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What is the effect of the corporate marriage of Disney and Pixar on their films' image quality?

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Abstract

This paper estimates the impact of Disney's acquisition of Pixar on the image quality of Disney's animated feature films. Image quality is one of the explicit measurements for the product's key attributes. By improving image quality, Disney reduces the cost of technology that animation makers use. Better image quality, therefore, signifies that another innovation has been created to make technology cheaper and more competitive. Although visual attributes in the animated films are the critical factor for the decision making of the firm's production, previous literature describes them as unobservable. This paper uniquely adopts a modern image quality assessment technique –Blind/Referencelss Image Spatial Quality Evaluator (BRISQUE)– used in engineering literature to quantify image quality. In this technique, statistical properties are used to extract features of the images, and this information is identified through the algorithm. Those predicted features are used to compute the image quality of animated films. To find the impact on quality improvement following the merger, this paper conducts a causal analysis using the Synthetic Control Method. Still, it is hard to know which variables should be included to find the optimal synthetic controls. In this studies, the best set of possible predictors is chosen by applying the out-of-sample (OOS) model selection technique. In the OOS approaches, the pre-treatment period is split into two parts. The first training set is used to build control units among all possible models. The second testing set is then used to evaluate the performance of each model, and the least root mean squared prediction error is selected as the best optimal set of alternative predictors. Our empirical findings from the SCM imply that the merger between Disney and Pixar has improved the image quality of Disney's animation since the transaction in 2006.

Keywords: Synthetic Control Method, Model Selection, Image Quality Assessment.
JEL Classification: C8, L1

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), Lucasfilm (4.05 billion USD, 2012), and 21st Century Fox (71.3 billion USD, 2019). The acquisitions of each company have somewhat different rationales. For instance, Disney bought Lucasfilm 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 financial performance (Korenkova (2019)). Beyond the financial performance, the effect 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 films. 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 infinite 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 films is based on the growth in the number of patents. Not all companies pursue acquisition to exploit the increase in patents. Some firms 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 effect of the merger on quality improvement.

Today Disney's animated films are highly acclaimed in outstanding storytelling and emotional resonance. As they release a new animated film, it consistently ranks at the top ten highest-grossing movies. However, Disney faced increasing competition, when in the late 1990s, their box office performances were not always stellar. For example, Pixar and DreamWorks incorporated their developed technology such as computer-generated sequences into their films. Disney had no striking computer graphics technology compared to other companies, but they had proficiency 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 financial 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 efficient.

This paper conducts a causal analysis of how the acquisition affected 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 effect 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 find 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 first empirical paper using the model selection method in this SCM literature.

Another main challenge is quantifying the image quality. No other paper measures the effect on the image quality from the acquisition. Instead, Zhang et al. (2017) estimate the effects 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 different 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 fields. 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 Adversarial Network (GAN) to improve quality, so they can make the rendering system cheaper through innovation.

[2]Reference image means a very good quality image that other image quality assessment techniques used to require.

(SVR) is exploited to measure the image quality. Selecting the features of image is the crucial part in the process of classification in the SVR. Features are the main information about the image that the algorithm identifies. Natural Scene Statistics (NSS) is extracted to compute those features from the image. The compelling part of the BRISQUE is that it reduces the number of unknown feature parameters to finite from infinite features in the image. We compute the image quality of animated films in each studio and use that as our explanatory variables.

The SCM is well-suited to estimate the effects of the merger between Disney and Pixar. This paper estimates that Disney's acquisition of Pixar notably improved Disney's animated films' image quality with the gap between Disney and the Synthetic Disney. An average of image quality increased 18 points more than the value it would have not acquired Pixar after 2006. To evaluate the credibility of our results, we carry out placebo studies. Permutation distribution is constructed by pooling the effect iteratively by applying the same method to the control units in the donor pool and putting the treated unit into the donor pool. Note that the placebo studies have been conducted for all animated studios. The results show that post-acquisition divergence in Disney is visibly larger than any of the divergences in the other studios.

2 Background

2.1 Development of animation technology

Animation is the process of bringing inanimate objects to objects through motion pictures. Animation techniques manipulate drawings and images the movement and present a narrative on screen. The history of animation extends from hand-drawn methods to computer graphics technology. The industrialization of the animation industry was established in New York around 1914, when American cartoonist Winsor McCay drew the first short animation, *Gertie the Dinosaur*. This animation involved the key elements of animation techniques such as keyframes, registration points, a tracing paper, and animation loops [3]. It influenced the next generation of animators such as the Fleischer brothers and Walt Disney.

Walt Disney Studio was founded in 1923 by brothers Walt and Roy Disney. They refined and developed the previous animation techniques, concentrating on quality. Toward the end of the 1920s, Walt Disney put the sound in cartoons, thus building on their huge success. Walt Disney's the first short animated film is *Steamboat Willie* in 1928, popularizing Mickey

[3]Keyframes are an animator's signpost, which they direct the animation software to know the movement of the images. Keyframes are used to mark the start and end of an action. Registration point is the native center $(0, 0)$ at all times of the object. Animation loop is causing an animation to repeat.

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 first feature length animation movie, *Snow White and the Seven Dwarfs*, in 1937. This film 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 film 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 first live-action films 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 figured out how to move, shade and light to objects before rendering them as animation frames. Superior software compressed the previous animation process and helped to produce animation.

John Lasseter cofounded the Pixar studio with Steve Jobs and Ed Catmull in 1986. Pixar aimed to develop computer technology. Pixar became a world leader in the field of computer animation, and its groundbreaking work advanced the animation industry. One famous CG software program is RenderMan, which creates complex, high quality photorealistic imagery (Raghavachary (2006)). In 1995, Pixar released its first full length computer graphics movie, *Toy Story*, which was a huge success, grossing $3.3 billion worldwide.

Meanwhile, DreamWorks was formed in 1994 by Steven Spielberg, David Geffen, and Jeffrey Katzenberg, three of the entertainment industry's biggest names. They have focused on computer-generated imagery (CGI) since 2003. The combination of comedy and high quality technology appealed to adults as well as children, such that DreamWorks became one of the most successful animation studios, and in 2007, it had the top grossing with the movie *Shrek the third*, $7.9 billion.

2.2 Mergers and Acquisition of Disney

Today Disney is renowned for their outstanding storytelling and emotional resonance to moviegoers. Their brand reputation has kept them at the top animation movie making companies for the past decades. In 2010s, they held seven of the top ten highest-grossing animated movies in USA and around the world. Nevertheless, their box office rankings were not always stellar. Disney started to face a ton of competition in the late 1990s as more animated studios developed their technology based on computer graphics. Disney's hand-drawn method was perceived as outdated to viewers as Pixar and DreamWorks movies were released. The box office performance of Disney dropped in the late 1990s and early 2000s. For example, the revenue of Tarzan, which was released in 1999, is $124,429,771 (adjusted in 2006 price index), whereas the revenue of Dinosaur in 2000 is $141,450,348 and the revenue of Atlantis in 2001 is $140,463,015. Hercules was the highest-grossing animated films of 1997. After all, Disney lost the throne in 1998, 1999, and 2001 to Pixar. Even though Disney introduced fully computer animated in 2005, Chicken Little, the movie "won" as the worst animated film in Stinkers Bad Movie Awards and took in only $21,228,878.

At that time, Pixar did not outsource its products to others, keeping their technology as their core competency. Still, Pixar and Disney had a good relationship where Disney funded and distributed Pixar's films. In January 2006, Disney announced that it would acquire Pixar at a valuation of 7.4 billion USD, but they decided to keep the animation studio separate. From the business and market side, Pixar wanted to expand their market power or reduce their financial risk in belonging to a parent company.

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, Hagedoorn and Van Kranenburg (2006); Giovanni (2012)). They use the random effects regression model and Poisson regression. In the animation industry, some firms have animation-related patents such as generating 3D animation sequences or editing 3D videos and images. After its acquisition of Pixar, Disney increased the number of patents and diversified its animation related to its patent portfolio (Insights (2022)). It is explicit that patents provide a second-best solution to the resulting problem to find the effect of M&A on quality improvement.

However, Zhao (2009) argues that firms engaging in acquisition activities are less innovative and show declines in technological innovation. The patent confers to an inventor the sole right for production. However, not all companies pursue the acquisition to exploit the increases in patents for this purpose. Not acquiring these inputs for technical innovation, some firms involved in this form of transaction acquire access to distribution channels, rise market power, or gain entry into new markets. Thus, a limitation of using the number of patents exists. For example, it is unclear which movie in the specific period paves the way for the application for patents as it takes time to apply and get acceptance. Usually, patent application takes up to 18 months to be approved.

This paper argues that, for the animation assessment, the image quality assessment approach is a more explicit measure to estimate the firm's transaction effect directly. Perhaps the only example of this type of inquiry, Han et al. (2021) signify to use unstructured data, which represents the product differentiation to analyze the business decision. They apply the design characteristics of fonts to investigate the effect of the M&A on font companies design change. Font shapes are also comprised of infinite number of parameters. They quantify font shapes by using a word embedding method from a neural network technique to transform font shapes into low dimensional vector, and finally construct the font design differentiation measures for their explanatory variables.

3.2 Image Quality Assessment

This paper is the first study applying image quality assessment techniques in economics. Image Quality Assessment (IQA) evaluates the perceptual quality of an image close to human vision. As human vision is subjective, it provides a better objective measure of the image. Studying image quality is desirable because it provides necessary guidance to optimize, construct or manage business decisions. Unstructured data such as images do not adhere to conventional data models, where it is more challenging to interpret and parse the hidden characteristics. The technical method for assessing image quality has been researched in the computer science and engineering fields. IQA is undergoing increasing popularity in the field of image processing. IQA algorithms take an arbitrary image as input and produce a quality index as output. IQA measures can be divided into three types: full-reference (FR), reduced-reference (RR), and no-reference (NR). The difference between the three measures is whether one needs a distorted image or not. A distorted image is a version of the original image that is distorted by noise, color transformation, geometric transformations, etc. FR needs a relatively clean, non-distorted, image to measure the level of distortion in an quality of distorted image. RR does not have a reference image, but needs some selective information to compare and measure the quality of the distorted image. NR does not require a base image, the only information that the algorithm receives is a distorted image that is being assessed. Previous literature about NR requires it to be distortion-specific where image distortion is known beforehand (Ferzli and Karam (2009)). Another method based on the Natural Scene Statistics (NSS) is proposed to use statistical model approaches in the wavelet domain (Moorthy and Bovik (2011)) and the DCT domain (Saad, Bovik and Charrier (2012)). The reason why previous literature uses the wavelet domain and the DCT domain to capture the change of image through given frequency. Compared to these two studies, Anish, Moorthy and Bovik (2012) demonstrate that BRISQUE is highly efficient as it does not require any transformation to calculate image frequency. In other words, BRISQUE does not require mapping to a different coordinate domain, proving better ability to predict the quality.

4 Methodology

4.1 Estimating the Impact of M&A with the Synthetic Control Method

The paper compares companies affected by the interest of event (in our case, M&A) to a group of unaffected companies. We have units indexed by $j = (1, \cdots, 12)$ observations on periods $t = 1996, ..., 2016$. Unit 1 (Disney) is exposed to the intervention during periods $T_0 + 1, ..., T$ that we say j=1, "treated unit". The remaining j are untreated units, $j = 2$ to $j = 12$ where we say "donor pool". Let Y_{jt}^1 be the outcome that would be observed for unit j at time t of the intervention. Let Y_{jt}^0 be the potential outcome that would be observed for unit j at time t in the absence of the intervention.

The aim of comparison case studies is to estimate the effect of Disney purchasing Pixar on Disney's image quality $\alpha_{1t} = Y_{1t}^1 - Y_{1t}^0$ for $t > T_0$. However, it is impossible to observe the Y_{1t}^1 and Y_{1t}^0 simultaenously. The observed outcome is $Y_{jt} = d_{jt}Y_{jt}^1 + (1 - d_{jt})Y_{jt}^0$, where $d_{jt} = 1$ if unit j is treated at time t and $d_{jt} = 0$ for otherwise. The first unit has been treated since $T_0 + 1$, hence $Y_{jt} = Y_{1t}^1$, $t > T_0$ and $Y_{jt} = Y_{jt}^0$ for $j = 2, ..., J+1$ and $t = 1, \cdots, T$. Y_{1t}^1 is observable so that the challenge is to predict the counterfactual outcome Y_{1t}^0.

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),

$$||X_1 = X_0 W||_V = \sqrt{(X_1 - X_0 W)' V (X_1 - X_0 W)} \tag{1}$$

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 image quality using the information of pixel intensities, the BRISQUE is the newest automatic spatial NR IQA model that image processing literature and research actively uses. It is a powerful tool, which provides a single score for the entire image quality. The technique relies on NSS, analyzing the image quality through a statistical process. Figure 1 shows the steps of arriving at the image quality assessment. First, we need to compute the locally normalized luminescence via local mean subtraction and divide it by the local deviation to find mean subtracted contrast normalized (MSCN) coefficients. The reason for computing MSCN is it provides a good normalization for pixel intensities. Next, we compute feature vectors from the given MSCN. Feature in an image is the information of the image such as edges, lines, the change in pixel values through blurring or noise, etc. Quality of image is a feature for image that valuation discovered. These features affect image quality. We need to form a set of features to capture image quality to feed to an SVM. Finally, we predict IQA using the SVM. The SVM is trained using those features extracted from images in the previous step and provide an information of visual quality.

Extracting Natural Scene Statistics in the Spatial Domain

The first step of the BRISQUE process normalizes the image intensity to find the amount of distortion of the image. The main idea in this step is that the natural image possesses 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 $i \in 1, \cdots, M$ and width $j \in 1, \cdots, N$, $I(i, j)$.

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

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

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

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 coefficients, namely: Horizontal (H(i,j)), Vertical(V(i,j)), Left-Diagonal (D1(i,j)), and Right-Diagonal (D2(i,j))[5]. Anish, Moorthy and

[4]In the implementation, Anish, Moorthy and Bovik (2012) set $K = L = 3$.

[5]

$$H(i,j) = \hat{I}(i,j)\hat{I}(i,j+1) \tag{5}$$

$$V(i,j) = \hat{I}(i,j)\hat{I}(i+1,j) \tag{6}$$

$$D1(i,j) = \hat{I}(i,j)\hat{I}(i+1,j+1) \tag{7}$$

$$D2(i,j) = \hat{I}(i,j)\hat{I}(i-1,j+1) \tag{8}$$

Bovik (2012) find that the MSCN coefficients are distributed as a Generalized Gaussian Distribution (GGD) and the pairwise products of neighboring coefficients are distributed as Asymmetric Generalized Gaussian Distribution (AGGD). The Appendix A.1 presents the GGD and AGGD to capture a broader spectrum of image statistics.

Calculating Feature Vectors and Predicting IQA

We have just derived one MSCN and four pairwise products of MSCN, which help to calculate a feature vector. MSCN is the distribution of pixel intensity which contains the information for an image. From MSCN, we need to capture features of the image, or the feature vector. In the original image, we could think of any dimension where the number of features is infinite. This is very high computational load to find those features. The compelling part is that this method reduces the number of parameters into finite numbers against the unknown infinite number of parameters.

In this method, the size of the feature vector is 36×1. The first two elements of the feature vector are calculated by fitting the MSCN image to a GDD, where it has two parameters - shape and variance. Each pairwise product element is calculated by fitting it into an Asymmetric for of Generalized Gaussian Fitting, which has four parameters: shape, mean, left and right variance. 36 features are used to identify distortions of the image and to perform distortion-specific quality assessment. Some might wonder why one needs to find 36 features instead of 18. As we discriminate the scale into two – original image scale and reduced resolution – we need 36×1 feature vector. In order to fit the unknown finite parameters, Lasmar, Stitou and Berthoumieu (2009) use maximum likelihood estimation, but having computational inefficiency, Anish, Moorthy and Bovik (2012) exploit moment-generating function. After fitting the parameters, it is possible to know the features of images.

In the final step, SVM is used to find IQA from the feature vector. SVM is one of the Machine Learning techniques implemented mostly in image recognition problems. It is one of the methods that predicts the category of the new example. This method aims to classify data based on statistical information extracted from pristine images. In image recognition, previous papers adopt SVM to assess image quality (Ferzli and Karam (2009); Narwaria and Lin (2010)). Like Anish, Moorthy and Bovik (2012), this paper also exploits the LIBSVM package provided by Chang and Lin (2011). The A.2 explains the training data in the SVM.

From SVR, one finally predicts IQA. The IQA index is inversely proportional to image quality so that smaller IQA values indicate low levels of image distortion whereas higher values indicate high levels of image distortion. For more a detailed explanation about the 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 firms' to measure the effect 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 effect 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 films, we take the average of those films. For the case where one firm 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 films. They provide the film's related features and still cuts of film. For IQA, the first 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 film (minutes), the number of producers, the number of film editors, the number of staff of the art, visual, and animation department. The number of staff involved in the production line provides a solid indicator of how the company focuses on image quality.

From the storyboard to the final frame of animated films, each film takes an average of three to five years to create (WaltDisney (2022)). The duration of the creation of each animated film 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 effect if the treated outcome and the counterfactual outcome differ 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 figure shows, the rest of the companies may not provide a suitable comparison group to study the effects of M&A on image quality. Before M&A between Disney and Pixar, Disney and other companies show different 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.

The synthetic Disney is constructed by the convex combination of companies that most closely resembled Disney in terms of possible values of image quality improvement predictors. Table 1 displays the comparison between Disney, Synthetic Disney and the average of other companies for the 1996-2006 period. The average of other companies does not seem to provide a suitable control group for Disney. In particular, the number of staff in the three departments is dissimilar. Further, the budget average of other companies was substantially lower than Disney's average, prior to the M&A between Disney and Pixar. In contrast, the synthetic Disney reproduces the values of budget almost the same as Disney. Table 1 underscores the predictors to consider estimating the effect of M&A on image quality. As a researcher, there are various candidate predictors to be considered. For example, a movie's length would affect the image quality, so it is included in the subset of predictors. As a movie's length becomes longer, image quality becomes poorer. However, the average of a movie's length is similar in Disney and other companies. It means companies follow the rule that animation should be about 90 minutes in length. WaltDisney (2022) also stresses the feature-length films are approximately 90 minutes, so this variable will not be an important factor for the quality. Thus, it is important for a researcher to test the performance of predictors before putting everything into a jar or cherry picking the variables.

Figure 3 represents trends of IQA for Disney and its synthetic counterpart from 1996 to 2006. The figure clearly shows that Disney Synthetic resembles its actual counterpart prior to the transaction. After the treatment, the IQA of Disney start to decrease, which means the quality of image improved. Again, the lower IQA index means better image quality. Furthermore, the goal of this paper is to select the best model among the alternative set of predictors. One tries to select the model with the highest predictive power under the smallest number of predictors. The first panel shows trends of IQA between Disney and Synthetic

Disney estimated by using only four predictors: budget, the number of film editors, and the number of staff in the visual departments. This model gets the smallest RMSPE among all possible candidate models at 0.806. The second panel depicts trends of IQA between Disney and Synthetic Disney computed by including all possible variables this paper considered: budget, the number of producers, the number of film editors, the number of staff in the visual and animation departments, and the average of IQA; here, RMSPE is 1.508. Instead of finding the synthetic Disney using all possible variables, a limited number of predictors are found to produce better prediction ability.

For comparison, Figure 4 shows trajectories of IQA for Disney and its synthetic but computed using other candidate models. In Figure 4.a, RMSPE is 3.388, and three variables are included to find synthetic groups. In Figure 4.b, RMSPE is 4.393, but six variables are included. Figures 3 and 4 demonstrate that the weights of each company differ as the set of predictors changes in the estimation process. Different models demonstrate different synthetic controls, which will influence on the treatment effect. Interestingly, the selected control units differ by alternative sets of predictors. If researchers do the specification searching, they might obtain different results from the other sets of control units. As selecting the control units is crucial in the causal analysis, the SCM is touted as obvious in selecting control units. These findings suggest implementing the model selection before reporting the final results to be transparent in the selection of control units.

Table 2 displays the weights of each company in the synthetic Disney. The weights reported in Table 2 indicate that a combination of Toei (0.275), DreamWorks (0.703), and Paramount (0.022) best produces IQA. In contrast, other combinations of control units in the donor pool comprise the synthetic controls in the other possible model. The second column of Table 2 shows the weights of control units where we use all candidates of predictors. Here, DremWorks is only selected as a control unit. Different models put the weights to different control units in columns 3 and 4. All other companies in the donor pool are assigned zero weights.

This paper shows the effect of M&A of Disney and Pixar on image quality. After M&A was accomplished, IQA plummeted, meaning the image quality performed better than in the previous period. Figure 5 plots the yearly gaps in IQA between Disney and its synthetic counterpart. It suggests that the firms' transaction hugely affected image quality, and this impact increased over time. Usually, the animation film takes three to five years to produce. The IQA of Disney decreases notably and is stable post 2009. The magnitude of the estimated effect after the treatment is crucial in the empirical analysis. The results provide evidence that the image quality improved at an average of almost 18 points for the entire 2006 to 2016 period than the value it would have been no transaction between these two 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 fit of synthetic control for unit j in the post-treatment period, relative to the quality of the fit 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 confirm that our estimated treatment effects for Disney are significantly large relative to that obtained when we conduct the same application to the firms in the donor pool.

8 Conclusion

This paper estimates the effect 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 first 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 findings 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 effect 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 firm's production, they are deemed to be unobservable attributes in the economic literature. As this paper quantifies the image quality, it is now possible to measure the quality improvement from the M&A. This paper finds that the merger between Disney and Pixar enhances the image quality of Disney's films after acquisition in 2006. It actually supports the argument that Disney developed their strategy to reboot their image quality and finally took back their throne in 2013 with *Frozen*.

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 economics. These techniques have been highly applied to epidemiological and clinical pathology studies in recent days. For example, several factors such as movements in an organ will degrade the image quality while taking an image of ultrasonic waves or magnetic resonance imaging. That is why those fields adopt IQA techniques to detect symptoms better quality of an image. It is so far an interesting field of research in the healthcare industry to use the IQA. Even though the quality of healthcare is a significant concern, previous economic studies show that mergers can positively or negatively impact health care quality in the health industry (Kessler and McClellan (2000); Gaynor (2004); Bloom et al. (2013). Future studies may show that the IQA can be used as a measurement for the quality improvement of health. This may contribute for the research to find other findings in the M&A literature of the health care industry.

9 Figures

Figure 1: Proccess of BRISQUE

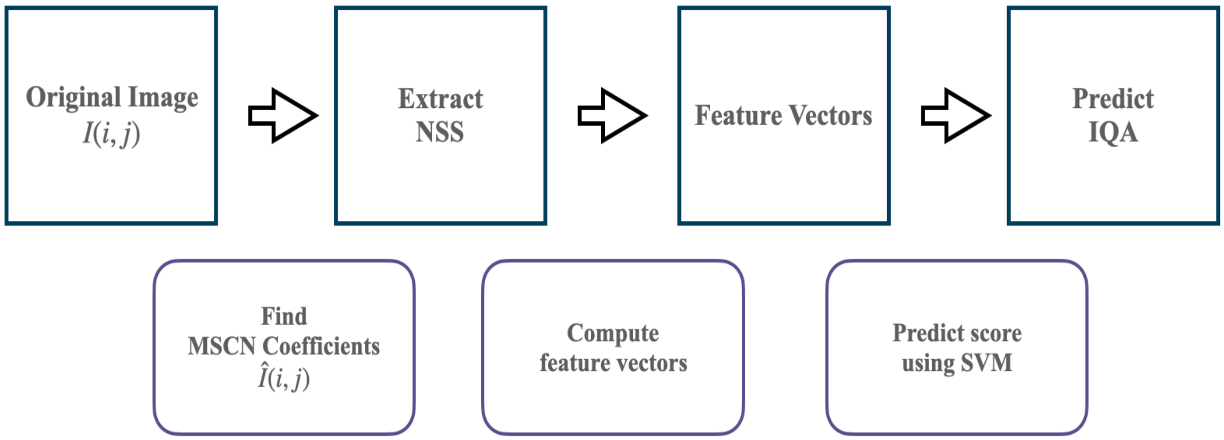
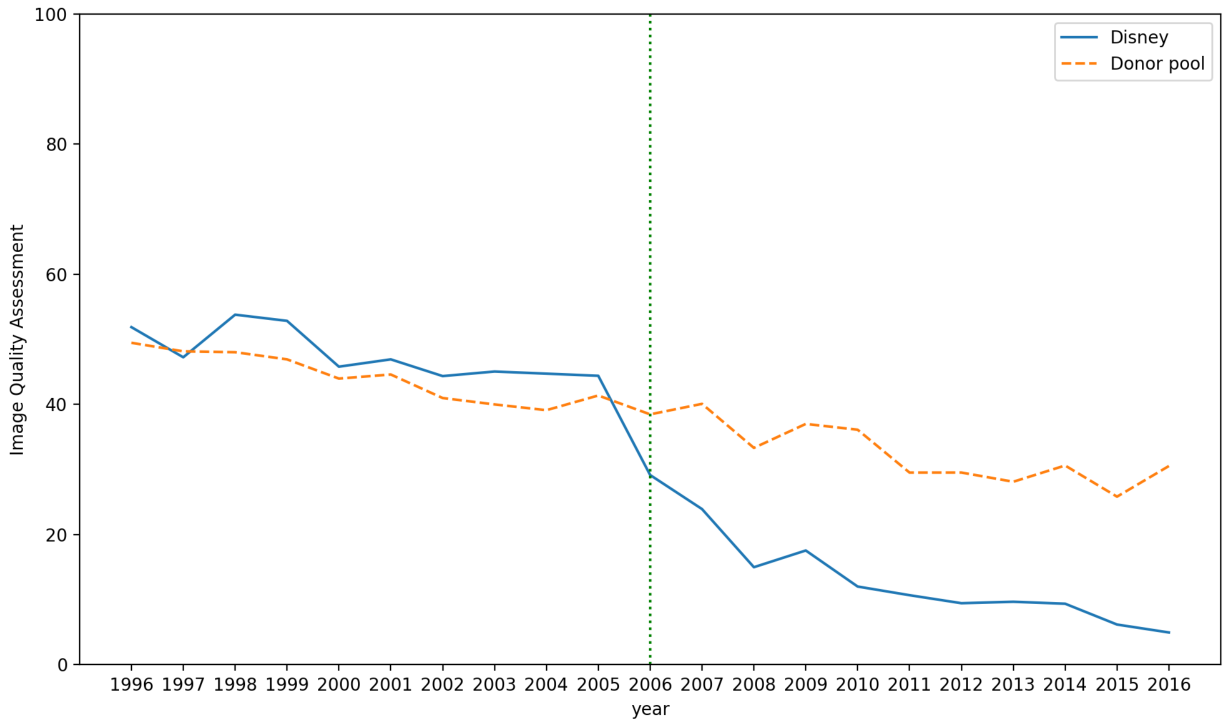
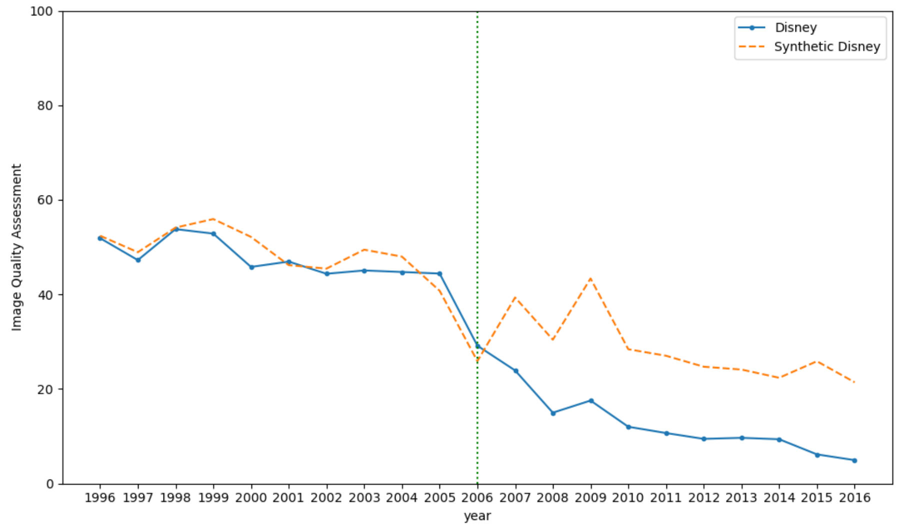


Figure 2: Trends in IQA: Disney and other animation companies



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



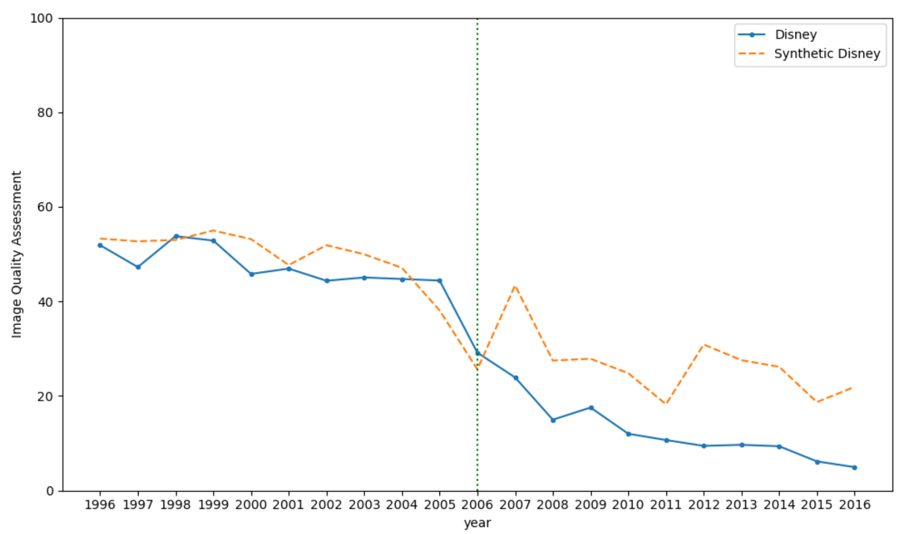
(a) Budget, the number of film editors, and the number of staff in the visual departments are included.

(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

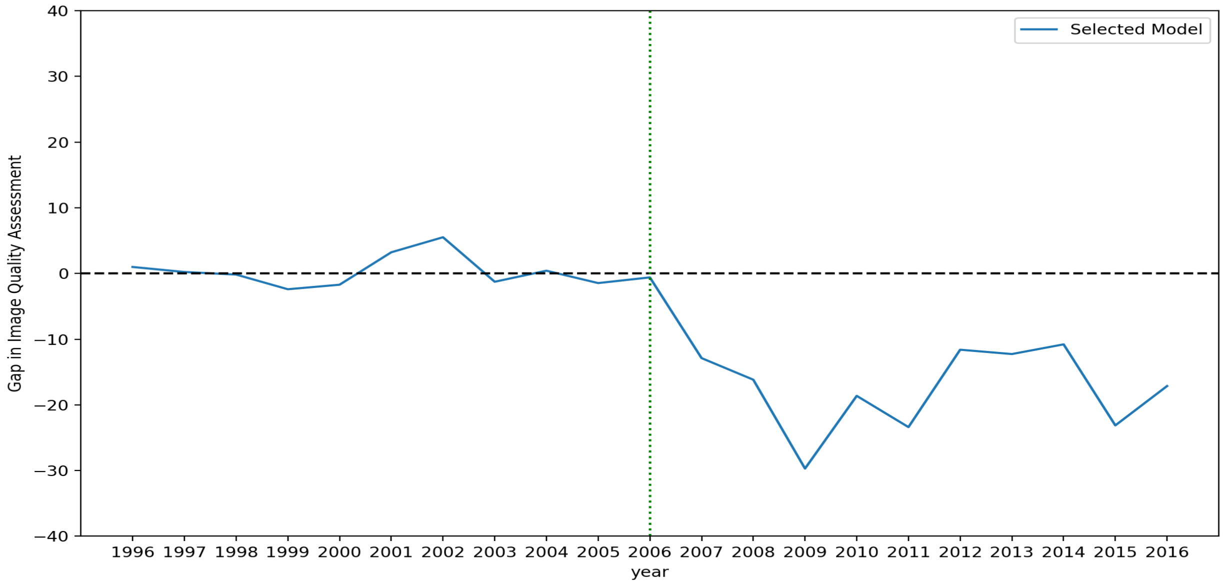
(a) The country of origin, budget, and the number of film editors are included.



(b) The country of origin, length, budget, the number of film editors, the number of staffs 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

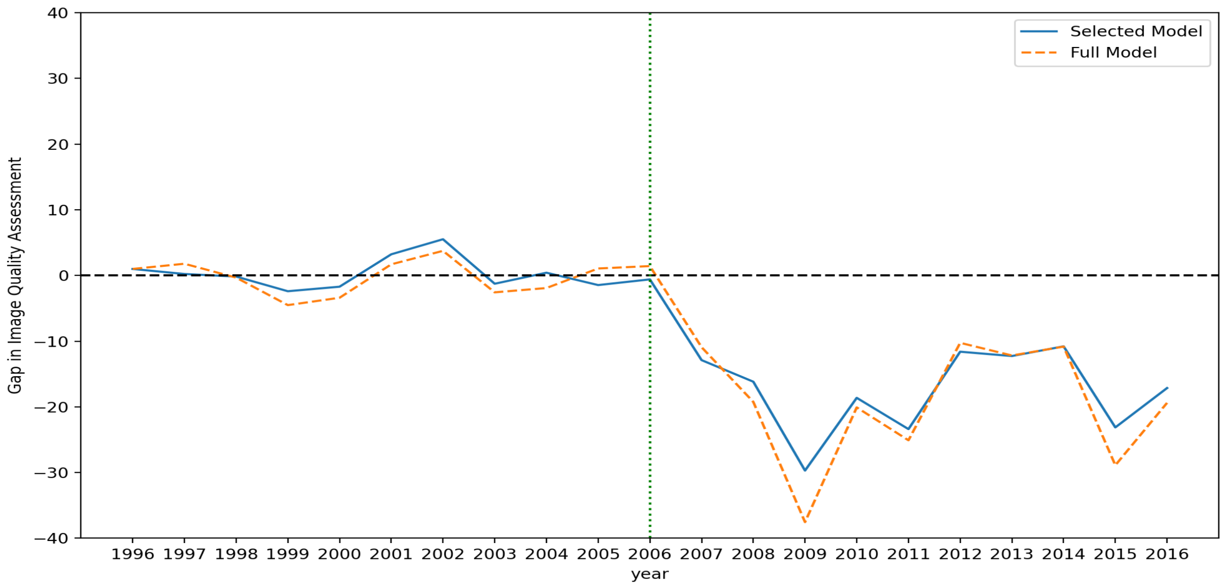


Figure 7: Ranking of the highest grossing movies of Disney and four other major studios

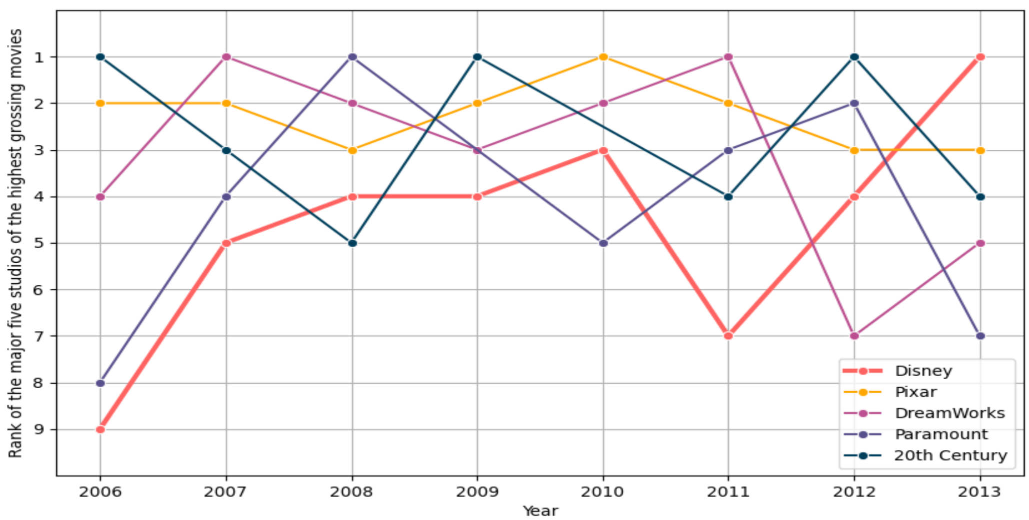
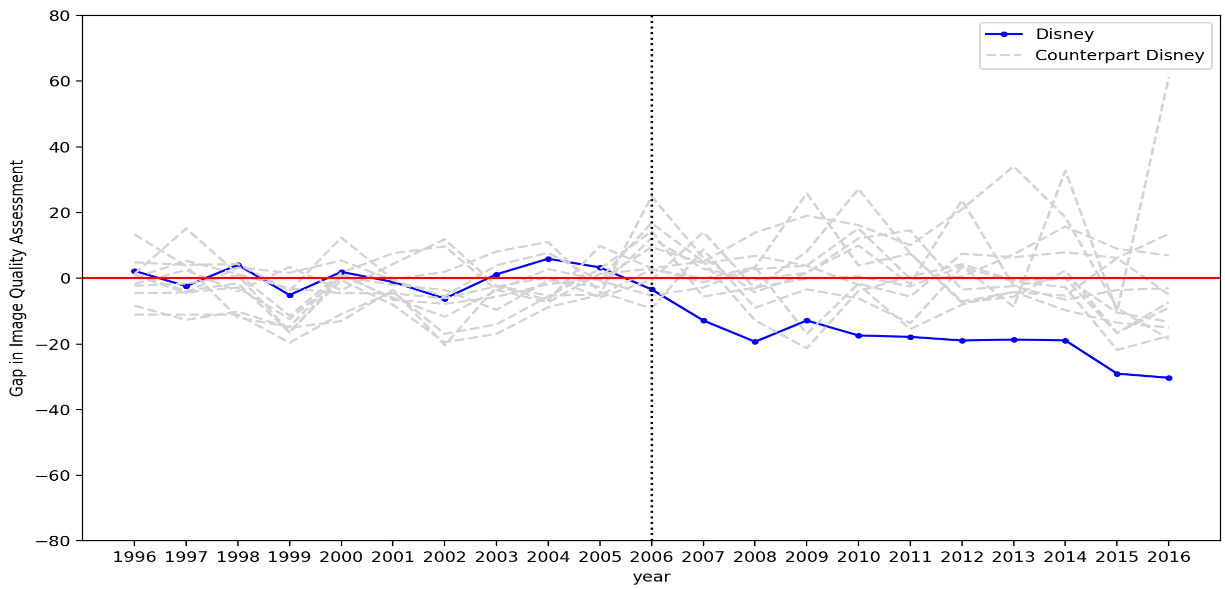
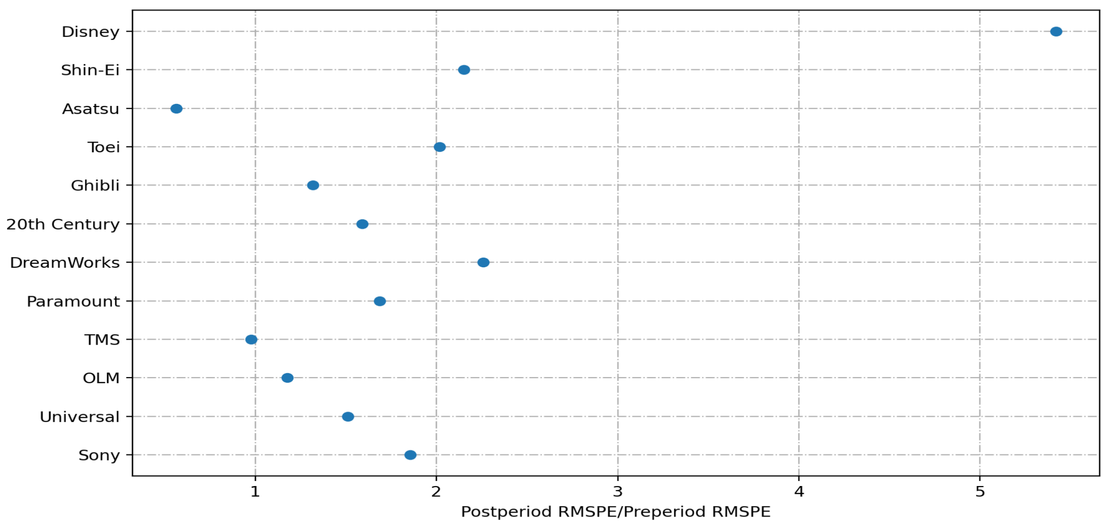


Figure 8: IQA gaps in Disney and Synthetic Disney and placebo gaps in all companies of the selected model



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

Figure 9: Ratio of Post M&A RMSPE to pre M&A RMSPE: Disney and other companies



10 Tables

Table 1: Average of predictor values

Variables	Disney	Synthetic	Average of others
IQA	49.92	46.21	43.75
Length of the movie	90.87	91.34	90.01
Budget	103,760,477	97,317,241.51	37,754,153.3
The number of producers	3.13	6.01	6.89
The number of film editors	1.55	2.10	1.78
The number of staff in the art department	43.27	43.42	17.15
The number of staff in the visual department	111.46	167.90	44.76
The number of staff in the animation department	261.64	214.97	116.91

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 effectively capture the broader spectrum of distorted image statistics where the GGD with zero mean is given by by (Anish, Moorthy and Bovik (2012)):

$$f(x;\alpha,\sigma^2) = \frac{\alpha}{2\beta\Gamma(1/\alpha)} exp\Big(-\Big(\frac{|x|}{\beta}\Big)^{\alpha}\Big) \tag{10}$$

where

$$\beta = \alpha\sqrt{\frac{\Gamma(1/\alpha)}{\Gamma(3/\alpha)}} \tag{11}$$

and gamma function Γ is:

$$\Gamma(\alpha) = \int_0^{\infty} t^{\alpha-1} exp^{-1} dt \tag{12}$$

$\alpha > 0$ is the shape of the distribution while σ^2 is the variance.

A sigle parameter from the GDD cannot provide the full information of the image, so the AGGD is used. The AGGD helps to find the features of paired products of the image. The AGGD with zero mode is as following equation.

$$f(x;\nu,\sigma_l^2,\sigma_r^2) = \begin{cases} \frac{\nu}{(\beta_l+\beta_r)\Gamma(1/\nu)} exp\Big(-\Big(\frac{-x}{\beta_l}\Big)^{\nu}\Big), & x < 0 \\ \frac{\nu}{(\beta_l+\beta_r)\Gamma(1/\nu)} exp\Big(-\Big(\frac{x}{\beta_r}\Big)^{\nu}\Big), & x \geq 0 \end{cases} \tag{13}$$

where ν is the shape parameter, σ_l^2 and σ_r^2 are the scale parameters that control the spread of each side of the mode, respectively.

B. Database for the SVM

The BRISQUE approach requires a training procedure to map quality to human ratings via the SVM. In the original paper, the trained data is chosen by taking a set of pristine images from the Berkeley image segmentation database and the similar kinds of distortions in the LIVE IQA database with JPEG 2000, JPEG, white noise, and Gaussian Blur. This paper also selects this set of pristine images from the same database. These database consist of 29 reference images with 7770 distorted images with five different distortion categories - JPEG2000, JEPG compression, additive white Gaussian noise (WN), Gaussian blur, and a Rayleigh fast-fading channel simulation. To correlate human vision, different mean opinion score (DMOS) is used to represent the subjective quality of the image. Each of the distorted images has an associated difference 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 difficult to construct cartoon database for the time constraint and expensive cost. Spearman rank order correlation coefficient (SROCC) is used to evaluate the prediction performance of IQA method. The recent developed technology (Chen et al. (2021)) show better performance than the BRISQUE using the cartoon images. However, this method only considers 2D images, and the performance was 0.8 better than the BRISQUE. This paper sticks to the original method since it considers 3D images and the better performance of the IQA will not matter much to our results.

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