The Impact of Tommy John Surgery on Free Agent Pitcher Contracts in Major League Baseball

by

Anuradha Danushka Nugawela

(Dan Nugawela)

A thesis presented to the Honors College of Middle Tennessee State University in partial fulfillment of the requirements for graduation from the University Honors College

October 2019

The Impact of Tommy John Surgery on Free Agent Pitcher Contracts in Major League Baseball

by

Anuradha Danushka Nugawela

(Dan Nugawela)

APPROVED:

_____

Dr. Michael Roach

Associate Professor, Economics and Finance

_____

Dr. Timothy Greer

Chair, Information Systems & Analytics

_____

Dr. John Vile

Dean, University Honors College

Abstract

This research examines whether Tommy John surgery has an effect on the Major League Baseball's starting pitchers' free agent contracts. I have used historical data on player performance and salary to see if there are differences in pay levels and the efficiency of the contract between pitchers who have had Tommy John surgery and those who have not. I have found that Tommy John surgery does not have a significant impact determining their contract, but prior performance is the main determination factor for their contracts. Furthermore, I found that salary efficiency depends on the players' prior performances and not Tommy John surgery.

Table of Contents

List of Figures

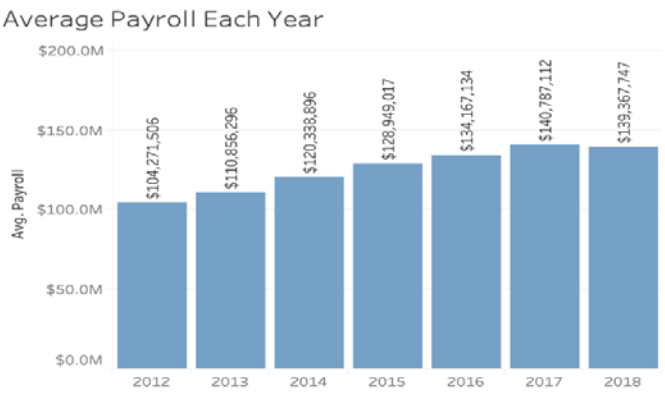
List of Tables

Introduction

Baseball, which is America's national pastime, is not only a popular sport in the United States, but also popular among South American countries and gaining traction in countries such as Japan and South Korea. With more and more fan bases around the world, it has become a multi-billion-dollar business. According to *Forbes* magazine, Major League Baseball saw a revenue of $10.3 billion in the year 2018. Also, revenue has increased by 377% since Bud Selig took over as the commissioner in 1992 (Brown, 2019).

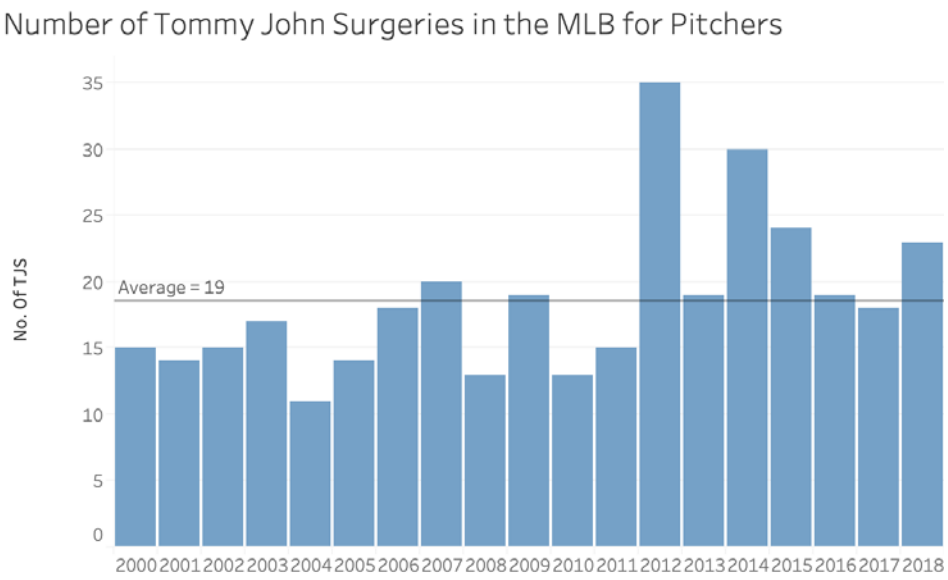
With Major League Baseball's popularity increasing, teams are spending millions of dollars on their players. According to *Spotrac.com*, in 2018 the estimated payroll for starting pitchers in the MLB for all 30 teams exceeded $842 million with an average allocation of $28 million per team. With starting pitchers such as Clayton Kershaw receiving a salary as high as $35 million and teams investing millions of dollars in their pitchers, it is imperative that the team executives make sound investments when they sign free agents. Figure 1 gives an indication of how payroll has increased in the past few years.

Figure 1-Average Payroll for MLB Teams through 2012-2018



Improvements in medicine have allowed players to get Tommy John surgery and return to the game within a year. In the past 18 years there have been 352 Tommy John Surgeries for MLB pitchers (see Figure 2), and on average 19 pitchers have undergone this surgery each year.

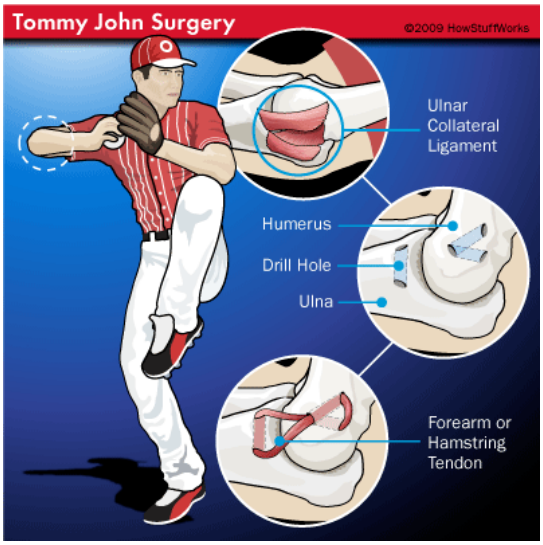
Figure 2-Number of Tommy John Surgeries for Pitchers from 2000-2018



This surgery, which is also known as ulnar collateral ligament reconstruction surgery, is a procedure in which the damaged ligament is removed and replaced with a transplanted tendon (Lasky, 2018). This surgery was performed on Los Angeles Dodgers pitcher Tommy John in 1974 and was thought to be career ending at that time. However, Tommy John defied these odds and went on to finish his career in 1989 (Lasky, 2018). Figure 2 shows how this type of surgery has increased in this millennium. From 2000-2014 there were 268 surgeries performed compared to just 34 surgeries performed from 1974-1999 (White, 2018). This is a rise of 688%, which is an exponential increase of Tommy John surgery.

Figure 3 shows where the surgery is performed on the pitcher's elbow. According to Lasky, "[Tommy John surgery] is a relatively noninvasive surgical procedure used to treat patients who have damaged or torn ulnar collateral ligament because of repetitive extreme stress. By removing the damaged ligament and replacing it with a transplanted tendon, surgeons can restore functionality and afford patients relief from pain" (Lasky, 2018).

Figure 3- Tommy John Surgery



There are a few reasons that Tommy John surgery has become more common, but the most common reason for the increase in the MLB is that players are throwing harder and faster. In the past, throwing pitches that were 90-100 mph was a rarity, but now pitchers throw over 100 mph on a regular basis (White, 2018). With recent players being physically stronger, the surgery has become more prevalent.

There is a common misconception among players, coaches, and even parents of youth players that Tommy John surgery gives a performance advantage for the pitchers. Research conducted by the American Orthopedic Society for Sports Medicine had

striking results. The study showed that 26% of collegiate athletes, 30% of coaches, 37% of parents, and 51% of high school athletes believe that Tommy John surgery should be performed as a prophylactic procedure to enhance performance before sustaining an injury (Erickson, 2015, p. 37). Furthermore, 28% of players and 20% of coaches believed that pitcher performance would increase after getting the surgery (Erickson, 2015, p. 37). This belief held by parents and players is based on their assumption that the expected improved performance gives the player a greater chance of being recruited by a top college or picked at a higher draft position, which may lead to higher career earnings.

The research done on the subject is mostly on performance metrics and return rates. In these studies, researchers have used traditional statistics, such as return to game after surgery, earned run average, velocity prior and after surgery, etc. These statistics are great to examine performance of a pitcher individually, but do not give a clear idea about the team's expected value of the pitcher. According to *Fangraphs*, sabermetrics such as Wins Above Replacement (WAR), gives statisticians the ability to assign a single figure to represent a pitcher's value. WAR attempts to address the question, if one player gets injured and gets replaced with a "replacement-level player," how much value is the team losing? For example, the starting pitcher X has a WAR of +9.7 and the replacement pitcher Y by definition has a WAR of 0.0, this means there is an expectation that pitcher X has more value. In fact, the expectation is that the team would lose an average of 9.7 games if player X is replaced by player Y (Slowinsky, 2010).

Research Question

When I researched previous articles written on the subject, I did not come across articles on the financial impact on Tommy John surgery. Published papers consist of

performance impact prior to and after undergoing surgery. Furthermore, statistics used are traditional rather than an advanced sabermetric such as WAR.

Since baseball is a 10.3 billion dollar business as of 2018 according to *Forbes,* it is imperative to look at the labor market for the sport. My research differs from other research because my focus point will be whether Tommy John surgery has an effect on salaries and efficiency per dollars spent of the contracts. My research focuses on the financial impact that TJS has on pitchers and whether it has a long-term impact on their contracts.

Literature Review

Rates of Return and Performance after Tommy John Surgery

Grant (2016) analyzes how Tommy John surgery can affect a pitcher's arm, performance, and career longevity by gathering in-game data. In this work, he analyzes whether Tommy John surgery can positively impact a pitcher's career in a manner that would prolong the career and whether there is a negative impact after the surgery is performed. In the methodology, he looks at pitch/fx data, which is a database that maps every baseball pitch that is thrown. Grant (2016) analyzes the pitches that span from 2008 to 2015 and took a sample of pitches from a year before the player underwent the surgery and pitches after the surgery. He used the spreadsheet which is compiled by the sabermetrician Jon Roegele to collect a random sample of pitchers who underwent surgery. Grant looked at pitch type, velocity and pitch result to determine the accuracy and velocity of each pitcher. Then the researcher conducted a comparative analysis of these variables to determine pre vs. post surgical differences on performance metrics.

After reviewing the results and correlations for the players, Grant determined there are many ways to evaluate how pitchers perform and how these injuries can affect their playing careers in the future (Grant 2016, p. 24). He concluded that some pitchers perform well and some don't after surgery and it is difficult to conclude the certainty of the results. He went on to say "situational decision in which the player's performance cannot be pinned to the elbow injury. Age, batter skill, league, player condition, weather, etc. influence the outcome" (Grant 2016, p. 26).

Erickson et al. (2014) researched return rates and performance after undergoing Tommy John surgery. They took a sample of 179 baseball pitchers who had a primary ulnar collateral ligament tear. The research consisted of demographic data such as age at the time of injury, Body Mass Index (BMI), year of surgery, games played before and after surgery, years played in MLB. They also looked into performance data such as innings pitched per game, games pitched per season, wins/losses per season, Earned Run Average (ERA), shutouts per season, and Walks plus Hits per Innings Pitched (WHIP). They discovered that, of the 179 pitchers, 83% returned to pitching in the Major League and 97.2% returned to pitching in both major and minor leagues combined and only a small percentage were unable to return to pitching in the professional leagues (Erickson et al, 2014, p. 538). Performance-wise, they found that pitchers who underwent Tommy John surgery had higher ERA, higher WHIP, and higher loss percentage prior and in the year of surgery (Erickson et al, 2014, p. 538). After undergoing surgery, the pitchers who underwent Tommy John surgery saw lower ERA, Lower WHIP, and lower loss percentage after returning to pitching post-surgery (Erickson et al, 2014, p. 538-39).

In response to this research, I found that the researchers gathered data in the year the pitchers underwent surgery and compared them to the performance data right after they returned to pitching from surgery. The data indicates the low-performance metric in the year they had ulnar collateral ligament tear. This might be due to the pain caused by the injury. Researchers indicate the performance was improved when they returned post surgery compared to the index year pitchers underwent surgery. This is a critical point because performance will increase after repairing the damaged ligament. But the researchers did prove that there is a higher rate of return to pitching in the professional landscape after this type of surgery.

Is there a Change in Pitching Velocity after Undergoing Tommy John Surgery?

There are scholarly research papers done on the change of pitch velocity after ulnar collateral ligament reconstruction surgery. A research by Jiang and Leland (2014) found that there was no significant loss of velocity. They sampled 41 MLB pitchers who underwent Tommy John surgery, and only 28 were deemed qualified for the research. They analyzed data of these 28 pitchers who at least played four seasons in the MLB and paired them with control group members who did not have any known UCL surgery. PITCH/fx, was used to gather data on pitch velocity for pitchers and were collected up to five consecutive years in the time span of 2007 to 2012, and the most common four types of pitches were taken in to consideration (fastball, changeup, curveball, and slider) (Jiang and Martin, 2014, p. 881). Results in pitching velocity suggested that there was a small decrease in the fastball and changeup velocities for each post-injury year in the study group, and the curveball velocity was found to decrease significantly in post injury second and third years (Jiang and Leland, 2014, p. 883). However, taking the mean

change in velocity of the study group and comparing that of the pair-matched control group, there were no significant changes in any of the years' post-surgery for any types of pitches (Jiang and Leland, 2014, p. 883).

Keller et al (2016), concentrated on 83 pitchers who underwent Tommy John surgery. According to Keller et a (2016), "The evaluation of pitch velocity compared with matched controls found no differences in pre surgery pitch velocities for fastballs (91.5 vs. 91.2 miles per hour [mph], p-value = .69), curveballs (78.2 vs. 77.9 mph, p-value = .92), sliders (83.3 vs. 83.5 mph, p-value = .88), or change-ups (83.9 vs. 83.8 mph, p-value = .96)" (Major League Baseball pitch velocity, 2016). However, it was found that pitchers who had surgery threw significantly more fastballs, which directly correlates to 2% increase in risk for Tommy John surgery for every 1% increase in fastballs thrown (Keller et al, 2016). The researchers concluded that there is no significant difference in pitch velocity after surgery, but MLB pitchers who throw fastballs were at a greater risk for undergoing Tommy John surgery.

The research by Jiang and Leland used demographic data as well looked at other statistics such as ERA, WHIP, innings Pitched, strikeouts per inning. But the glaring deficiency in their research was sample size. Out of 41 MLB pitchers, they could only qualify 28. The sample size is too small to determine significant changes in velocity. On the other hand, the Keller et al (2016) research had a larger sample size, but only evaluated data two years prior and two years after the surgery. However, they determined that throwing too many fastballs may be a risk factor for another injury.

Can Fastball Pitch Velocity Predict Tommy John Surgery in MLB Pitchers?

In the world of data analytics, predictive analytics mesh together. Professional sports is a billion dollar industry, and investment in players is imperative for ball club executives. If team doctors can evaluate pitchers in risk to undergo Tommy John Surgery, that is a significant advantage to the decision-makers of the team.

Research conducted at Rush University Medical Center by Chalmers et al (2016) looked at fastball pitches using the PITCH/fx database which is publicly available. The data included a total of seven million pitches, and included a total of 1,327 pitchers, with 1,018 control pitchers (who did not undergo surgery) and 309 pitchers who underwent Tommy John surgery (Chalmers et al, 2016, p. 2,131). The results indicated that peak velocity was significantly higher among pre-injury pitchers than control group pitchers (93.3 mph vs 92.1 mph) (Chalmers et al, 2016, p. 2,132). The pitcher age and BMI were secondary predictors to UCL injuries as well (Chalmers et al, 2016, p. 2,130).

This research shows that pitchers who are trying to pitch harder and faster are at risk for undergoing Tommy John surgery. The researchers mention the limitations of this research since this data was collected using publicly available tools, certain variables were not included such as hand dominance, medical history, pitch counts in non-competitive settings (Chalmers et al, 2016, p. 2,134). But overall, this research showed comparative differences between velocities of athletes who underwent surgery and the control group.

Does the Use of Advanced Metrics Show a Decline of Player Value after Tommy John Surgery?

Selley et al. (2018) explored correlation of player value in relation to UCLR surgery. Selley et al discussed the conflicting conclusions of prior research done on MLB pitchers who had Tommy John surgery done. One of the main concerns for the researchers was how prior research might be out of date because their findings were based upon traditional pitching statistics (Selley et al, 2018, p.129-30).

The researchers compiled data sets of traditional, value-based sabermetrics, and demographic data spanning from 1991 to 2016 of MLB pitchers who underwent Tommy John surgery. The research showed that pitchers who sustain ulnar collateral ligament injuries are more valuable and perform at a higher level than average MLB pitcher (Selley et al, 2018, p. 130). Furthermore, pitchers' value decreased post-surgery due to the fact their careers were cut short after the injury, and the research concluded that advanced sabermetrics should be used to evaluate the effects of performance and efficiency because they visualized performance clearly (Selley et al, 2018, p. 130).

This is one of the only studies that was done based on advanced sabermetrics: WAR and Fielding Independent of Pitching (FIP) values. I agree with the researchers that this type of performance metrics should be used to determine player value to the team after undergoing Tommy John surgery because WAR and other advanced analytics they used give a better insight of the bigger picture of the pitcher rather than traditional statistical data.

Conclusion of the Literature Review

Most of the research done on this subject was based upon traditional statistics such as ERA, innings pitched, home runs given, win/loss percentages, saves, or games started to name a few. With the introduction of advanced sabermetrics, such as WAR, FIP, and WHIP, baseball statistics have transitioned into a more advanced mathematical wager. Furthermore, most of the research is concentrated on player performance. The only research that was based upon player value was done by Selley et al (2018). They considered measurements such as WAR, although there was no clear monetary value assigned to each pitcher. Therefore, it is difficult to assess the risk of salary reductions by looking at this research. This paper extends that line of research by incorporating salary data for MLB starting pitchers and to see if teams are pricing in any differences efficiently.

Hypothesis Statement

Without using traditional statistics to measure a pitcher's performance, I will use WAR to represent their value for the team in a single value. Using this measurement and whether they had Tommy John surgery in the past, I will look at their free agent contracts. By doing so, the objective is to determine whether there is a wage penalty or premium associated with starting pitchers who underwent Tommy John surgery versus starting pitchers who never underwent Tommy John surgery after accounting for age and previous performance.

Furthermore, I will test the second hypothesis, which is whether the efficiency of contracts differs between these groups. I will use the data to determine whether the WAR per dollar is lower or higher for Tommy John surgery and whether some of these players

who have had surgery indeed are subject to a penalty or teams are overpaying them. I believe this research will benefit front office executives and baseball analytics personnel in determining salary standards for starting pitchers who have undergone Tommy John surgery when they are signing them in free agency. In summary here are the two hypothesis I am testing:

H1: There are no differences in salaries based on Tommy John Surgery.

H2: There are no differences in efficiency based on Tommy John Surgery.

Data and Methodology

To conduct my research, I needed several pieces of key data. The data points are as follows:

- List of MLB starting pitchers who underwent Tommy John surgery.
- Ages of the pitchers at time of free agency.
- Free agent salaries.
- WAR prior to free agency and WAR post free agency.
- Average salary of pitcher free agent contracts.

The list of pitchers who underwent Tommy John Surgery was downloaded from *MLBReports.com,* which had been created by a baseball analyst for *FanGraphs* named Jon Roegle. This list contains all players in the majors, minors, and college baseball players who underwent Tommy John surgery, the age they had the surgery, the position they play, and years it took them to recover from the surgery for the time span of 1974 to present. From this list, I filtered the pitchers who underwent surgery from 2012-2018.

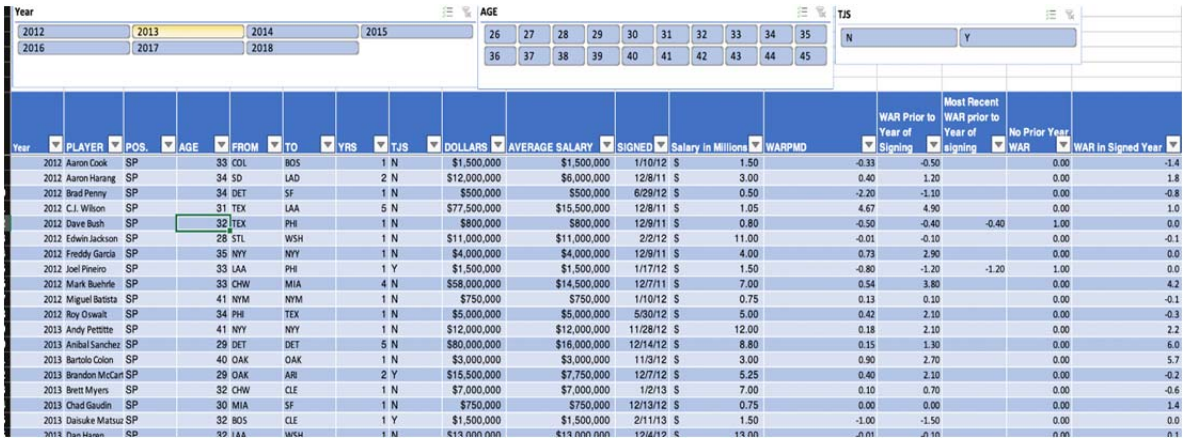
To obtain free agent data, I turned to *Spotrac.com,* which is a source of player statistics and free agent salary information. From this database, I filtered free agents who

were starting pitchers in the Major League from 2012-2018. Then this list was cross-referenced with Jon Roegle's Tommy John surgery list of pitchers. Then I was able to separate players who underwent surgery and the control group, the pitchers who never had surgery.

To gather WAR values for pitchers, I used the baseball statistics website, *Baseball-Reference.com.* I obtained WAR values of the players prior to signing free agent contracts and the year following the signing. Then I created tables for different WAR values and the associated average salary for that range for pitchers who underwent surgery and the control group. Then I calculated WAR per million dollars (WARPMD) rate for the pitchers and analyzed efficiency of contracts. There were 173 observations of pitchers during the 2012-2018 period who signed free agent contracts. A part of the data dashboard is shown as an example below.

Table 1 – Data Dashboard for Free Agent Starting Pitchers From 2012-2018

Example



Year: 2012, 2013, 2014, 2015, 2016, 2017, 2018

AGE: 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45

TJS: N, Y

Year	PLAYER	POS.	AGE	FROM	TO	YRS	TJS	DOLLARS	AVERAGE SALARY	SIGNED	Salary in Millions	WARPMD	WAR Prior to Year of Signing	Most Recent WAR prior to Year of signing	No Prior Year WAR	WAR in Signed Year
2012	Aaron Cook	SP	33	COL	BOS	1	N	$1,500,000	$1,500,000	1/10/12	$ 1.50	-0.33	-0.50		0.00	-1.4
2012	Aaron Harang	SP	34	SD	LAD	2	N	$12,000,000	$6,000,000	12/8/11	$ 3.00	0.40	1.20		0.00	1.8
2012	Brad Penny	SP	34	DET	SF	1	N	$500,000	$500,000	6/29/12	$ 0.50	-2.20	-1.10		0.00	-0.8
2012	C.J. Wilson	SP	31	TEX	LAA	5	N	$77,500,000	$15,500,000	12/8/11	$ 1.05	4.67	4.90		0.00	1.0
2012	Dave Bush	SP	32	TEX	PHI	1	N	$800,000	$800,000	12/9/11	$ 0.80	-0.50	-0.40	-0.40	1.00	0.0
2012	Edwin Jackson	SP	28	STL	WSH	1	N	$11,000,000	$11,000,000	2/2/12	$ 11.00	-0.01	-0.10		0.00	-0.1
2012	Freddy Garcia	SP	35	NYY	NYY	1	N	$4,000,000	$4,000,000	12/9/11	$ 4.00	0.73	2.90		0.00	0.0
2012	Joel Pineiro	SP	33	LAA	PHI	1	Y	$1,500,000	$1,500,000	1/17/12	$ 1.50	-0.80	-1.20	-1.20	1.00	0.0
2012	Mark Buehrle	SP	33	CHW	MIA	4	N	$58,000,000	$14,500,000	12/7/11	$ 7.00	0.54	3.80		0.00	4.2
2012	Miguel Batista	SP	41	NYM	NYM	1	N	$750,000	$750,000	1/10/12	$ 0.75	0.13	0.10		0.00	-0.1
2012	Roy Oswalt	SP	34	PHI	TEX	1	N	$5,000,000	$5,000,000	5/30/12	$ 5.00	0.42	2.10		0.00	-0.3
2013	Andy Pettitte	SP	41	NYY	NYY	1	N	$12,000,000	$12,000,000	11/28/12	$ 12.00	0.18	2.10		0.00	2.2
2013	Anibal Sanchez	SP	29	DET	DET	5	N	$80,000,000	$16,000,000	12/14/12	$ 8.80	0.15	1.30		0.00	6.0
2013	Bartolo Colon	SP	40	OAK	OAK	1	N	$3,000,000	$3,000,000	11/3/12	$ 3.00	0.90	2.70		0.00	5.7
2013	Brandon McCarthy	SP	29	OAK	ARI	2	Y	$15,500,000	$7,750,000	12/7/12	$ 5.25	0.40	2.10		0.00	-0.2
2013	Brett Myers	SP	32	CHW	CLE	1	N	$7,000,000	$7,000,000	1/2/13	$ 7.00	0.10	0.70		0.00	-0.6
2013	Chad Gaudin	SP	30	MIA	SF	1	N	$750,000	$750,000	12/13/12	$ 0.75	0.00	0.00		0.00	1.4
2013	Daisuke Matsuzaka	SP	32	BOS	CLE	1	Y	$1,500,000	$1,500,000	2/11/13	$ 1.50	-1.00	-1.50		0.00	0.0
2013	Dan Haren	SP	32	LAA	WSH	1	N	$13,000,000	$13,000,000	12/4/12	$ 13.00	-0.01	-0.10		0.00	0.1

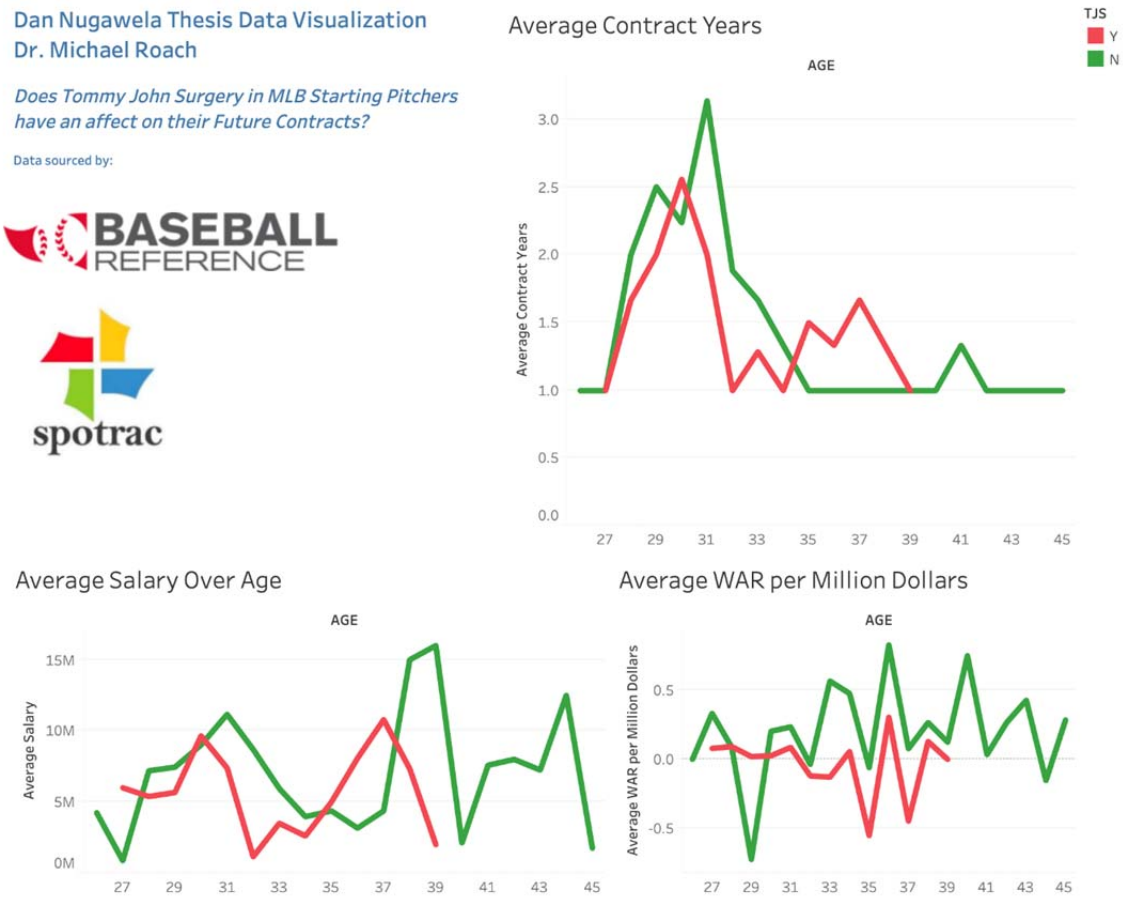
After gathering these data points, I ran regression analysis using the statistical software STATA. According to Perloff and Brander (2017), regression analysis "is a statistical technique used to estimate the mathematical relationship between a dependent

variable…. and one or more explanatory variables" (Perloff and Brander, p. 56). In this case, the explanatory variables were the binary variables that showed whether the pitcher had Tommy John surgery or not, which will have a value of 1 for Yes and a value of 0 for No. Then the other variables were the age and WAR value prior. The dependent variables were the average free agent salary, contract years, and WARPMD. One of the issues I was running into with the data was, that there were some pitchers who did not pitch prior to their surgery. Therefore, they did not have a measurable WAR value and I replaced their WAR values with the most recent WAR prior to signing. The descriptive tables depicting average annual salary, average contract years, average annual salary, average WARPMD, and average WAR prior to signing are shown in the appendices.

Interpretation of Data

Figure 4 below displays the relationship between pitchers' ages and average salaries, average contract years, and average WAR per million dollars, but it was hard to establish clear pattern for the correlation between the two groups. Contract years peaked at around ages 28-32 and then declined. Average salary and average WAR per million dollars did not have clearly established patterns.

Figure 4- Data Visualization for Average Contract Years, Average Salary, and Average WAR per Million Dollars



The regression models include the variable that is predicted, Tommy John surgery dummy variable, where if a pitcher had surgery, the value is one and if they did not have surgery, the value is zero. Then I used the WAR prior to year of signing. Next I used age and free agent year, which are determined through a set of dummy variables. For example, if the pitcher's age is equal to 26, then the value of the dummy variable is one and if the condition is not true, it is zero. Subsequently, the same method was used to determine the dummy variable for the contract year. I predicted the average salary in millions using this basic structure:

$$Average\ Salary\ in\ Millions = \beta_0 + \beta_{1\ tjsdummy} + \beta_{2\ WAR\ Prior\ to\ Year\ of\ signing} + \beta_{3\ Age\ Range(agedummy)} + \beta_{4\ Year\ Range\ (yeardummy)} + \varepsilon$$

The average salary in millions is the variable that indicates the average free agent salary for MLB starting pitchers. However, in this model, the T-stat value was less than 2.00 for Tommy John surgery dummy variable (Yes=1 and No=0). From a statistical perspective this is insignificant and could determine the surgery has no bearing on their free agent salary. But T-stat for WAR prior to signing was statistically significant, because it is greater than 2.00. Therefore, we could conclude that the main predictor of the average salary is pitcher's WAR prior to signing and not whether they had surgery. I used a similar structure to predict the contract years:

$$Contract\ Years = \beta_0 + \beta_{1\ tjsdummy} + \beta_{2\ WAR\ Prior\ to\ Year\ of\ signing} + \beta_{3\ Age\ Range(agedummy)} + \beta_{4\ Year\ Range\ (yeardummy)} + \varepsilon$$

The contract years is the variable that indicates the length of the free-agent contract. However, I found that Tommy John surgery does not have any bearing on the number of years for pitcher's contract, but again the main predictor was the WAR prior to signing. I used this basic structure to predict WARPMD.

$$WARPMD = \beta_0 + \beta_{1\ tjsdummy} + \beta_{2\ WAR\ Prior\ to\ Year\ of\ signing} + \beta_{3\ Age\ Range(agedummy)} + \beta_{4\ Year\ Range\ (yeardummy)} + \varepsilon$$

WAR per million dollars variable is the variable that indicates the efficiency of their contract. The efficiency is how many wins does the team gets per million dollars spent on their contract. This model concluded that Tommy John surgery did not have any bearing on the efficiency of their contract, but again it was their WAR prior to signing predicted the efficiency of the contract.

Results

After running regressions on average salary, contract years, and WAR per million dollars, the appended result table is shown below.

Table 2 – Regression Results

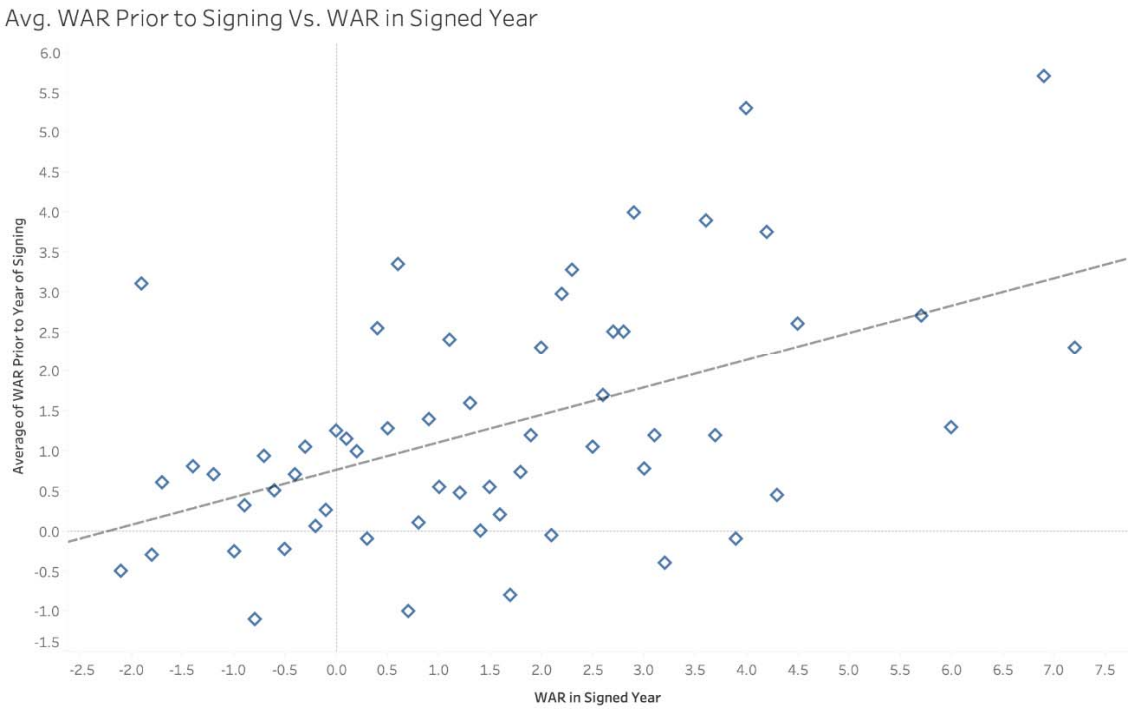
Dependent Variables	(1) Average Salary in Millions	(2) Contract Years	(3) WARPMD
tjsdummy coefficient	-0.588	-0.0969	-0.0134
Std. Error	(0.886)	(0.198)	(0.0992)
t-stat for TJS	-0.664	-0.490	-0.136
WAR Prior to Year of Signing coefficient	2.046***	0.396***	0.227***
Std. Error	(0.227)	(0.0507)	(0.0255)
t-stat for WAR prior to signing	9.003	7.810	8.916
Constant Coefficient	7.191	0.298	-0.777
Constant Std. Error	(5.316)	(1.186)	(0.595)
Constant t-stat	1.353	0.251	-1.305
Observations	173	173	173
R-squared	0.456	0.482	0.431
r2_a	0.355	0.385	0.324

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

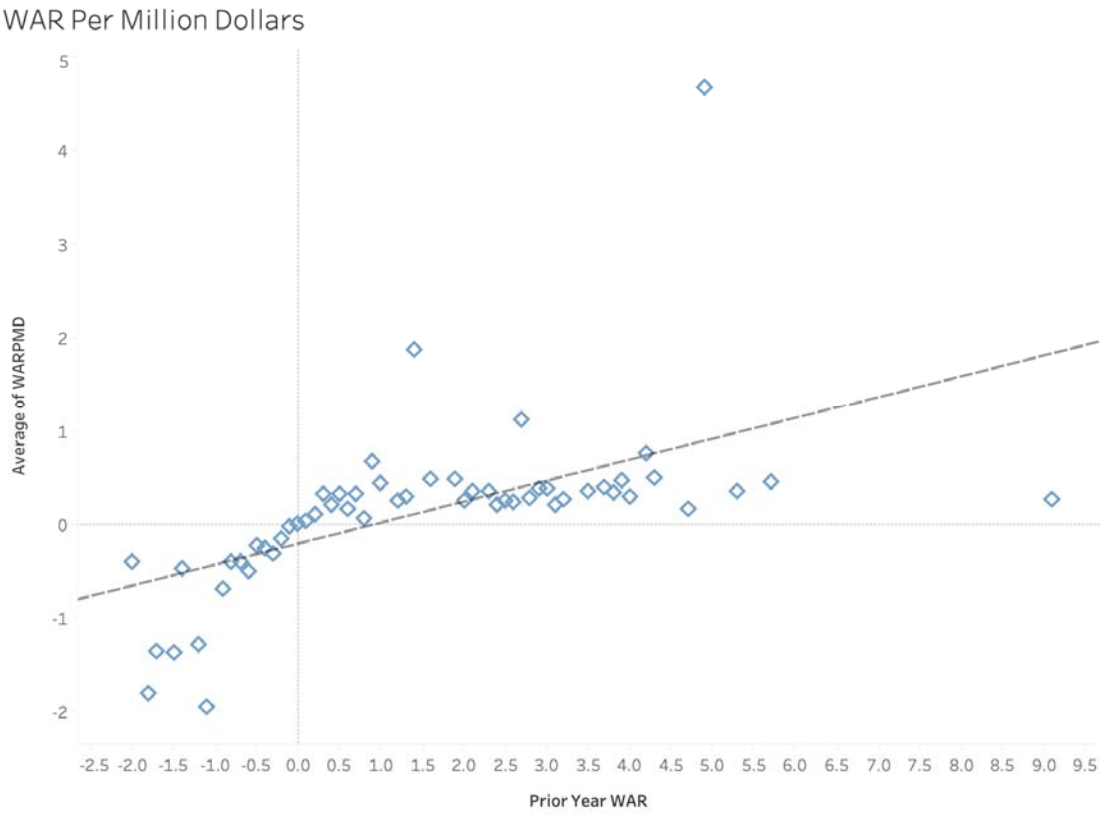
I also researched researched the predictor of pitchers' average WAR in signed year. The expectation of the relationship between prior year WAR and WAR in signed year was that prior year WAR had a direct impact on the WAR in signed year. The expected result was, that as prior year WAR increased, the WAR in the signed year increased as shown in Figure 5.

Figure 5 – Scatter Plot and Trend Model Average WAR Prior to Signing Vs. WAR in Signed Year



However, I found something interesting between the efficiency (average WAR per million dollars) and WAR prior to signing. As I plotted the average WAR per million dollars over WAR prior to signing, I was able to confirm the results from the regression model that the prior year WAR predicted the efficiency of the contract. This finding is the most significant and the surprising finding in my research. It means prior year WAR has a bearing on their free agent contract efficiency, and teams are getting more value per dollar on high WAR players. The linear trend model confirms this finding as shown in Figure 6.

Figure 6 – Scatter Plot and Linear Trend Model for WAR per Million Dollars Vs. Prior Year WAR



Conclusion

With baseball being a large revenue maker and the MLB being one of the top leagues in the United States, free agents and their contracts are an important element to the business side of the game. As in most sports, human beings are susceptible to injuries. With number of Tommy John surgeries increasing, I wanted to research the economic impact for players and teams.

Looking at the two groups of starting pitchers who underwent Tommy John surgery and pitchers who did not undergo Tommy John surgery, there were no clear patterns established for whether pitchers who had surgery had lesser contracts. After using linear regression models for variable predictors such as average salary, contract years, and WARPMD**,** I found that having Tommy John surgery had no impact on a starting pitcher's free agent contract. The statistical insignificance of the coefficient, from the regression models proves this. Interestingly, the WAR prior to signing the free-agent contract drives the average salary, contract years, and salary efficiency. The regression models prove this because the t-stat coefficient, which is greater than 2.00. The most interesting finding from this research was that WAR prior to signing dictates how efficient the pitcher is going to be after signing their free-agent contract regardless of Tommy John surgery. However, further research can be done for different positions in the game for different surgeries to find out whether the predictions will be similar. Furthermore, similar testing can be done in basketball or football gathering data on injuries and player efficiencies.

References

Brown, M. (2019, January 7). MLB Sees Record Revenues Of $10.3 Billion For 2018. *Forbes*. Retrieved from https://www.forbes.com/sites/maurybrown/2019/01/07/mlb-sees-record-revenues-of-10-3-billion-for-2018/#612f86465bea

Bryant, J. (2016). *The Effect of Tommy John (UCL) Reconstructive Surgery on a Pitcher's Arm and Career Progression* (Doctoral dissertation, Bryant University). Retrieved from https://digitalcommons.bryant.edu/honors_mathematics/23/

Chalmers, P. N., Erickson, B. J., Ball, B., Romeo, A. A., & Verma, N. N. (2016). Fastball pitch velocity helps predict ulnar collateral ligament reconstruction in major league baseball pitchers. *The American Journal of Sports Medicine*, *44*(8), 2130-2136. Retrieved from Health & Wellness Resource Center database. (edsgcl.468826090)

Encyclopedia of Baseball Players. (n.d.). Retrieved from Baseball-Reference.com website: http://www.baseball-reference.com

Erickson, B. J., Gupta, A. K., Harris, J. D., Busch-Joseph, C., Bach, B., Abrams, G., . . . Romeo, A. (2014). Rate of Return to Pitching and Performance After Tommy John Surgery in Major League Baseball Pitchers. *American Journal of Sports Medicine*, *42*(3), 536-543. http://dx.doi.org/10.1177/0363546513510890

Erickson, B.J., (2015). The Epidemic of Tommy John Surgery: The Role of the Orthopedic Surgeon. *The American Journal of Orthopedics*, *44*(1), 36-37. Retrieved from https://www.amjorthopedics.com/sites/default/files/issues/articles/ajo04401e036.pdf

Jiang, J., & Leland, J. M. (2014). Analysis of Pitching Velocity in Major League Baseball Players Before and After Ulnar Collateral Ligament Reconstruction. *The American Journal of Sports Medicine*, *42*(4), 880-885. https://doi.org/10.1177/0363546513519072

Keller, R., Marshall, N., Guest, J.-M., Okoroha, K., Jung, E., & Moutzouros, V. (2016). Major League Baseball pitch velocity and pitch type associated with risk of ulnar collateral ligament injury. *Journal of Shoulder and Elbow Surgery*, *25*(4), 671-675. https://doi.org/10.1016/j.jse.2015.12.027

Langer, C. (2014, December 15). Tommy John Surgery Statistics. In *Sporting Charts*. Retrieved January 27, 2019, from https://www.sportingcharts.com/articles/mlb/tommy-john-surgery-statistics.aspx

Lasky, J. (2018). Tommy John Surgery. *Research Starters*. Retrieved from EBSCOhost eBook Collection database. (Accession No. 100259366)

Perloff, J. M., & Brander, J. A. (2017). *Managerial economics and strategy* (2nd ed.). Boston: Pearson.

Roegle, J. (n.d.). TJ Surgery: All Time MLB List [Table]. Retrieved from https://docs.google.com/spreadsheets/d/1gQujXQQGOVNaiuwSN680Hq-FDVsCwvN-3AazykOBON0/edit#gid=0. Retrieved on January 16th, 2019

Selley, R., Portney, D., Lawson, C., Shockley, M., Christian, R., Saltzman, M., & Hsu, W. (2018). Advanced Baseball Metrics Demonstrate Significant Decline in MLB Pitcher Value after Tommy John Surgery. Journal of Shoulder and Elbow Surgery, 27(4), 129-130. https://doi.org/10.1016/j.jse.2018.02.019

Slowinsky, J. (2010, February 15). What is WAR? Retrieved from Fangraphs website: https://library.fangraphs.com/misc/war/

Starting Pitcher Spending. (n.d.). In *Spotrac.com.* Retrieved January 27, 2019, from https://www.spotrac.com/mlb/positional/2018/starting-pitcher/

White, D. (2018, March 29). The Tommy John Surgery Explosion in the MLB. Retrieved January 27, 2019, from Samford University website: https://www.samford.edu/sports-analytics/fans/2018/The-Tommy-John-Surgery-Explosion-in-the-MLB

Appendix 1 – Table: Average Annual Salary

	TJS			
	Y		N	
Age	Average of Annual Salary	No of Observations	Average of Annual Salary	No of Observations
26			4,250,000	1
27	6,000,000	2	875,000	2
28	5,388,889	3	7,195,000	5
29	5,666,667	3	7,447,475	8
30	9,648,148	9	9,012,255	17
31	7,388,889	9	11,162,222	15
32	1,150,000	4	8,697,010	17
33	3,500,000	7	5,945,833	12
34	2,613,333	3	3,968,889	15
35	5,000,000	2	4,375,000	8
36	8,083,333	3	3,166,667	3
37	10,791,667	6	4,375,000	4
38	7,333,333	3	15,000,000	1
39	2,000,000	1	16,000,000	1
40			2,125,000	2
41			7,583,333	3
42			8,000,000	1
43			7,250,000	1
44			12,500,000	1
45			1,750,000	1

Appendix 2 – Table: Contract Years

	TJS			
	Y		N	
Age	Average of Contract Years	No. of Observations	Average of Contract Years	No. of Observations
26			1.00	1
27	1.00	2	1.00	2
28	1.67	3	2.00	5
29	2.00	3	2.50	8
30	2.56	9	2.24	17
31	2.00	9	3.13	15
32	1.00	4	1.88	17
33	1.29	7	1.67	12
34	1.00	3	1.33	15
35	1.50	2	1.00	8
36	1.33	3	1.00	3
37	1.67	6	1.00	4
38	1.33	3	1.00	1
39	1.00	1	1.00	1
40			1.00	2
41			1.33	3
42			1.00	1
43			1.00	1
44			1.00	1
45			1.00	1

Appendix 3 – Table: WARPMD

	TJS			
	Y		N	
AGE	No. of Observations	Average of WARPMD	No. of Observations	Average of WARPMD
26			1	(0.14)
27	2	0.38	2	(1.20)
28	3	0.71	5	0.12
29	3	0.68	8	(0.05)
30	9	(0.02)	17	(0.03)
31	9	(0.03)	15	0.58
32	4	(0.63)	17	0.06
33	7	(0.17)	12	0.13
34	3	(0.66)	15	(0.20)
35	2	0.20	8	0.22
36	3	0.06	3	(0.14)
37	6	0.22	4	(0.07)
38	3	(0.03)	1	0.35
39	1	0.30	1	0.25
40			2	0.41
41			3	0.31
42			1	0.05
43			1	0.17
44			1	0.25
45			1	(0.51)

Appendix 4 – Table: WAR prior to signing

	TJS			
	Y		N	
Age	No. of Observations	Average of WAR Prior to Year of Signing	No. of Observations	Average of WAR Prior to Year of Signing
26			1	(0.60)
27	2	1.15	2	(0.90)
28	3	1.70	5	0.62
29	3	1.80	8	1.00
30	9	0.86	17	0.99
31	9	1.46	15	1.87
32	4	(0.78)	17	1.32
33	7	(0.31)	12	0.75
34	3	(0.97)	15	0.44
35	2	1.70	8	0.74
36	3	1.20	3	0.13
37	6	2.55	4	0.93
38	3	0.20	1	5.30
39	1	0.60	1	4.00
40			2	1.30
41			3	2.63
42			1	0.40
43			1	1.20
44			1	3.10
45			1	(0.90)