment gap is about 5 times larger than the pre-treatment gap on average. These results con rm that our estimated treatment e ects for Disney are signi cantly large relative to that obtained when we conduct the same application to the rms in the donor pool.

8 Conclusion

This paper estimates the e ect of Disney's acquisition of Pixar on Disney's image quality applying the synthetic control method. Economists are confronted with the question of which variables to use in the SCM. This paper adopts an out-of-sample technique to select the optimal model in the SCM. Among all possible candidate sets of models, synthetic controls were selected using the rst 70% of the pre-treatment period. Then, this analysis selected the smallest RMSPE of models computed using the 30% of the pre-treatment period. The empirical ndings is the image quality improved 18 points after the merger compared to the pre-treatment period. Moreover, the estimated results using all predictors show more change in the magnitude of the quality improvement, which alerts researchers to take notice of the interpretation of the treatment e ect after the interest.

In addition, this paper introduces a modern image quality assessment technique currently used in engineering literature to measure the image quality. Even though these visual attributes are the crucial part for the decision behavior of the rm's production, they are deemed to be unobservable attributes in the economic literature. As this paper quanti es the image quality, it is now possible to measure the quality improvement from the M&A. This paper nds that the merger between Disney and Pixar enhances the image quality

The limitation of this paper is that it does not consider all images in the feature-length animated movie analyzed. It is too time consuming and expensive to measure all the scenes in a movie, so it is impossible to quantify the quality of all the images. Moreover, Abadie, Diamond and Hainmueller (2010) and Ferman, Pinto and Possebom (2020) propose using longer pre-treatment period of time for a good synthetic control fit. However, there are few companies that produced animation over 20 years before the treatment period. For this reason, we only select 10 years ahead of the treatment for the estimation. This paper obtains good measurement of fit with 10 years prior to the 2006 merger, so we have shown that the SCM works well in the short-term period.

There is still an unanswered question from the acquisition how Pixar's market entry affected their power in the movie industry or their financial performance. Nevo (2000) estimates the effects of the mergers with differentiated products. He estimates the effect of the horizontal merger to the cereal industry concentration. One can extend his research to the vertical merger between Disney and Pixar on the industry concentration of Disney or Pixar. This case, the price is fixed, while Nevo (2000) did not. All animated studios have the same market price of their films (except movies provided through streaming service), because the ticket price of a movie in the theatre is stable. Besides the price, it is possible to think about the cost side only. Berry and Waldfogel (2010) assume that the marginal cost is constant in quantity but increases in quality, and study the effect on the market size. The movie industry might be distinctive to apply this theorem, because the cost of producing animation decreases as the quality increases. Thus, it might be interesting to observe the change in the producer welfare as the cost of production decreases but quality increases for the further research.

Lastly, the automated image quality assessment can be applied to other fields in eco-

9 Figures

Figure 1: Proccess of BRISQUE

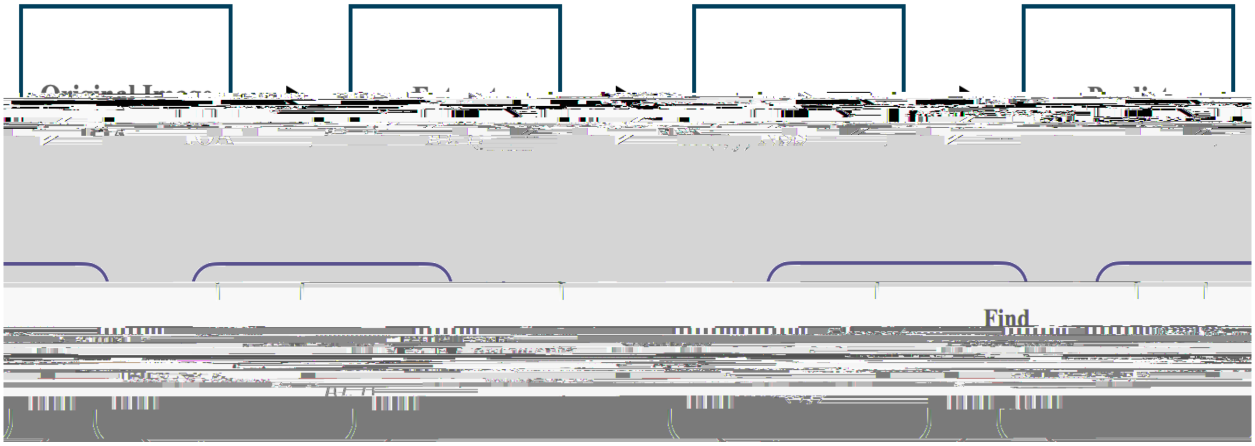
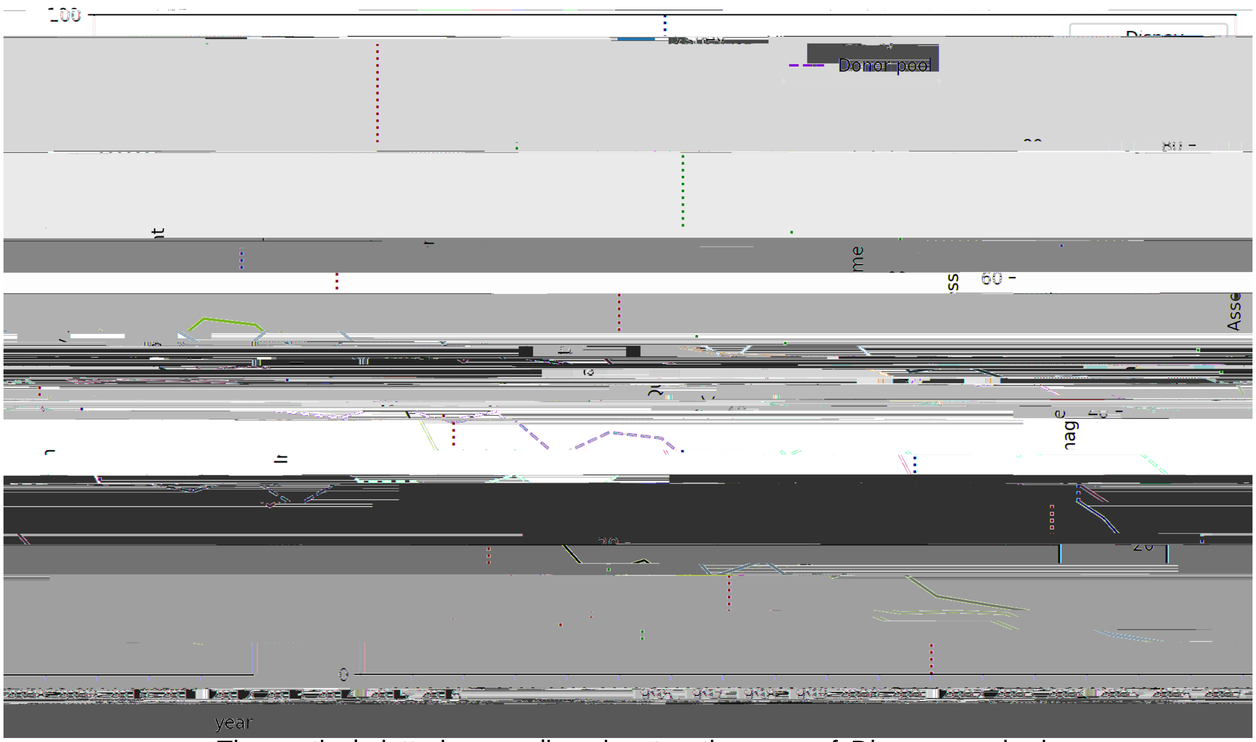


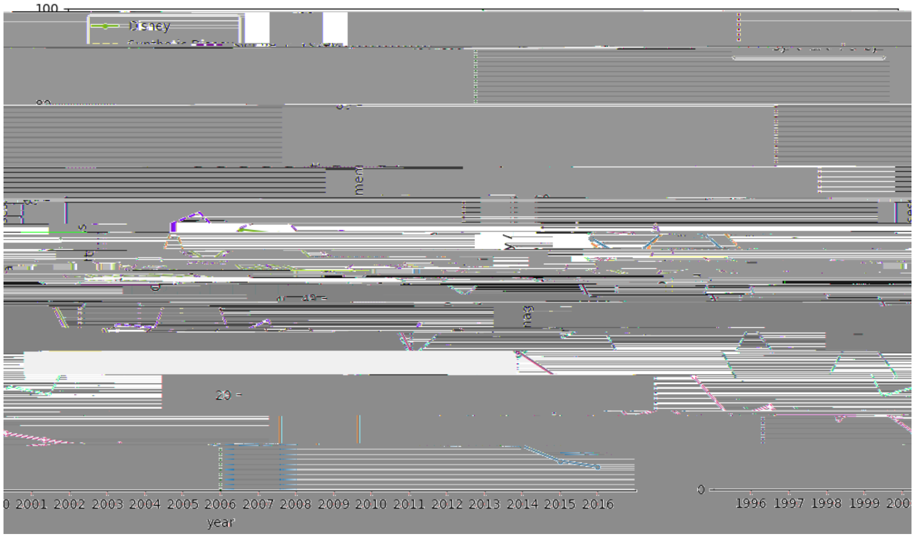
Figure 2: Trends in IQA: Disney and other animation companies



The vertical dotted green line denotes the year of Disney acquired Pixar. The dashed orange line represents the average of IQA of units in the donor pool.

Figure 3: Disney and synthetic controls IQA

(a) Budget, the number of lm editors, and the number of sta in the visual departments are included.



(b) Full model (all variables are included.)

Note: The vertical dotted green line denotes the year of Disney acquired Pixar.

Figure 4: Disney and synthetic controls IQA

(a) The country of origin, budget, and the number of lm editors are included.

(b) The country of origin, length, budget, the number of lm editors, the number of sta s in the visual department, and IQA are included.

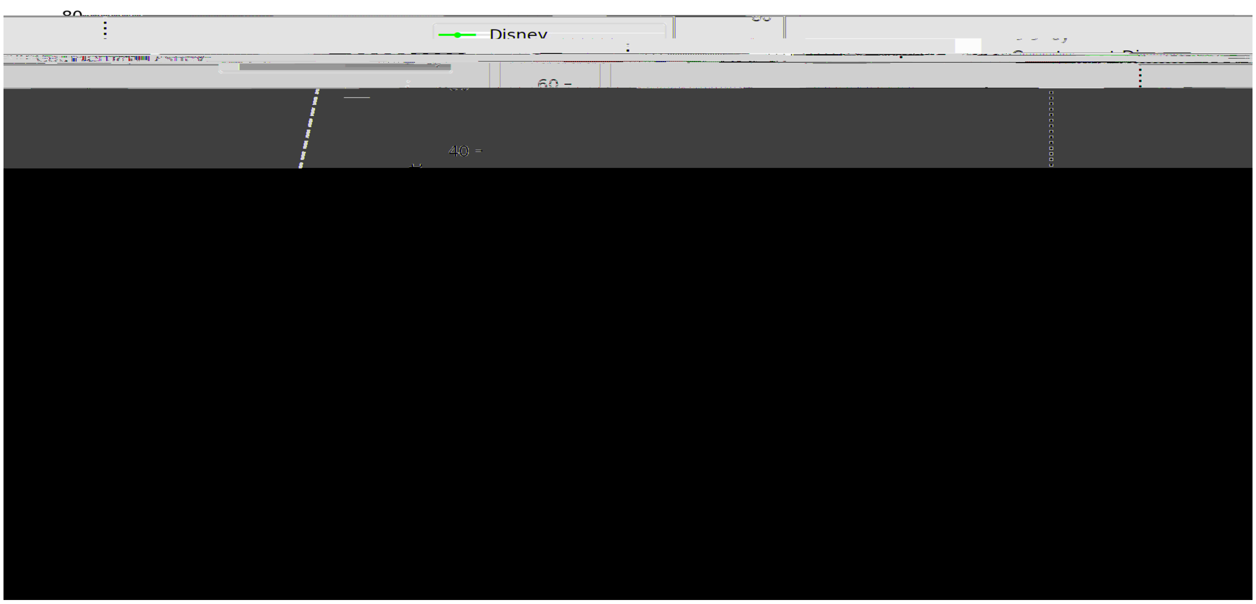
Note: The vertical dotted green line denotes the year of Disney acquired Pixar.

Figure 5: IQA gaps between Disney and synthetic Disney of the selected model

Note: The vertical dotted green line denotes the year of Disney acquired Pixar.

Figure 6: IQA gaps between Disney and synthetic Disney: Selected Model vs Full Model

Figure 8: IQA gaps in Disney and Synthetic Disney and placebo gaps in all companies of the selected model



Note: The vertical dotted green line denotes the year of Disney acquired Pixar.

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Table 2: Company Weights in the synthetic Disney

Company	Selected Model	Full Model	Comparison Model 1	Comparison Model 2
Toi	0.275	-	-	-
Ghibli	-	-	0.418	-
20th Century	-	-	0.582	0.75
DreamWorks	0.703	0.999	-	-
Paramount	0.022	-	-	0.25

Supplementary for the Image Quality Assessment

A. Generalized and Asymmetric Generalized Gaussian Distribution

The generalized Gaussian distribution can be used to e ectively capture the broader spectrum of distorted image statistics where the GGD with zero mean is given by by (Anish, of 29 reference images with 7770 distorted images with ve di erent distortion categories - JPEG2000, JEPG compression, additive white Gaussian noise (WN), Gaussian blur, and a Rayleigh fast-fading channel simulation. To correlate human vision, di erent mean opinion score (DMOS) is used to represent the subjective quality of the image. Each of the distorted images has an associated di erence DMOS in the database.

The limitation of using this database in this paper is that it does not consist of many cartoon or computer graphic images. I admit this limitation, but it is di cult to construct cartoon database for the time constraint and expensive cost. Spearman rank order correlation coe cient (SROCC) is used to evaluate the prediction performance of IQA method.

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