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NHL Team Production

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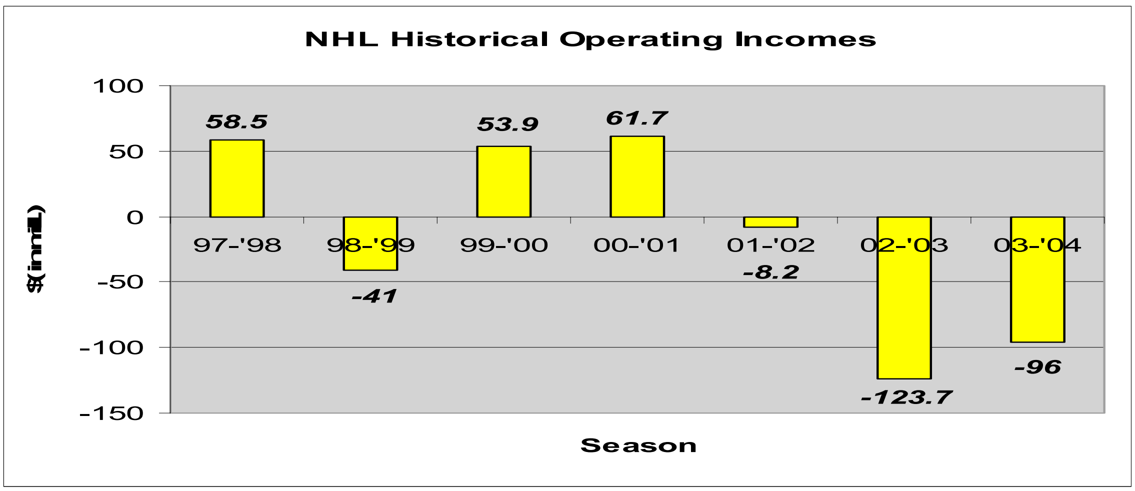
Abstract: In the past few years, the National Hockey League (NHL) has struggled financially. Teams within the NHL and the league itself have been struggling to make money, and last year the NHL season did not take place because of a labor dispute and resulting lockout between the players and owners. Therefore, this makes the NHL a very appropriate target for study. As previous research on various professional sports and the NHL have shown that winning teams are going to draw more fans, determining what makes NHL teams win games is a worthy endeavor. This study does just this. By using Ordinary Least Squares regression and a data set compiled on numerous individual and team statistics for the 1999-2000 through the 2003-2004 seasons, this study determines the various factors that contribute to Team Point production and Goals Allowed in the NHL. Of special note is the finding that Major Penalties, most commonly assessed for fighting, do in fact help NHL teams win games. Hopefully by seeing what aspects of the game lead to NHL team success, the league can determine how to draw more fans in order to make more revenue.

KEYWORDS: (National Hockey League, Production, Wins)

I. INTRODUCTION

Right now the National Hockey League is in an interesting position. In the past few years it has run into numerous problems experiencing many financial dilemmas. Teams within the NHL and the league itself have been struggling to make money, and last year the NHL season did not take place because of a labor dispute and resulting lockout between the players and owners. Figure 1 displays the NHL's operating income for the past seven years. Obviously, something needs to be done.

FIGURE 1



Source: Andrew's Dallas Stars Page.[1]

However, after not playing last season, the NHL has once again resumed play this year after the installment of a new salary cap and some adjustments and additions to previous aspects of the game. The ultimate goal of these new regulations is to draw more fans to NHL games in order to make more money. In the 2002-2003 season 50% of the NHL's revenues came from ticket sales,[2] and an additional 30% came from in-arena sales.[3] Thus, 80% of the league's revenue can be traced directly back to the fans. If the NHL can increase attendance throughout the league, the individual teams and the league itself should make more money.

Now, as the NHL has made these adjustments to bring more fans to the games, fans also want to see their team win. As numerous studies have shown, attendance at professional sporting events is significantly impacted by a team's success.[4] Better teams that win more games are going to draw more fans, and they are going to gain more support off the playing field as well. Sports teams are profitable entities and a winning record is an important factor in determining their financial success. Thus, taking a look at NHL team production, or essentially the individual and team factors that lead to wins in the NHL, is a very relevant and useful topic of interest for professional hockey. By understanding the idea of team production better, maybe the NHL can receive a deeper insight into their financial situation.

This study will attempt to construct a production function for the National Hockey League. Two empirical models using Ordinary Least Squares Regression are employed; one using Team Points as the dependent variable and one using Goals Allowed as the dependent variable. Using both of these measures together should give a very comprehensive appraisal of team production in the NHL. Section two of this study reviews the literature dealing with various production models focusing on professional sports. Section three presents the data and methodology employed, and section four presents the results of the regression analysis. The final section then discusses the conclusions drawn from the study, as well as suggestions for future research.

II. CURRENT RESEARCH ON PRODUCTION IN SPORTS AND THE NHL

There have been numerous studies completed applying production functions to professional sports. In a pioneering study on Major League Baseball, Scully examines the link between pay and performance of professional baseball players. He uses a two part regression model to link win percentage to team revenue, and then estimates a player's marginal revenue product to examine whether players are paid according to their performance and draw of fans. Results of the analysis assert that four main factors contribute to MLB baseball player salaries: hitting or pitching performance, weight of player's contributions to team performance, number of years in the majors, and bargaining power of star players.[5]

In another study done on Major League Baseball, John Bradbury sets up a model to separate pitcher and fielder contributions to team production. He uses a multiple regression model to measure both pitcher and fielder contributions to Earned Run Average (ERA.) Bradbury includes strikeouts, walks, homeruns, and hit batters, which are all Defense Independent Pitching Statistics (DIPS), as a measure of pitchers' contributions to run prevention. For fielder contributions, Bradbury includes Batting Average Allowed on Balls In Play (BABIP.) Ultimately, Bradbury finds that BABIP does in fact have a large impact on ERA; therefore ERA is not the best measure of a pitcher's marginal revenue product to a team's success. Bradbury concludes that future studies should use DIPS for this measure.[6]

Also examining Major League Baseball and salary, Depken investigates the effects of wage disparity on team productivity. He uses data from 1985 to 1998 and a regression model measuring team productivity as win percentage. Depken concludes that higher total salary levels heighten team performance, whereas higher wage disparity hinders team performance.[7] Frick, Prinz, and Winkelmann repeat this study, but look at all of the four major sports (baseball, basketball, football, and hockey.) Using win percentage as a measure of team performance and the Gini-index to measure wage disparity, Prinz and Winkelmann use data from up to 16 consecutive seasons. They conclude that in football and baseball a higher degree of inequality in salary dispersement results in poorer performance, whereas basketball and hockey are affected conversely.[8]

Berri does a similar study to Scully's, but instead of baseball Berri examines the National Basketball Association. Like Scully, Berri computes a production function based on wins for an NBA player and then measures each player's marginal product. Berri's results show that rebounds, avoidance of turnovers, and shooting efficiency are the most influential statistics contributing to team success. The study also concludes that Dennis Rodman; not Michael Jordan; was actually the most valuable player in the NBA for the 1997-98 season.[9]

In another study done on NBA production, Anthony Onwuegbuzie creates a model to determine the factors associated with team success. Using win percentage as the dependent variable, the results show that, like Berri, field goal percentage is the best predictor of success. In addition, though, Onwuegbuzie also asserts that the average three point conversion percentage of the opposing team has the second largest impact on win percentage. Thus, the study concludes that the attainments of the offense are more important than defensive accomplishments in predicting an NBA team's success.[10]

In looking at a team's efficient use of its players, Zak, Huang, and Siegfried complete another study on production in the NBA. They use a Cobb-Douglas production frontier along with individual game data for the 1976-77 season. Like Berri, this study finds that rebounds, turnovers, and shooting percentage are the most important factors of output. Also, with the inclusion of an error term in the production frontier to calculate efficiency, the study generates an exact ranking of teams that the actual win/loss record reports.[11]

For hockey, production models are less numerous, and although there have been a few completed, most studies done on the NHL deal with violence and/or salary discrimination. In one study completed on violence, Stewart, Ferguson, and Jones set up a multiple equation regression model using data from the 1981, '82, and '83 NHL seasons to assess violence's role in drawing fans and winning. The results assert that violence does draw fans, but not if it costs the team wins. Also, the study concludes that violence is in fact used as a profit maximizing tool by NHL teams.[12]

Jones and Nadeau present a second study on violence. They use data for 388 players from the 1989-90 season, and a variant on the standard earnings function model of human capital theory tests whether violence is used as a salary and/or employment determinant. The overall conclusion is that the coefficients of the model are significantly different for skillful and violent players; thus, violence is a significant determinant of employment and salary.[13]

Discrimination is the topic of several of the NHL papers that have been written thus far. The most often studied question here is whether there is wage discrimination against French-Canadian players. In one study completed, Jones and Walsh set up a regression equation relating player salaries to skills and discrimination. They use data from the 1977-78 season and ultimately assert that skills are the prime determinant of player salary, but also that there is evidence of salary discrimination for defenseman of French-Canadian descent.[14] Marc Lavoie, Gilles Grenier, and Serge Coulombe add to this conclusion with their 1987 study. The results of their work shows that Francophones (French-Canadians) and Europeans significantly outperform Anglophones (English-Canadians) and Americans in both offensive and defensive categories. In addition, because French-Canadians are shown to be drafted in later rounds than English-

Canadians of equal talent, there is substantial evidence of hiring discrimination (direct discrimination, regardless of skills, size, or player contribution) against French-Canadians.[15]

In response to this however, Jones, Nadeau, and Walsh find very little evidence in their 1999 study that salaries in the NHL are based on either the players' ethnicity or the consumers' ethnic preference. Only evidence of salary advantages for veteran players could be found.[16]

Kahane, on the other hand, attempts to define the sources of production inefficiency in the NHL, and uses a stochastic frontier approach to do so. He uses data from the 1989-98 seasons, and asserts that inefficiencies can be traced back to coaching ability, team ownership, and management experience. Also, the results show that teams with unusually high or low numbers of French-Canadians tend to be less efficient.[17] And, in a final study dealing with the NHL, Kahane and Idson examine whether coworker productivity is a factor in an NHL player's salary. The results show that team attributes do in fact have an impact on an individual's salaries. Therefore, in the production process, teammates seem to be complements in the NHL.[18]

Although there is quite a bit of literature dealing with team production in professional sports, we notice that studies on this issue in professional hockey are sparse. Most of the studies completed on the NHL deal either with violence or discrimination. In addition, throughout the literature examined, various production models are used, and the results of previous studies do not always agree with one another. Especially with the NHL having the problems that it has had recently, a straight forward approach to a team production model is needed. Because most studies measuring team success deal with salary in the NHL, a production model based solely on wins or Team Points would be useful for professional hockey. And taking from previous studies dealing with production in professional sports, both teamwork and individual skills will be integral in this study.

III. THE EMPIRICAL MODEL AND DATA

As wins and win percentage have often been employed in production models dealing with professional sports, the NHL does not base their rankings on either of these measures. In contrast, rankings in the NHL are determined by Team Points, where each team receives two points for a win and one point for a tie after regulation. If a team then wins in overtime, another point is awarded, and the losing team walks away with one point.[19] In addition, because previous studies measuring production in the NHL have merely dealt with individuals,[20] Team Points will be a great overall measure of an entire team's performance.

In addition though, a separate production model accounting for Goals Allowed will also be included as a further measure of a team's defensive production. As Team Points will be used as an overall measure of an NHL team's success, Goals Allowed will give a deeper insight into defensive contributions to team production.

The data used for this study includes quantitative statistics for all NHL teams starting from the 1999-2000 season through the 2003-2004 season. For the seasons 2000-2001 through 2003-2004, the data set will include statistics for all 30 NHL teams. In contrast, for the 1999-2000 season, the data set includes only 28 NHL teams as the Columbus Blue Jackets and Minnesota Wild teams were both added in the 2000-2001 season. This yields a total of 148 observations.

The data employed is taken from a combination of three different sources: NHL.com,[21] The National Hockey League Official Guide and Record Books,[22] and a data set compiled by Stacey Brook (Vucurevich School of Business, University of Sioux

Falls).[23] Because NHL.com's statistics only date back as far as the 2001-2002 season, a data set collected by Stacey Brook is utilized to fill in statistics for the 1999-2000 and 2000-2001 seasons (this data was also taken from NHL.com, so the data set remains consistent.)[24] In addition, because NHL.com's statistics do not date back to these two seasons, and because goaltender statistics were not included in the initial data set compiled by Stacey Brook, this study uses The National Hockey League Official Guide and Record Book(s) to collect both number of Saves by a team throughout a season and the average Save Percentage of a team per season.[25] All variables included in the data set are presented in Table 1.

TABLE 1
List of All Variables/Statistics Used and Their Description

VARIABLE NAME	DESCRIPTION
PTS	Team Points: Total team points accumulated by a team (2 points for a win, 1 point for a tie)
GA	Goals Allowed: Total goals allowed by a certain team
A	Assists: Total assists accumulated by a team
SHOTS	Shots: Total shots accumulated by a team
TFW	Total Face-offs Won
TFL	Total Face-offs Lost
MAJORS	Major Penalties taken (5 minute penalty or more)
PIM	Penalties In Minutes: Total penalty minutes accumulated by a certain team
G	Goals For: Total number of goals scored by a certain team
ESG	Even-strength Goals
SHG	Short-handed Goals
PPG	Power-play Goals
PLSMIN	Team's total Plus/Minus (a player receives a plus when he is on the ice when his team scores a goal; receives a minus when he is on the ice when the opposing team scores a goal)
SAV	Saves: Total saves made by a team's goaltender(s)
G/SHOTS	Shooting Percentage
SAVPCT	Save Percentage: Average save percentage of a team's goaltender(s)
YEAR	Season: Time dependant variable accounting for which season the statistics come from

The basic empirical models using Team Points and Goals Allowed as dependent variables are displayed in Equations 1 and 2. Both of these measures used together, PTS and GA, should allow for a very comprehensive appraisal of the factors leading to NHL team production and success. The model using PTS is presented below.

$$PTS = \alpha_0 + \alpha_1 GA + \alpha_2 A + \alpha_3 TFW + \alpha_4 TFL + \alpha_5 PIM + \alpha_6 MAJORS + \alpha_7 ESG + \alpha_8 PPG + \alpha_9 SHG + \alpha_{10} G/SHOTS + \alpha_{11} PLSMIN + \alpha_{12} SAV + \alpha_{13} YEAR + e \quad (1)$$

Because PTS is an all-inclusive measure of a team's productivity, whereas GA is a more defensively focused measure, different variables are included in the respective equations. The Ordinary Least Squares (OLS) equation utilized with GA as the dependant variable is as follows:

$$GA = \alpha_0 + \alpha_1 LOG(TFW) + \alpha_2 LOG(TFL) + \alpha_3 LOG(PIM) + \alpha_4 LOG(G) + \alpha_5 LOG(SAVPCT) + \alpha_6 LOG(SHOTS) + \alpha_7 LOG(MAJORS) + \alpha_8 LOG(YEAR) + e \quad (2)$$

The logs of all independent variables are included in this model due to increased fit. In addition, it also aided with problems of non-normality of error. The variable YEAR is included in both models as a time dependent variable to correct for autocorrelation.

Independent Variables

The independent variables included in the two Ordinary Least Squares (OLS) regression models can be characterized into a few different categories.

Goals

Obviously, Goals are going to play a large part in any team's ability to win games. Thus, in the NHL, Goals are expected to have a significant and positive effect on the production of Team Points. Even-strength Goals, Power-play Goals, and Short-handed Goals will all be included in the PTS model. All are expected to have a positive effect on Team Points. The independent variable Goals For will be included in the model using Goals Allowed as the dependent variable. As all of the variables accounting for goals scored by a team are expected to have a positive effect on Team Points, the variable of Goals For is expected to have a negative effect on Goals Allowed.

However, the expected outcome of Goals For is still a bit unclear within the GA model. As one might think that being scored on would only hurt an NHL team's play even more, some teams might need something to kick them into action. Where one team is better at playing with the momentum, scoring a goal could jumpstart the opposing team to begin playing harder and smarter. Therefore, although Goals For is expected to have a negative impact on Goals Allowed, it is still a bit uncertain.

Goaltending

Goaltending is another huge aspect of hockey. A team's goaltender has an enormous impact on a team's success due to the fact that he can single-handedly keep the opposing team from scoring goals. The two variables included in the model accounting for Team Points are Saves and Goals Allowed. As a Save is preventing the opponent from scoring, Saves are expected to affect Team Points positively. In contrast, the Goals Allowed variable is expected to affect Team Points negatively. Obviously, as goals are going to help a team win games, Goals Allowed should have the opposite effect.

Save Percentage will be used as the ultimate measure of goaltender contributions to NHL Goals Allowed. As this statistic measures the amount of Saves made in ratio to the total number of shots faced by a team's goaltender(s), this should be a very comprehensive measure of a goaltender's role in defensive production. Save Percentage is expected to affect Goals Allowed negatively, as it implies that Saves are being made.

Penalties

The two statistics accounting for penalties in this study are Penalties In Minutes and Major Penalties. Both are included in each model, and although Penalties In Minutes should definitely have a negative effect on Team Points and a positive effect on Goals Allowed, the effect that Major Penalties will have on both models is a bit uncertain.

A Major Penalty is a five-minute penalty, and the team assessed must play short-handed for all five minutes, regardless if the opposing team scores. Thus, Major Penalties can be a more severe detriment to a team than a two-minute minor penalty. On the other hand, most Major Penalties that are called are assessed as a result of fighting. In this case, both teams are almost always penalized, which results in no power-plays for either team. Thus, as neither team gains a man-up advantage here, Major Penalties may not necessarily have a negative effect on Team Points (or a positive effect on Goals Allowed.)

In addition, fighting can also be used as a tool in the NHL. As Stewart, Ferguson, and Jones have shown that violence attracts fans to NHL games,[26] Jones, Nadeau, and Walsh have also shown that violence is a significant determinant in a player's employment and salary.[27] Therefore, bigger and more physical players are in fact hired and paid for their brutish style of play. Following, NHL teams often have a player that will initiate fights in order to motivate his team and spark some enthusiasm and better play from his teammates. Because momentum is a big part of the game of hockey, fighting is often used to regain momentum for the instigating team. Therefore, as fighting can help elicit stronger play from an NHL squad, and doesn't always imply a team being short-handed, Major Penalties' impact on Team Points and Goals Allowed is undecided.

Face-offs

Face-offs are also a big part of the game of hockey. Each time there is a stoppage of play in hockey, the puck is dropped between two opposing players, and they battle for control of the puck. If a player is able to win a lot of face-offs, this helps his team control the puck, gives them more chances to score goals, and a better shot at winning games. In contrast, if a player is not able to win a lot of face-offs, this gives the opposing team an advantage. Therefore, Total Face-offs Won is expected to affect Team Points positively and Goals Allowed negatively, while Total Face-offs Lost is expected to have the opposite effect on each model.

Shooting

Goals cannot be scored in hockey unless you shoot the puck. Thus, some sort of variable accounting for shots must be included in this study. The simple statistic of Shots will be included in the model accounting for Goals Allowed, and Shooting Percentage will be included as a determinant of Team Points. The more shots a team takes, the more chances they have of scoring goals, and the better chance they have of winning games. In addition, because Shots imply that a team has control of the puck (almost always in the opposing team's zone,) this variable can count as some measure of momentum in the Goals Allowed model. Because Shots taken by a team imply that the puck is nowhere near their own goaltender, Shots is expected to have a negative effect on Goals Allowed. In contrast, Shooting Percentage is expected to have a positive effect on Team Points, as a higher shooting percentage implies that more goals are being scored on the same amount of shots.

Assists

As hockey is a team sport, player cooperation is an integral part of the game. Thus, some aspects of teamwork should be included in the production model. Therefore, the simple statistic of Assists is included as an independent variable in the Team Points model. As Assists help Goals happen and Goals are going to help NHL teams win games, Assists are expected to have a positive effect on Team Points.

Plus/Minus

A final variable that will be included in this analysis of NHL Team Production is that of Plus/Minus. This statistic is kept for each individual player and shows whether a player has contributed more to goals, or has been scored on more while he is on the ice. If a player is on the ice while his team scores a goal, a player receives a "plus." If he is on the ice while the opposing team scores, the player receives a "minus." These "plusses" and "minuses" are then tallied throughout the season to assess how well a player plays both offensively and defensively. A high, positive Plus/Minus statistic is one sign of a good player. This variable will be included only in the Team Points model, but is expected to have a positive effect in that equation.

IV. REGRESSION RESULTS

Tables 2 and 3 summarize the results of the OLS regressions run for both the Team Points and Goals Allowed models. Three variations of each model are employed; the dependent variables themselves, the square root of each dependent variable, and the log of each dependent variable are all included in an attempt to find the best fit. In addition, these different variations are used to illustrate that the results are not driven by functional form. All econometric problems were tested for within these models and corrections were employed when necessary.[28] The coefficients for each independent variable are presented in the following tables along with their corresponding t-statistics, which are displayed in parentheses underneath the coefficients. The R-squared and adjusted R-squared values are displayed in the bottom rows of the tables as well.

TABLE 2
Ordinary Least Squares Regression Results for PTS: Coefficients and t-statistics

VARIABLE	Dependent Variable: **PTS**	Dependent Variable: **PTS^(1/2)**	Dependent Variable: **LOG(PTS)**
C *Constant Term*	-16.13736 (-0.033086)	-5.94690 (-0.21810)	-1.23227 (-0.18510)
GA *Goals Allowed*	-0.20473 (-6.82809)**	-0.01156 (-7.20152)**	-0.00263 (-7.35331)**
A *Assists*	0.06034 (6.10861)**	0.00325 (5.68038)**	0.00069 (4.51836)**
TFW *Total Face-offs Won*	0.00303 (2.10461)*	0.000199 (2.47852)**	.000052 (2.66374)**
TFL *Total Face-offs Lost*	-0.00358 (-2.59215)**	-0.00024 (-3.02605)**	-.000061 (-3.20374)**
PIM *Penalties In Minutes*	-0.01087 (-4.08019)**	-0.00059 (-3.86525)**	-0.00013 (-3.45491)**
MAJORS *Major Penalties*	0.07587 (2.32994)*	0.00406 (2.16972)*	0.00087 (1.88263)
ESG *Even-strength Goals*	0.08888 (2.39096)**	0.00460 (2.24202)*	0.00095 (1.99966)*
PPG *Power-play Goals*	0.21923 (5.1880)**	0.01085 (4.78435)**	0.00217 (4.12753)**
SHG *Short-handed Goals*	0.29421 (3.40514)**	0.01477 (3.10186)**	0.00298 (2.64666)**
G/SHOTS *Shooting Percentage*	21.8182 (0.36897)	3.09951 (0.96464)	1.104995 (1.46089)
PLSMIN *Plus/Minus*	0.02790 (4.00674)**	0.00154 (3.90684)**	0.00035 (3.45499)**
SAV *Saves*	0.00420 (2.31710)*	0.00021 (1.95699)*	.000044 (1.54728)
YEAR *Season*	0.04787 (0.19705)	0.00746 (0.54961)	0.00282 (0.84994)
R-squared	.95451	.95433	.94712
Adjusted R-squared	.95009	.94990	.94199

t-statistics in parentheses
* indicates significance at the 95% confidence level
** indicates significance at the 99% confidence level

TABLE 3
Ordinary Least Squares Regression Results for GA:
Coefficients and t-statistics

VARIABLE	Dependent Variable: **GA**	Dependent Variable: **LOG(GA)**	Dependent Variable: **GA^(1/2)**
C *Constant Term*	3533.531 (.22921)	16.22397 (.23445)	110.2369 (.21499)
LOG(TFW) *Total Face-offs Won*	-44.936 (-2.63234)**	-.18357 (-2.43002)**	-1.43553 (-2.54219)**
LOG(TFL) *Total Face-offs Lost*	21.289 (1.16570)	.07110 (.86574)	.61999 (1.01750)
LOG(PIM) *Penalties In Minutes*	48.659 (3.97558)**	.22393 (3.96765)**	1.64555 (3.98315)**
LOG(G) *Goals For*	-47.667 (-3.69999)**	-.20271 (-3.52015)**	-1.55305 (-3.62637)**
LOG(SAVPCT) *Save Percentage*	-2033.383 (-14.68109)**	-9.05105 (-15.12466)**	-67.68388 (-15.06263)**
LOG(SHOTS) *Shots*	-45.890 (-2.00105)*	-.21893 (-2.10827)*	-1.57931 (-2.05915)*
LOG(MAJORS) *Major Penalties*	-11.621 (-2.08196)*	-.05934 (-2.31999)*	-.41495 (-2.20687)*
LOG(YEAR) *Season*	-397.363 (-.19545)	-1.24170 (-.13611)	-11.2238 (-.16602)
R-squared	.75307	.74340	.74972
Adjusted R-squared	.73886	.72863	.73531

t-statistics in parentheses
* indicates significance at the 95% confidence level
** indicates significance at the 99% confidence level

Goals

Even-strength Goals (ESG), Power-play Goals (PPG), and Short-handed Goals (SHG) all received positive coefficients within the Team Points (PTS) model as expected. Obviously, scoring goals is going to enhance a team's chances at winning games, and the fact that all three of these variables are significant for all three PTS models exemplifies this point. Also, the fact these variables acquired some higher coefficients explains that they have a very large effect on a team's ability to win games.

Furthermore, within the GA models, the independent variable Goals For (G) acquired a negative coefficient and is significant the 99% confident level. A possible hypothesis set forward in section III asserted that scoring a goal could motivate the opposing team to improve their play. However, the result that G has a negative impact on GA emphasizes the idea that the majority of the time, most NHL teams do not react positively after allowing a goal. This reiterates the importance of momentum in the game of hockey.

Goaltending

All of the variables dealing with goaltending in this study produced results as expected. For the PTS models, Saves (SAV) received a positive coefficient and GA received a negative coefficient. If a team's goaltender can keep the puck out of their net and can keep the opposing team from scoring, they should have a better chance at winning games. In contrast, as GA has a negative impact on PTS, this implies that allowing an opposing team to score goals hinders the chances of winning games. The GA variable is found to be significant at the 99% confidence level for all PTS models and the SAV variable is significant at the 95% confidence level for the two econometrically sound PTS models.[29] Save Percentage (SAVPCT) was not included in the PTS model due to multicollinearity issues with SAV.

Accounting for goaltender contributions within the GA models is the statistic of Save Percentage (SAVPCT.) This is the most influential variable in the models run for GA. This is represented by the extremely high negative coefficients and t-statistics obtained by SAVPCT in these models. The coefficients obtained for SAVPCT are vastly larger than any other variable included in the GA models and are all significant at the 99% confidence level. With a higher average Save Percentage fewer goals are allowed against a team.

Therefore, goaltending is clearly shown to be a huge factor in the success of an NHL team.[30]

Penalties

Within the PTS models, a negative coefficient was obtained for Penalties in Minutes (PIM). PIM is a statistic totaling an entire team's penalty minutes over the course of a season. PIM implies that a team has taken numerous penalties and is playing a man-down, which is a huge disadvantage. Therefore, the more penalties a team takes, the harder it is going to be for them to win games. Furthermore, the PIM variable received a positive coefficient in the GA models. This makes sense, in that a team cannot expect to kill every penalty they receive, and thus, GA will increase with an increase in PIM. PIM is significant at the 99% level for all six equations.

Now, in addition to PIM being included in the analysis of NHL team production, a variable accounting for Major Penalties is also included. A Major Penalty (MAJORS,) is a penalty of five minutes, normally assessed for overly aggressive activity such as fighting. For all three PTS models, MAJORS received a positive coefficient, and for all three GA models MAJORS received a negative coefficient. This implies that MAJORS help a team win games, as well as enhance their ability to keep the opposing team from scoring. This is a very interesting finding, but one that can be rationally explained.

Any time a team is playing short-handed this is going to put them at a disadvantage. However, with Major Penalties, as in the case of fighting, many are called as coincidentals. A coincidental penalty is a penalty that is assessed to one player from each team at the same time. Therefore, both teams must send one of their players to the penalty box and neither team plays a man-up nor a man-down, but rather, both teams have an equal amount of players on the ice. Thus, this explains why MAJORS does not have a negative effect on a team's ability to win games, and does not contribute to additional Goals Allowed.

What is the role of fighting in hockey?[31] Essentially, a player might play extremely aggressively and may pick a fight in order to spark some enthusiasm and some extra passion from his team. If a team is not playing well, and a player shows his eagerness to win by initiating a fight, the momentum of the game can change and some extra effort can be elicited from his team as a result. Therefore, because it is significant at the 95% confidence level within the PTS models, and it has acquired a positive coefficient, Major Penalties can help a team win games. Furthermore, because MAJORS has acquired a negative coefficient and is significant in all GA models at the 95% confidence level, this implies that Major Penalties do in fact help a team keep the puck out of their own net. Whereas being scored on does not have the ability to strike a team into action (Goals For (G) having a negative impact on GA,) MAJORS, and more specifically fighting, can in fact change the momentum of the game.

Face-offs

As expected, Total Face-offs Won (TFW) has a positive effect on PTS and a negative impact on GA. This implies that winning face-offs does in fact help a team win games and does aid in keeping the opposing team from scoring. TFW is significant in all six models; in five-out-of six at the 99% level. On the other hand, Total Face-offs Lost (TFL) received a negative coefficient in the three PTS models. Just as winning face-offs helps a team win games, losing face-offs is giving the other team control of the puck, and is giving them more opportunities to take shots and score goals. TFL is significant at the 99% confidence level for all PTS models.

Although TFL received the expected positive coefficient for all three GA models, the variable is not significant in any of the models. The implication of this result is that winning face-offs keeps an opposing team from scoring goals more so than losing face-offs allows an opposing team to score. It is plausible that a team is able to recover more often from a lost face-off than an opposing team is able to score goals as a result. For example, even though a forward has lost a battle for the puck, the opposing team still has to beat the defensemen and goaltender. In addition, the lack of significance of TFL could be attributed to the location of the face-off. It is rare for a team to score from outside the opposing team's zone, and therefore, Face-offs Lost which do not occur in a team's defensive zone are not nearly as important in preventing goals as the face-offs taken in close proximity to their goaltender. Thus, although TFW keeps an opposing team from scoring goals, TFL doesn't necessarily imply a great chance for the opponent to score.

Shooting

Although G/SHOTS received positive coefficients as expected for all three models with PTS as the dependent variable, the fact that it is not significant at a high level implies that shooting percentage does not have a very strong impact on winning games in the NHL. One explanation for this might be that even though a team does not score on a high percentage of their shots, they are still able to score goals. If a team can keep their opponents from scoring goals, then a low Shooting Percentage might not matter if they can at least score one goal on any number of shots. Another explanation that can be given for the insignificance of Shooting Percentage is that the variable was fairly similar for all teams in the data set. A lack of variation in this variable could contribute to insignificance in the regression models.

Within the GA models, SHOTS received a negative coefficient and is significant at the 95% level. This implies that taking shots does in fact help keep the opposing team from scoring, once again exemplifying the importance of momentum in hockey.

Assists

Assists (A) are found to affect Team Points (PTS) positively. In addition, (A) is significant for all models at the 99% confidence level. This agrees with the hypothesis set forward in section III. As hockey is a team sport, player cooperation is an integral part of the game, and as an Assist implies that a goal is scored, Assists are going to help NHL teams win games. This concurs with Kahane and Idson's (2000) study done on co-worker productivity in the NHL, reasserting if two teammates work exceptionally well together, this is going to help their team win games, and their organization is going to pay them more for their contributions. [32]

Plus/Minus

The variable Plus/Minus (PLSMIN) also received a positive coefficient for all three PTS models. As a player receives a "plus" each time he is on the ice while his team scores a goal, and receives a "minus" each time he is on the ice while the opposing team scores, it makes sense that a high, positive PLSMIN is going to help a team win games. This variable is significant at the 99% confidence level for all three PTS equations.

Ultimately, the results of both models are very impressive. The fact that the significance and signs of all coefficients agree with each other for each model demonstrates the strong fit of the data and the strength of its validity. Furthermore, nearly all of the variables acquiring a positive coefficient in the PTS model acquired a negative coefficient in the GA model; this is exactly as expected. The R-squared values for all three PTS models are extremely high (around the 95% range,) implying a very strong fit of the regression equations, and the obtained F-statistics of around 200 assure that the coefficients can be trusted and are not equal to zero.[33] In addition, all of the R-squared values for the GA models are around .75. This is a fairly strong fit as well, as it implies that 75% of the variation in GA is explained by the individual models. The F-statistics obtained for the three GA models are all around 50, which is well above the critical value needed to ensure that every coefficient is not equal to zero.[34]

V. CONCL USIONS

This study has attempted to set up a comprehensive team production function for the National Hockey League. In the past, studies have been completed with this goal in mind for other professional sports. However, a production model specific to the NHL and the game of hockey has yet to be produced. The purpose of this work was to do just this.

This paper has taken into consideration the previous studies dealing with production in professional sports, and also many inquiries dealing with the NHL. Most studies completed on the NHL have dealt with either violence or discrimination, and these and others often include salary as a focus. In contrast, this study has succeeded in looking solely at what makes an NHL team win games. Although violence was a very important topic in this study, salary considerations and discrimination were left alone. Because this study presents something very new under the subject matter of professional hockey, its findings are of note.

Using data collected from a variety of sources accounting for five NHL regular seasons (1999-2000 through 2003-2004,) this study uses Ordinary Least Squares regression to estimate the effects of numerous variables on Team Points (PTS) and Goals Allowed (GA.) These two sets of models were used to account for nearly all aspects of the game of hockey and cover both offensive and defensive contributions.

The results are very consistent throughout all the models used, showing striking similarity in the magnitude and signs of the variables, as well as common significant t-statistics. Both sets of regressions run for PTS and GA report impressive fits of the data with great R-squared values and F-stats.[35] All of the variables GA, A, TFW, TFL, PIM, MAJORS, ESG, PPG, SHG, PLSMIN, SAV, SAVPCT, and SHOTS were found to be significant factors that help explain NHL team success.

Two major findings of this study involve the evaluation of momentum and fighting, or Major Penalties. Ultimately, both of these aspects of the game of hockey have been found to have a significant effect on a team's ability to win games. First, the result of Goals For having a negative impact on Goals Allowed implies that teams generally do not bounce back instantly after they have been scored on. Rather than causing a team to be sparked into action, being scored on only seems to create more momentum for the scoring team. In contrast to this fighting has been shown to have the ability to change the momentum of the game. As MAJORS were found to have a positive effect on PTS and a negative effect on GA, this implies that Major Penalties (more specifically fighting) do in fact aid a team's success. Even though fighting results in a penalty, it is shown to be able to jump start a team into action and elicit better play. For example, if a team is not playing well, a player might start a fight with the opposing team in order to get the momentum of the game back on his side.

These results exemplify the importance of physical play and momentum in the NHL. If a team has the momentum of the game going their way, chances are they are going to win that game. Furthermore, as Jones and Nadeau found in their 1997 study that violence is a significant determinant of employment and salary in the NHL,[36] the results obtained here further iterate the significance of fighting and aggressive play in hockey. With the implementation of its new rules for the 2005-2006 season trying to curb violent play and increase offensive production with more stringent penalty calling, this might be something for the National Hockey League to keep in mind.

Future Research

Although this study was successful in assessing NHL team productivity, and the regression models were very effective, the inclusion of additional variables could be worthwhile. Due to inconsistencies in the data sources used for this paper and the lack of availability of numbers, giveaways and takeaways, hits, blocked shots, and penalty-kill and power-play percentages were not included in this study. Incorporating these statistics could prove to be very useful. In addition, because of recent revenue declines in the NHL attendance issues are a very appropriate topic for future research. The fans are a source of revenue for teams, so further assessment of what brings NHL fans to the arenas would be useful to the industry. With the NHL instituting new rules to call more penalties and increase scoring and offensive play in order to draw more fans, a study in a few years using this new data would make sense.

[1]Andrew's Dallas Stars Page, "NHL Business, 97-'98 through 03-'04 Forbes Numbers," available from http://www.andrewsstarspage.com/NHL-Business/index.htm, visited 4/10/06.

[2]Andrew's Dallas Stars Page, "NHL Business, 2002-2003 Levitt Report Numbers," http://www.andrewsstarspage.com/NHL-Business/index.htm, visited 4/10/06.

[3]Ibid.

[4]Studies done by Dobson and Goddard (1995) for English professional soccer, DeSchriver and Jensen (2002) for Collegiate football, Welki and Zlatoper (1994) and Depken (2001) for NFL football, Kahane and Schmanske (1997) for Major League Baseball, Berri, Schmidt, and Brook (2004) for the National Basketball Association, and Hansen and Gauthier (1989) for the National Hockey League.

[5]Gerald Scully, "Pay and Performance in Major League Baseball," *The American Economic Review,* Vol. 64, No. 6, 1974: 915-930.

[6]John Bradbury, "Sorting Out the Joint Production of Defense in Baseball," *Working Paper,* 2005.

[7]Craig Depken, "Wage Disparity and Team Productivity: Evidence from Major League Baseball," *Economics Letters,* Vol. 67, 2000: 87-92.

[8]Bernd Frick, Joachim Prinz, and Karina Winkelmann, "Pay Inequalities and Team Performance," *International Journal of Manpower,* Vol. 24, No. 4, 2003: 472-488.

[9]David Berri, "Who is "Most Valuable"? Measuring the Player's Production of Wins in the National Basketball Association," *Managerial and Decision Economics,* Vol. 20, No. 8, 1999: 411-427.

[10]Anthony Onwuegbuzie, "Factors Associated with Success Among NBA Teams," *The Sport Journal,* Vol. 3, No. 2, 2000.

[11]Thomas Zak, Cliff Huang, and John Siegfried, "Production Efficiency: The Case of Professional Basketball," *The Journal of Business,* Vol. 52, No. 3, 1979: 379-392.

[12]K.G. Stewart, Donald Ferguson, and J.C. Jones, "On Violence in Professional Team Sport as the Endogenous Result of Profit Maximization," *Atlantic Economic Journal,* Vol. 20, No. 4, 1992: 55-65.

[13]J.C. Jones, S. Nadeau, and W.D. Walsh, "The Wages of Sin: Employment and Salary Effects of Violence in the National Hockey League," *Atlantic Economic Journal*, Vol. 25, No. 2, 1997: 191-206.

[14]J.C. Jones and William Walsh, "Salary Determination in the National Hockey League: The Effects of Skills, Franchise Characteristics, and Discrimination," *Industrial and Labor Relations Review*, Vol. 41, No. 4, 1988: 592-604

[15]Marc Lavoie, Gilles Grenier, and Serge Coulombe, "Discrimination and Performance Differentials in the National Hockey League," *Canadian Public Policy – Analyse de Politiques*, Vol. 13, No. 4, 1987: 407-422.

[16]J. Colin H. Jones, Serge Nadeau, and William D. Walsh, "Ethnicity, Productivity and Salary: Player Compensation and Discrimination in the National Hockey League," *Applied Economics*, Vol. 31, 1999: 593-608.

[17]Leo Kahane, "Production Efficiency and Discriminatory Hiring Practices in the National Hockey League: A Stochastic Frontier Approach," *Review of Industrial Organization*, Vol. 27, No. 1, 2005: 47-71.

[18]Todd Idson and Leo Kahane, "Team Effects on Compensation: An Application to Salary Determination in the National Hockey League," *Economic Inquiry* Vol. 38, No. 2, 2000: 345-57.

[19]NHL Rulebook, "Rule 89; Tied Game," available from http://www.nhl.com/rules/rule89.html, visited 12/12/05.

[20]Lavoie, Grenier, and Coulombe (1987) and Jones, Nadeau, and Walsh (1999).

[21]The National Hockey League, "Stats," available from http://www.nhl.com/nhlstats/stats?service=page&context=Home, visited 8/10/05.

[22]The National Hockey League, *The National Hockey League Official Guide and Record Book/2001-2006*, Kingston, NY: Total Sports Publishing Inc., 2000-2005.

[23]Stacey L. Brook, "National Hockey League Team Production," *Working Paper*, 2001.

[24]Ibid.

[25]The National Hockey League, *The National Hockey League Official Guide and Record Book/2001-2006*, Kingston, NY: Total Sports Publishing Inc., 2000-2005.

[26]K.G. Stewart, Donald Ferguson, and J.C. Jones, "On Violence in Professional Team Sport as the Endogenous Result of Profit Maximization," *Atlantic Economic Journal,* Vol. 20, No. 4, 1992: 55-65.

[27]J.C. Jones, S. Nadeau, and W. D. Walsh, "The Wages of Sin: Employment and Salary Effects of Violence in the National Hockey League," *Atlantic Economic Journal* 25, No. 2, 1997: 191-206.

[28]White's correction for standard errors was used to correct heteroscedasticity, and the time-dependent variable YEAR is included as a fix for autocorrelation. In addition, Jarque-Bera statistics were calculated as a test for non-normality of error. However, as the model using the log of PTS as the dependent variable had a problem with error normality, the square root of PTS and PTS itself are included as dependent variables as well. Thus, the only econometric problem that still exists in the models is that of non-normality of error within the log of PTS model; all other problems have been accounted for.

[29]SAV was not found to be significant for the Log(PTS) model, which has problems with normality of error.

[30]Saves (SAV) were not included in the GA models due to enormous problems with normality of error. With SAV included in the model for GA, J-B statistics between 6,000 and 8,000 were reported. These values are well above the 5.99 Chi-squared maximum limit set to assure normality of error. Therefore, to preserve the validity of this study, the SAV statistic was omitted from the models using GA as the dependent variable.

[31]Most major penalties are assessed as a result of a fight, and the subsequent explanation follows from this assumption.

[32]Todd Idson and Leo Kahane, "Team Effects on Compensation: An Application to Salary Determination in the National Hockey League," *Economic Enquiry,* Vol. 38, No. 2, 2000: 345-357.

[33]Byron D. Eastman, *Interpreting Mathematical Economics and Econometrics*, New York: St. Martin's Press, 1984: 59-94.

[34]Byron D. Eastman, *Interpreting Mathematical Economics and Econometrics*, New York: St. Martin's Press, 1984: 59-94.

[35]The R-squared values for all the models using PTS as the dependent variable are around 95%. The R-squared values produced by the models accounting for GA are around 75%. All F-stats are well above the critical value required. The F-stats for the PTS models are around 200, and the F-stats for the GA models are around 50.

[36]J.C. Jones, S. Nadeau, and W. D. Walsh, "The Wages of Sin: Employment and Salary Effects of Violence in the National Hockey League," *Atlantic Economic Journal*, Vol. 25, No. 2, 1997: 191-206.