A QUANTITATIVE ANALYSIS OF UNRESTRICTED FREE AGENCY IN THE NHL: PREDICTED PROBABILITY EFFECTS

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A QUANTITATIVE ANALYSIS OF UNRESTRICTED FREE AGENCY IN THE NHL: PREDICTED PROBABILITY EFFECTS

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Abstract

This paper adds to the exploration of the factors that influence free agent signings in the NHL. The idea that signing high-caliber unrestricted free agents in the NHL leads to long-term success is common in the world of hockey, despite the lack of statistical evidence to support it. Using annual data between the 2011-2012 and 2016-2017 NHL seasons, this study utilizes probability-based models and a nonlinear binomial regression to analyze the factors that influence unrestricted free agent signings. The results from this study show that teams' needs at specific positions, the number of unrestricted free agents available, and playoff qualifying have the most significant impacts on unrestricted free agent signings during this period of time. Like prior research, this study suggests that free agent signings can alter a team's performance in the subsequent season, but true statistical evidence is not present to quantify unrestricted free agent value, nor teams' suitability for a player.

KEYWORDS: (State Income Taxes, National Hockey League (NHL), Free Agency, Hockey)
JEL CODES: (Z2, D00, M1)

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ON MY HONOR, I HAVE NEITHER GIVEN NOR RECEIVED UNAUTHORIZED AID ON THIS THESIS

Jackson Ross

Signature

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Introduction

A common belief in professional team sports is that teams that are formed with the most skilled players should achieve the most success at the conclusion of the season. While individual statistics and player performance suggest that skillful players have a significant impact on team success, there are numerous other variables that influence a team's ability to both win and succeed financially. Building upon similar studies, the subject of this research pertains to the highest level of professional hockey in the world, the National Hockey League (NHL). The research conducted in this study analyzes the factors that affect NHL teams' abilities to sign unrestricted free agents. The data collected for this study covers six years of NHL free agency between the 2011-2012 and 2016-2017 seasons. The goal of this research is to be able to assist in the understanding of the impact that unrestricted free agents in the NHL have on their teams.

Due to a shortened lockout season in 1994-1995, the NHL and the National Hockey League Players' Association (NHLPA) instituted a Collective Bargaining Agreement (CBA) to establish the terms and conditions of employment for their players and to clarify the rights that each club possesses (NHLPA, n.d.). This agreement is important to this research because it highlights how both teams and players must operate to sign players to employment contracts. The league's CBA has been modified several times since its initial introduction, and the current CBA is expected to last through the 2025-2026 NHL season.

Following a lockout season in 2004, the NHL installed a salary cap, which represents a limit to the amount that an NHL team spends on paying their players. The spending limit for teams varies every year as league revenues fluctuate each season, but the salary cap still regularly affects player transactions and teams' operations every season.

The free agency market in the NHL is comprised of two different types of free agents, restricted and unrestricted. An unrestricted free agent (UFA) is the status that is acquainted with a player that does not have their contractual playing rights owned by any team and is therefore permitted to sign a standard player contract (SPC) with any NHL team following the completion of the prior season. A restricted free agent (RFA) is the status granted to a player that does not meet the requirements for an UFA. To clarify, a RFA is a player that is still under contract with one organization but is approaching the final year of their contract term, so their rights are still owned by that team. However, a RFA is approaching free agency in the future, so other teams in the league are allowed to pursue this player by offering them a future contract. In this case, the contract is known as an offer sheet, and the new team that signs the player must distribute compensatory draft picks to the team from which they took the player. Both UFA and RFA status are subject to several requirements that will be explained later, on a more in-depth level.

Taxation also plays a significant role in the salary structure for player contracts. A player's net earnings are "diminished by a number of factors including escrow, agent fees, and taxes" (Goldman, How Much Do NHL Players Really Make? Part 2: Taxes, 2019). Players across the league are all subject to taxation regulations depending on the country, state or province, and city in which they reside. Taxation plays a unique role in a player's net earnings depending on their country of residency and citizenship. For example, numerous American-born players play for Canadian teams and vice versa, and international tax treaties affect the outcome of a player's earnings.

When approaching this research, it is also essential to consider players' skillsets, players' experience, teams' geographic location, teams' composition, and teams' overall success. Although an elementary understanding of the NHL's salary cap, CBA, and free agent market is critical to the analysis of this research, several other variables influence an NHL team's ability to land a free agent on their team.

The organization of this research is structured as follows: Literature Review, Methodology, Results and Analysis, and Conclusion. The literature review showcases several previous studies that capture an array of factors that influence free agent signings in professional sports. The methodology section explains the approaches used in this study to capture the factors that impacted unrestricted free agent signings in the NHL between the 2011-2012 and 2016-2017 seasons. After the model is defined, the data for the study will be portrayed. Upon the depiction of the data, the results will be noted and analyzed, which will assist in the conclusion of the study. The research question for this study is:

What were the determinants of unrestricted free agent signings in the NHL between the 2011-2012 and 2016-2017 seasons?

Literature Review

The fundamental organization of professional sports in North America has evolved in the last forty years. For the four major professional sports leagues in North America: Major League Baseball (MLB), National Basketball Association (NBA), National Hockey League (NHL), and National Football League (NFL), this period has marked a transformational shift in both competitive balances in the leagues and players' power in terms of their ownership rights. Within this window of time, each league has implemented its form of a salary cap, which limits the amount a team can pay its players. The salary cap is a structure that ensures the total amount a team can spend on player salaries across an entire active player roster (Staudohar, 1998).

The progression of the salary cap era in professional sports has been a result of labor strikes, also known as lockouts in sports. Lockouts have ensued due to disagreements between leagues' ownership entities and their players over the dispersion of power and shared revenues. As a result of lockouts, each league has witnessed the installment of player unions, CBAs, salary caps, and free agent markets.

In the last decade, free agency in NHL off seasons has generated considerable interest. Alongside the effects of the salary cap, the free agent market has arguably one of the biggest impacts on teams' success the following season. With strong beliefs regarding the importance of signing high-end unrestricted free agents, several strategies have been created to analyze the effect of free agents on their respective teams. This literature review examines a variety of factors that impact free agent signings in the entirety of professional sports. To assist in the progression of this study, the literature review is split into multiple sections: Free Agency, Salary Cap/Payroll, Taxation, Player Assessment, and Team Assessment. These sections encompass appropriate literature that assists in the understanding of the research that is being analyzed in this study.

2.1 Free Agency/Salary Cap/Payroll

The National Hockey League's salary cap and free agent market coincide with respect to how teams execute their operations and player transactions. The purpose of this section is to explain the details of the salary cap and free agent market. This section also outlines how a player enters the league contractually and the requirements a player must meet to be classified as an UFA, RFA, or contracted player.

Typically, a player will enter the NHL through the NHL Entry Draft. When a player is drafted by a team, that particular team owns their playing rights and holds their rights for seven years or until they reach 25 years of age (CapFriendly, 2021). When a rookie player at this age is signed by a particular team, drafted or not, the team then signs the player to an entry-level contract that spans between one and three years depending on their age. Once a player has fulfilled their entry-level contact, they become a free agent. Several details differentiate the types of free agent a player can become, predominately age and years of experience.

2.1 (a) Free Agency

A player becomes an unrestricted free agent once their contract expires on July 1st following the conclusion of the league's season (CapFriendly, 2021). To be listed as an unrestricted free agent (UFA), a player must meet the following requirements:

1. The player is 27 years old on June 30th of the contract's expiration year.

2. The player has seven accrued seasons of experience. An accrued season is granted to a player that was on an active roster for 40 regular-season games (30 as a goaltender). A full regular-season is 82 games.
3. The player must meet the requirements for Group 6 UFA Status.
    a. The player is 25 years or more on June 30th of the contract's expiration year.
    b. The player has completed three or more professional seasons including minor league and European professional leagues.
    c. The player has played less than 80 NHL games, or 28 NHL games of at least 30 minutes for a goalie.

A player that is no longer on an entry-level contract, but does not fulfill the UFA requirements, becomes a RFA upon the expiration of their entry-level deal (CapFriendly, 2021). A restricted free agent must meet the following requirements:

1. If the player is between the age of 18-21, they must have three years of professional experience.
2. If the player is between the ages of 22-23, they must have two years of professional experience.
3. If the player is 24 years or older, they must have one year of professional experience.

2.1 (b) Salary Cap/Payroll

An understanding of how players are signed to SPCs, or entry-level contracts provides a guideline for how teams operate within the league's salary cap. The NHL salary cap was instituted in the 2005-2006 season following a leaguewide lockout in the 2004-2005 season. The purpose of the salary cap is to promote competitive parity across the league with respect to franchises' revenues and resources. Teams like the New York Rangers, who are currently valued at $1.65 billion, would likely have an advantage over teams such as the Florida Panthers, currently valued at $295 million (Forbes Media LLC. , 2021). An advantage would exist without the salary cap because the higher valued franchises would be able to operate with greater financial resources to sign the best players in the league. With a salary cap in place, all 32 teams in the league can compete on the same financial playing field, promoting balance in terms of ability to sign players and ensuring competitive gameplay.

The three components of the NHL salary cap are the salary cap ceiling, salary cap floor, and salary cap hit. The salary cap ceiling establishes the maximum amount of money a team can spend on player salaries (CapFriendly, 2021). This number changes every year depending on the NHL's generated income from previous seasons. The salary cap floor refers to the minimum amount of money that a team must spend on player salaries (CapFriendly, 2021). The salary cap floor exists to ensure that players are paid their value for a season and to prevent teams from intentionally throwing, or tanking seasons. The salary cap hit indicates the amount of salary cap space that a player's contract occupies on the roster, which is calculated by the average dollar figure of their contract (CapFriendly, 2021). All salaries are paid in United States dollars.

Several previous studies have been done to examine the effects of professional sports leagues' salary caps on competitive balance, team revenues, and determinants of players' salaries. The discrepancies that exist amongst the literature pertain to the focal point of the studies being individual players or collective teams. It is also important to note that until recently, the majority of sports economics literature steered away from NHL analysis. The research conducted in this study focuses solely on variables that affect NHL free agent signings and differs from previous literature in that it is a cumulation of both individual and team factors that are being examined to distinguish an ability to sign players.

(Grossman, 2010) conducted an econometric analysis that focused on the NHL's salary cap effect on the competitive balance of the league and the determinants of team revenue. This study intended to explain the variables that influenced both performance and revenues, and why they may have changed as a result of labor disputes in the league. Using two separate regressions with points and revenues as dependent variables, Grossman concluded that there was no statistical significance between the NHL salary cap and points earned throughout a season. The impact of the salary cap on generated revenues was higher in variation but was still not statistically significant. It is difficult to create a perfect model, especially in this study because several of the variables were controlled by individual players, and many others were controlled by the team as a unit. Because of this variation, it makes it more difficult to achieve statistical significance in the study.

Grossman's work serves as a foundation of how the salary cap in the NHL affects the structure of teams' rosters. By analyzing data prior to and following the installment of the NHL salary cap in the 2005-2006 season, Grossman was able to highlight how teams may alter their strategies for paying players. Grossman's investigation into the salary cap intersects with the research conducted in this study as it showcases how general managers of NHL teams must structure their rosters effectively with respect to the amount of money and the duration that they sign free agents for. This crossover reveals that there is a certain level of skill to operating and constructing an NHL roster, suggesting that the salary cap plays an intricate role in a team's ability to sign unrestricted free agents.

Assessing player value also plays a significant role in teams' operations within the salary cap. Tonack's paper explores the factors behind assessing NHL centers' value based on their on-ice performance. With the use of linear regression and 17 independent variables that categorize performance measures, this paper concludes that management must efficiently spend their limited salary dollars and players must receive proper financial compensation (Tonack, 2021). This model also unveils predicted salaries that can be used in comparison with actualized SPCs to establish which players are underpaid and overpaid.

Tonack's research applies to the research conducted in this study because it is indicative of the competition that exists in the NHL's free agent market. There are several variables to consider when assessing free agent value, but the overhanging challenge for teams' management is to operate effectively within the confines of the salary cap. To create a winning team, management must abide by the structure of the cap and wisely distribute their salary spending across their roster. A relationship between salary cap and player value likely exists, and this relationship is likely an integral factor in a team's ability to sign an unrestricted free agent.

Ian Young's (2015) research explores the determinants of an NHL player's salary. Young's research indicated that certain factors were more significant to a player's salary depending on their position. Using a Gini coefficient to assess the significance of winning percentage, the conclusion stated that “general managers should not place a large weight on the salary distribution of their team”, but the presence of more star players on a roster creates excitement that attracts fans; thus, “general managers should not worry about salary inequality when signing stars” (Young, 2015). Young’s conclusions suggest that salary distribution from a managerial standpoint is of minimal importance, but the analysis conducted in this research will attempt to show how the salary cap alters the nature of a team’s salary dispersion across their players. If a team needs a player in free agency to fill a certain role within a specific spending bracket, the salary cap will likely affect a team’s ability to sign unrestricted free agents that meet their needs. Thus, Young’s belief that general managers should be unbothered with salary inequalities on their roster is possibly misconstrued.

2.2 Taxation

A player’s net earnings are influenced by several variables including taxes and escrow. An understanding of the NHL salary cap, players’ cap hits, and player salaries are essential to see how a player’s net income is altered from their SPC.

Under the Collective Bargaining Agreement, the NHL and NHLPA collect payments from all players in the case of diminished revenues, which is known as escrow. Under the agreement, the league notes that a team can “withhold a certain percentage of Player’s Salary and Bonus obligations throughout each League Year and that such funds, if any shall be held in an Escrow Account” (Goldman, How Much Do NHL Players Really Make? , 2018). Escrow is collected throughout the season and then redistributed at the end of the season to ensure that revenues are dispersed evenly between players and owners. Thus, players' net earnings are subject to a changing escrow rate, a rate that is mutually agreed upon between the NHL and NHLPA.

Taxes also play a considerable role in player earnings in the NHL. With 32 teams currently in the league across the United States and Canada, there is a notable variance in tax rates that players' contracts are subject to. Between state and provincial taxes, city income taxes, and jock taxes, a player's net earnings can be noticeably diminished. A player's earnings with respect to taxes also depend on how they file their taxes, as they can file as single, married, or file separately. Based upon league contract requirements, all players are placed in the highest tax bracket regardless of their filing status.

State income taxes also play a role in player earnings. There are some states in the league that have a flat tax rate, some that have a variable tax rate, and some that do not collect income taxes. The Dallas Stars, Florida Panthers, Tampa Bay Lightning, Vegas Golden Knights, Nashville Predators, and Seattle Kraken all play in states that do not levy state income taxes. In addition to state income taxes, some cities issue income, or residential taxes, that affect the teams located in New York City, Philadelphia, Pittsburgh, Detroit, and Columbus.

Federal and provincial taxes in Canada operate similarly to those in the United States in that a player's income is taxed in tiers. A challenge in taxation arises in the case that an NHL player registers as a resident in one country but is liable to pay taxes in the country in which they play hockey. Instead of being taxed twice, a player in this scenario receives tax relief via a tax treaty that exists between the United States and Canada that designates where residential income tax is owed. In short form, the treaty notes that "as long as an athlete of a Canadian franchise is not in the United States (and vice versa) for more than 183 days in a 12-month period, they receive tax relief from the Canada-US income tax treaty and aren't double taxed – although they still may face jock taxes for those away games" (Goldman, How Much Do NHL Players Really Make? Part 2: Taxes, 2019). Not every state chooses to abide by the federal tax treaty, so some players are still subject to double taxation depending on their residency. It should also be noted that there is a diverse range of nationalities and countries of residency that exist in the NHL, in addition to American and Canadian players.

Jock taxes pertain to fees that are issued to players that are designated as visiting workers. A jock tax forces an NHL player to pay taxes in the numerous states that they play in throughout a season. John DiMascio dives into the formalities of the jock tax in his paper, *The "Jock Tax": Fair Play or Unsportsmanlike Conduct*. This paper discusses the details of the jock tax and how it affects professional athletes. DiMascio concludes that the tax itself "may not be a problem for those at the top of the pay scale, it is certainly felt by lower paid athletes" (DiMascio, 2006). This analysis may not pertain to the entirety of the research conducted in this study, but a jock tax is still applicable. It is possible that a lower-end, but desirable, unrestricted free agent would want to sign a contract and reside in a country, state or province, and city in which they would face fewer taxes. UFAs that are not high grossing players for a team are still subject to jock taxes, therefore, it is probable that playing for a team in a more tax-friendly environment would be more suitable for that player.

Amy Otte (2015) explores income tax against Major League Baseball free agent signings in her paper, *State Income Tax Effects on MLB Free Agent Contract Negotiations in the Areas of Salaries and Bonuses*. As hypothesized, Otte's research reveals that “as state income tax increases, a player’s average salary over the contract increases” (Otte, 2015). Otte’s work also suggests that teams located in places with higher income tax rates are at a competitive disadvantage when offering contracts to free agents versus teams that are located in states with no or low-income tax rates. The nature of Otte’s study is similar to the one conducted in this paper, but the two explore different professional sports leagues that have contrasting rules within the confines of their salary cap. Due to these differences, there are various factors that influence unrestricted free agent signings that are specific to each sport. In this research, it is predicted that there are other factors besides state income tax that have considerable impacts on an NHL teams’ ability to sign UFAs.

State income taxes also have implications on teams’ chances of winning, which is examined in Erik Hembre’s (2018) research, *State Income Taxes and Team Performance: Do Teams Bear the Burden?*. Hembre’s study investigates the effect of “income tax rates on professional team performance between 1977 and 2016 using data from professional baseball, basketball, football, and hockey in the United States” (Hembre, 2018). A regression is used for tax rates on winning percentages to assess the significance of the question. Hembre concludes that after the mid-1990s, income taxes started to have more implications on the competitive balance that exists in professional sports. It is noted that this effect is concentrated in the NHL where player contracts and spending are more limited than leagues like the MLB. “Both player salaries and player mobility have risen over the past twenty years, income taxes now factor into team performance” (Hembre, 2018). Hembre’s approach assists this study as NHL teams’ ability to win games and championships is often influenced by the composition of their roster, which derives from their ability to sign unrestricted free agents that are suitable to their cap needs and desired team characteristics.

2.3 Player Assessment

Assessing the value of an NHL player requires a blend of quantitative and qualitative analysis. A challenge in assessing player value is that a projected result is not always an ensured outcome in the game of hockey. There are various statistics including point production, average time on ice, and age that provide quantitative indications of expected results for an NHL player. These statistics are objective, but a player's assessment is also often open to subjective interpretation. This means that those conducting evaluations at the NHL level, often scouts and management teams, look beyond just a player's gameplay statistics. Factors such as coachability, leadership, and teamwork all influence the evaluation of a player and are important to a team's success. However, this section will focus on the quantitative statistics that are critical to the value of an NHL unrestricted free agent.

B. Tarter, Kirisci, R. Tarter, Jamnik, Gledhill, and McGuire (2009) use a sports performance index to predict NHL player value. Their research focuses on top NHL prospects that are approaching the NHL Entry Draft. Using an expert level report known as the Central Scouting System (CSS) and cross-referencing it with position-specific variables, it was concluded that "quantitative methods are useful tools which can assist expert decision makers to select the best prospects in the NHL Entry Draft" (Barry Tarter, 2017). The authors also note that quantitative analysis is critical to assessing player value at the NHL value, but it does not supersede expert opinions, such as scouts and general managers. The research conducted in this study is revealing because it is indicative of the subjective and objective overlap that exists in valuing a hockey player. The research in this paper focuses on position-specific contractual data in order to clarify teams' needs when examining unrestricted free agents. However, it is important to note that a decision made by a player to sign, and the decision made by a team to sign a player does not only stem from quantitative information.

(McGinnis, 2013) explored the return on investments of NHL players and how such a return on investment compares to the value of a player. To measure success, McGinnis collected statistics like games played, average time on ice, number of shifts, and total points. Because there are different positions on the ice, McGinnis looked at position-specific statistics. For forwards and defensemen, points, average time on ice, shift length, and games played were measured for their worth in dollar amount. With this information, it was discovered how much a player was able to produce each season. Each player's dollar amount was averaged to find the value for that specific player. Goalie values were measured on the worth of wins, losses, and saves for a year. This exploration into a player's value is immensely applicable to the future of hockey operations at the NHL level. Like the study by McGinnis, the work conducted in this research paper will also analyze position-specific needs to identify the objectivity that exists in the valuation of an NHL unrestricted free agent. With an understanding of player values, both players and franchises can use such information to exploit their worth and increase profitability.

2.4 Team Assessment

Free agency in the NHL is a competitive two-way street, particularly when it comes to signing UFAs. On one hand, a team takes several precautionary steps to evaluate a player's skill and value to a team to determine if they are worthy of adding to their roster. On the other hand, an unrestricted free agent uses their title and power to their advantage by creating bidding wars for their player services to ensure that they are being compensated properly for their value. This section will explore some of the factors that an unrestricted free agent may consider when assessing the strength and worth of a suitable team for their playing future.

Chan, Cho, and Novati (2012) focused their research on quantifying the contribution of NHL player types to team performance. To grasp the diversity of player types that exist in the NHL, these authors classified players into distinct categories for strategic analysis and noted that "variability within the clusters suggests that additional insight might be gained by isolating and quantifying the value of individual players" (Timothy C. Y. Chan, 2012). The research conducted in this paper is similar to the work of Chan, Cho, and Novati with respect to assessing an NHL player's value. However, this study differs from the previous literature in that it does not focus solely on player position statistics. Rather, the work conducted in this study uses players' positions to assess the roster spaces that a team may or may not need to fill.

Kahane and Shmanske (2010) conducted a study that focused on roster turnovers and attendance in Major League Baseball (MLB). Their work explored the idea that loyal fan bases preferred to have the composition of their team remain relatively the same every year. In their research, these authors set controls for price, income, population, and numerous other variables. The results of their regression model concluded that "for each percentage point increase in the turnover of the composition of the team, attendance will fall by about 0.7%". The research conducted in this study explores a similar question regarding the importance of attendance in professional sports. However, unlike Kahane and Shmanske, this research approaches average home attendance in the NHL as a factor that incentivizes unrestricted free agent signings. This study uses average home attendance as a quantitative proxy for the market size and appeal of an NHL franchise to an available player.

The literature review that has been conducted for this research amasses a variety of studies across several fields to demonstrate the intricacies of the NHL free agent market. Free agency has been a notable topic in the NHL for the past decade, and previous studies suggest that free agent signings in the league are a combination of team-based and player-based factors. Exploration into free agent markets and salary caps in professional sports is not new to the public, however, there is minimal literature that focuses on the behavior of the two in professional hockey. The NHL specifically offers opportunities to explore the impact that free agent signings have on team success and franchise revenues. This study will add to the increasingly popular research into the free agent markets of the NHL and aims to explain how unrestricted free agent signings in the league are a result of a combination of individual and team statistics. The goal of the research is to provide an answer to the question: What were the determinants of unrestricted free agent signings in the NHL between the 2011-2012 and 2016-2017 seasons? With an answer to this question, there will be further evidence to support the theory that free agent signings play a major role in team success in terms of wins and financial health.

Methodology

The objective of the analysis conducted in this study is to highlight the underlying factors that are intertwined in the process of NHL teams' attempts to sign unrestricted free agents (UFAs). The timeframe of this study spans between the 2011-2012 season through the 2016-2017 season. These seasons were selected for the study because they occurred in the last decade, which is reflective of the modern interest in the NHL free agent market among the developing realm of sports data analytics.

Free agency in the NHL is a captivating market as it is indicative of the competitiveness that fuels the league. Assessing player value in unrestricted free agents is a complicated task, thus, operations for an NHL club must consider numerous factors when approaching a free agent player. Prior research has revealed that "team attributes have both direct effects on individual player compensation and indirect effects through altering the rates at which individual player productive characteristics are valued" (Kahane, 2000). The motivation behind this research is to determine if there are certain factors that either inhibit or promote an NHL team's ability to sign unrestricted free agents.

As the previous research indicates, determining appropriate values for both player and team characteristics can be challenging and subjective, thus, it is unlikely that one factor is increasingly significant in comparison to the others. The methodological framework for this study stems from the use of probability-based models, known as probit and logit. These models are most suitable to the data because they are indicative of the odds ratio, or probability, that a certain variable influences a team's ability to sign an UFA, or a team's ability to sign five or more UFAs. This study uses logit and probit models because the standard Ordinary Least Squares (OLS) regression model is flawed in terms of the question being asked. An OLS model assumes that the conditional probability function is linear. The research question being asked consists of binary dependent variable(s) that are observed as values of 0 and 1, hence the usage of the logit and probit models.

Before collecting the final results for this analysis, the models were tested for econometric errors, which revealed that several of the variables were contaminated with multicollinearity. To combat multicollinearity, an Ordinary Least Squares (OLS) regression was run to reveal which predictors were highly linearly related. From there, variables were manually removed from the model if their correlation coefficient was greater than a value of 0.7. Once the issue of multicollinearity was resolved, a robustness test was run alongside the OLS regression to ensure that the updated model would perform without any errors in the results. The OLS regression does provide consistent unbiased estimates of the marginal probability effects within the model, but the model does not include any limitations on the predictions of the dependent variable, *signplyr*; thus, nothing is forcing the predictions to exist between the values of one and zero. The OLS regression results, summary statistics, and pairwise correlations from this model can be found in Appendix A, Appendix B, and Appendix C.

Since the research question and hypotheses being examined in the study require parameters on the dependent variable, it is necessary to use a nonlinear model that forces the tested outcomes to lie between one and zero. The probit model calls for the usage of the maximum likelihood estimator, which enables the dependent variable to exist within the necessary parameters. This ensures that the model is maximizing the joint probability of observing the values that were chosen.

When using a probit or logit model, the initial model is run, and then the marginal effects command is used to enable diminishing returns in a non-linear relationship. Following these steps, a command is used to display the classification tables for the models, which indicates the success of the model and the observed percentage of correctly predicted outcomes. Sensitivity percentages indicate the number of correctly predicted one values classified by the model. Specificity percentages indicate the number of correctly predicted zeros classified by the model. A perfect model would have a combined total percentage of 200% for its classification table results. The probit model accounts for the thirty NHL teams and six seasons (2011-2012 to 2016-17) collectively. The results that are drawn from the model are indicative of the factors that had the greatest probability of altering unrestricted free agent signings in the league across the six years.

3.1 Model

The models are listed below:

Logit: $P\,(Y = 1|X) = G(X\beta) = [(e^{X\beta})/\,(1 + e^{X\beta})$

Probit: $P\,(Y = 1|X) = G(X\beta) = \int(2\pi)^{-.5}\,exp(-X\beta^2/2)$

Fitted Values for Logit and Probit:

$\lim_{X\beta \to \infty} G(X\beta) = 1$

$\lim_{X\beta \to \infty} G(X\beta) = 0$

3.2 Variables

- *signplyr* is a dummy variable that indicates whether a team signed an UFA during the free agency window of that year. Data for this variable is collected from spotrac.com.
- *signplyr5ormore* is a dummy variable that indicates whether a team signed five or more UFAs during the free agency window of that year. Data for this variable is collected from spotrac.com.
- *tmcapspace* refers to the remaining space in salary cap dollars that a team has to work with for a season. Cap space is relevant to this study because it is indicative of a team's financial standing with respect to the salary cap. Thus, it implies whether a team has enough space and money to sign an unrestricted free agent. Cap space data is collected from spotrac.com.
- *teamfwdcap* represents the total salary cap hit that a team's forwards are occupying on the team's overall cap hit. The summation of the forward's cap hit for a team is relevant to the data because it is suggestive of whether a team may or may not attempt to sign an unrestricted free agent forward during the free agency window. Data on teams' forward cap hits is collected from spotrac.com.
- *teamdefcap* represents the total salary cap hit that a team's defensemen are occupying on the team's overall cap hit. The summation of the defensemen's cap hit for a team is relevant to the data because it is suggestive of whether a team may or may not attempt to sign an unrestricted free agent defenseman during the free agency window. Data on teams' defensemen cap hits is collected from spotrac.com.

- *fwddummy* is a variable that has been created to signify a team's needs at the forward position. The binary variable was created by collecting a team's forward cap hit for a particular season and comparing it to the leaguewide average cap spent on forwards for the same season. If a team spent less than the leaguewide average at forward, they were granted a value of 1, implying that they may inquire about signing an UFA forward during the free agency window. If a team spent more than the leaguewide average at forward, they were assessed a value of 0, implying that they would unlikely attempt to sign an UFA forward during the free agency window.
- *defdummy* is a variable that has been created to signify a team's needs at the defenseman position. The binary variable was created by collecting a team's defensemen cap hit for a particular season and comparing it to the leaguewide average cap spent on defensemen for the same season. If a team spent less than the leaguewide average at defensemen, they were granted a value of 1, implying that they may inquire about signing an UFA defenseman during the free agency window. If a team spent more than the leaguewide average at defense, they were given a value of 0, implying that they would unlikely attempt to sign an UFA defenseman during the free agency window.
- *fwdsonfullros* indicates the number of players that a team has at the forward position for a particular season. This variable is also used to indicate whether a team may need to acquire more forwards for the upcoming season. Data for this variable is obtained from spotrac.com.

- *defonfullros* indicates the number of players that a team has at the defense position for a particular season. This variable is also used to indicate whether a team may need to acquire more defensemen for the upcoming season. Data for this variable is obtained from spotrac.com.
- *winpct* is a calculated rate that indicates a team's number of wins against the 82 games played in a regular-season. A team's winning percentage is relevant to the study because it is reflective of a team's success and therefore, a team's appeal to a free agent. The data used to calculate teams' winning percentages across the six seasons was collected from nhl.com.
- *tmptspct* is an indicator of the number of points a team is rewarded in the standings divided by the number of maximum points possible. This variable differs from winning percentage in that a team can still obtain a single point in the regular-season standings for an overtime or shootout loss, whereas a team is assessed two points for a win. This statistic is reflective of a team's success and appeal. Points percentages are collected from hockey-reference.com.
- *tmstinctx* represents the state or provincial income tax rate for a single filer in the state or province in which the NHL team is located. State or provincial tax rates may or may not factor into an unrestricted free agent's decision to sign with a particular team. Information on tax rates is collected from taxtips.ca and taxfoundation.org.
- *plyofftm* is a dummy variable that indicates whether a particular team made the playoffs in the previous season. This is indicated by either a 1(YES) or 0(NO). A team's ability to make the playoffs may or may not persuade an unrestricted free

agent to sign with their organization. Information on this variable can be found at nhl.com.

- *avghomeatt* is a variable that represents the average home attendance for a team in a particular season. Average home attendance is relevant to the study because it represents a franchise's market appeal to a free agent. Data on this variable is obtained from espn.com.
- *champrate* is a variable that was calculated to display the rate at which each team has been winning Stanley Cup championships since the establishment of their franchise. Championship rate is relevant to the material because it captures the overall championship success of a team, and thus implies an appeal to free agents who want to play for winning teams. The data used to calculate this variable was obtained from the NHL archives at nhl.com.
- *totalfa* is an explanatory variable that is used in the nonlinear binomial regression. This variable represents the total number of unrestricted free agent defensemen and forwards available across the study period.
- *numfasgn* is the dependent variable used in the nonlinear binomial regression. This variable denotes the total number of unrestricted free agent signings that occurred over the studied period.

3.3 Limitations and Hypotheses

Limitations

The models used in this study are subject to limitations and it is unlikely that a perfect model exists for the questions being analyzed in this research. One limitation that exists is that tax rates between American states and Canadian provinces differ in their structure and the tax variable in the model contains a vast majority of American-based teams. The models are also unable to account for subjective factors such as coachability, teamwork, and leadership, which can be integral factors in assessing a player's worth to a team. The models also attempt to account for team-based and player-based variables together to assess the predicted probability of signing UFAs. This leads to less specific, or broader parameters, and affects the models' strength and variables' significance.

Hypotheses

Upon collection of the data and prior to any statistical testing, several hypotheses were constructed with regard to the models. Extensive background and familiarity with the sport of hockey should also be noted for influencing such hypotheses.

Hypothesis 1

A team's cap hit can vary annually depending on roster space and needs. Maneuvering cap space while fielding a competitive team involves high levels of creativity and knowledge at the managerial level in the NHL. Thus, it is predicted that *tmcapspace* will be statistically significant and have a positive effect relative to teams' ability to sign unrestricted free agents.

Hypothesis 2

A team's needs at a certain position plays an important role at the managerial level when constructing a team's roster. Forwards and defensemen each play unique roles within a team and occupy different percentages of a team's roster. With this knowledge, it is presumed that teams weigh the value of forward and defensemen positions and contracts independently. With fewer defensemen than forwards on an NHL roster, it is possible that general managers need to place more weight on defensemen's contracts.

Thus, it is predicted that spending at the defense position (indicated by *tmdefcap* and *defdummy*) will have a statistically significant and positive effect on unrestricted free agent signings.

Hypothesis 3

Income taxes are believed to play a significant role in free agent signings in the NHL because it is a generalized belief that players enjoy playing in locations that will not significantly alter their contract value as a result of local income taxes. It is predicted that state and provincial income taxes will have a positive effect on signing unrestricted free agents.

Hypothesis 4

A team’s points percentage from the previous season is associated with their number of wins and is suggestive of their regular season success and appeal to free agents. However, the composition of a team on a yearly basis can alter, thus, there are no guarantees of wins based upon the assessment of a team on paper. It is predicted that both the win percentage and points obtained percentage variables will not have a positive effect on unrestricted free agent signings.

Hypothesis 5

It is likely that a team’s ability to make the playoffs and pursue a Stanley Cup (awarded to the postseason winner in the NHL) influences a player’s decision to sign with a certain team. It is predicted that the playoff indicator variable will increase the probability of signing unrestricted free agents.

Results and Analysis

This section consists of the results from the models used to analyze the factors that influence unrestricted free agent signings in the NHL on a seasonal basis between 2011 and 2017. These models are also used to analyze the testable hypotheses listed in the methodology section.

It should be noted that the initial models that were used for the research question were adjusted several times in order to produce results that are statistically significant. To construct models that would produce statistically strong results, five different approaches were taken. The first four approaches use probit and logistic models to convey the results. The last approach uses a negative binomial regression (*nbreg*). The negative binomial regression is used because the response variable, (*numfasgn*), is a count variable that has the same length of observation time. This model assumes that the dependent variable is "over-dispersed and does not have an excessive number of zeros" (Bruin, 2006).

Approach 1

The first approach used a blend of all explanatory variables. This approach used quantity-based and priced-based variables alongside state income taxes, playoff presence, average home attendance, and championship rates against teams' abilities to sign unrestricted free agents. For this model, *avg$onfwdpsz* and *avg$ondefpz* were also added to see if the average contractual spending on forwards and defensemen per season played a role in unrestricted free agent signings. This model was initially run with *signplyr* as the dependent variable; however, the model was not statistically significant, nor strong.

This probit model was then altered to see the effects of the same explanatory variables against the probability of signing five or more unrestricted free agents, which is indicated by *signplyr5orm*. Average spending on defensemen, playoff qualifying, and average home attendance all proved to be statistically significant in this model.

TABLE 1: Approach 1 Marginal Effects

Variables	dy/dx	Delta-method Std. Err.	z	P>z	[95% conf.	Interval]
tmcapspace	0.000	0.000	0.250	0.801	-0.000	0.000
tmfwdcap	0.000	0.000	0.870	0.386	-0.000	0.000
tmdefcap	0.000	0.000	0.500	0.618	-0.000	0.000
avg$fwdpsz	0.000	0.000	0.980	0.328	-0.000	0.000
avg$defpsz	-0.000	0.000	-1.930	0.054	-0.000	0.000
fwddummy	-0.043	0.120	-0.360	0.721	-0.278	0.193
defdummy	-0.006	0.114	-0.050	0.958	-0.229	0.217
fwdsonfullros	-0.026	0.019	-1.400	0.162	-0.063	0.011
defonfullros	-0.039	0.027	-1.440	0.150	-0.092	0.014
tmptspct	-0.007	0.007	-1.040	0.300	-0.020	0.006
tmstinctx	-0.001	0.007	-0.200	0.842	-0.014	0.012
plyofftm	0.197	0.119	1.660	0.097	-0.036	0.430
avghomeatt	-0.000	0.000	-2.870	0.004	-0.000	-0.000
champrate	0.099	0.612	0.160	0.871	-1.100	1.298

Observations = 180

Average spending on defensemen was statistically significant at the 10% level with a z-score of -1.93 and a near zero marginal effects coefficient. These results suggest that average spending on defensemen had a minimal effect on signing five or more UFAs. Playoff qualifying was statistically significant at the 10% level with a z-score of 1.66 and a margins coefficient of 0.20, indicating that a one unit increase in qualifying for the playoffs increased the predicted probability of signing five or more unrestricted free agents by 20%. This result is unsurprising because the relationship between signing unrestricted free agents and teams' abilities to field a championship contending roster abides by basic intuition in hockey. Players likely prefer to sign and play for a team that has a chance of winning the Stanley Cup. Average home attendance was statistically significant at the 1% level with a z-score of -2.87 and a near zero margins coefficient, indicating that a one unit increase in average home attendance leads to minor decrease in the predicted probability of signing five or more UFAs.

The classification table associated with this model, found in Appendix D, indicates that its sensitivity was 56.47% and specificity was 68.42%, signifying that this model could have been more successful with its predictions. The results from this model are not overly insightful or surprising as it was hypothesized that playoff qualifications would have a positive effect on unrestricted free agent signings, which is the key takeaway from this model.

Approach 2

The second approach used player quantity-based explanatory variables alongside team points percentages, state income taxes, playoff qualifying, average home attendance, championship rates, and position specific dummy variables against the dependent variable. Once again *signplyr* was initially tested against these variables but proved to be insignificant and proved to have issues with collinearity, so *signplyr5orm* was used instead.

TABLE 2: Approach 2 Marginal Effects

Variables	dy/dx	Delta-method Std. Err.	z	P>z	[95% conf.	Interval]
fwddummy	-0.119	0.069	-1.710	0.086	-0.254	0.017
defdummy	-0.010	0.073	-0.140	0.887	-0.153	0.132
ufafwdsaval	0.008	0.002	3.470	0.001	0.004	0.013
ufadefaval	-0.004	0.003	-1.290	0.197	-0.011	0.002
fwdsonfullros	0.015	0.020	0.750	0.455	-0.024	0.053
defonfullros	-0.021	0.027	-0.800	0.421	-0.074	0.031
tmptspct	-0.004	0.006	-0.620	0.534	-0.016	0.008
tmstinctx	-0.001	0.006	-0.230	0.817	-0.014	0.011
plyofftm	0.117	0.111	1.050	0.291	-0.100	0.334
avghomeatt	-0.000	0.000	-2.800	0.005	-0.000	-0.000
champrate	0.066	0.552	0.120	0.904	-1.016	1.149

Observations = 180

The position specific forward dummy variable was statistically significant at the 10% level with a z-score of -1.71 and a margins coefficient of -0.12, revealing that a one unit increase in position specific needs for a forward player leads to 12% decrease in the predicted probability of signing five or more UFAs. The number of unrestricted free agent forwards available was statistically significant at the 1% level with a z-score of 3.47 and a margins coefficient of 0.01, indicating that a one unit increase in the number of unrestricted free agent forwards available increased the predicted probability of signing five or more unrestricted free agents by 1%. Average home attendance remained statistically significant, as it was seen in the first model.

The classification table associated with this model, found in Appendix E, indicates that its sensitivity was 74.12% and specificity was 66.32%, signifying that only 70.00% of the model was correctly classified. The results from this model reveal that the number of unrestricted free agent forwards available in the free agent market has a positive effect on signing five or more UFAs. Surprisingly, the number of defensemen available did not have the same effect, perhaps this is because there is a greater number of forwards available in the market and on teams' rosters.

Approach 3

The next approach used price-based explanatory variables against the same dependent variable. The marginal effects from this model revealed statistical significance in average spending on UFA defensemen and average home attendance. As seen in the previous models, average home attendance had statistical significance, but did not have a considerable impact on the predicted probability of signing five or more UFAs. Average spending on defensemen per season was again statistically significant, but like average home attendance, it had a near zero effect on predicted probabilities of signing UFAs.

TABLE 3: Approach 3 Marginal Effects

		Delta-method				
Variables	**dy/dx**	**Std. Err.**	**z**	**P>z**	**[95% conf.**	**Interval]**
teamcappct	0.370	0.568	0.650	0.515	-0.744	1.484
tmfwdcap	0.000	0.000	0.920	0.360	-0.000	0.000
tmdefcap	0.000	0.000	0.270	0.783	-0.000	0.000
avg$fwdpsz	0.000	0.000	1.360	0.175	-0.000	0.000
avg$defpsz	-0.000	0.000	-3.090	0.002	-0.000	-0.000
fwddummy	-0.060	0.123	-0.490	0.625	-0.301	0.181
defdummy	-0.021	0.116	-0.180	0.854	-0.250	0.207
tmptspct	-0.007	0.007	-1.090	0.276	-0.021	0.006
tmstinctx	-0.002	0.007	-0.220	0.824	-0.015	0.012
plyofftm	0.142	0.118	1.200	0.230	-0.090	0.373
avghomeatt	-0.000	0.000	-2.470	0.013	-0.000	-0.000
champrate	0.125	0.624	0.200	0.842	-1.098	1.348

Observations = 180

The classification tables for this model, found in Appendix F, did not possess high levels of statistical success because only 64.44% of the predicted variable was correctly classified. However, this model was relevant to the study because it emphasizes that price-based explanatory variables may not possess as much influence on unrestricted free agent signings in the NHL as the previous literature and common knowledge suggest.

Approach 4

A logistic model was then used to test similar variables as the previous models did so but examined the predicted probabilities effects on *signplyr*. This model reveals that the number of forwards on a full roster, playoff qualifying, and teams' win percentages were statistically significant. The previous models have already explained the importance of playoff qualifying to a teams' abilities to sign UFAs. The intrigue of this model lies in the statistical significance of win percentages and the number of forwards on full rosters.

TABLE 4: Approach 4 Logistic Odds Ratio Marginal Effects

		Delta-method				
Variables	**dy/dx**	**Std. Err.**	**z.**	**P>z**	**[95% conf.**	**Interval]**
teamcappct	-0.312	0.403	-0.770	0.439	-1.102	0.479
tmfwdcap	-0.000	0.000	-1.280	0.201	-0.000	0.000
tmdefcap	-0.000	0.000	-0.790	0.431	-0.000	0.000
fwddummy	-0.055	0.062	-0.880	0.378	-0.176	0.067
defdummy	-0.069	0.058	-1.190	0.232	-0.183	0.044
fwdsonfullros	-0.051	0.009	-5.850	0.000	-0.068	-0.034
defonfullros	-0.006	0.011	-0.580	0.565	-0.028	0.015
winpct	-0.787	0.276	-2.850	0.004	-1.328	-0.246
tmstinctx	0.002	0.004	0.610	0.543	-0.005	0.009
plyofftm	0.203	0.054	3.780	0.000	0.098	0.308
avghomeatt	0.000	0.000	0.010	0.994	-0.000	0.000
champrate	-0.290	0.286	-1.010	0.311	-0.851	0.271

Observations = 180

Winpct was statistically significant at the 1% level with a z-score of -2.85 and a marginal effect coefficient of -0.79. This result means that a one unit increase in teams' win percentages leads to a 79% decrease in the predicted probability of signing an unrestricted free agent. *Fwdsonfullros* was statistically significant at the 1% level with a z-score of -5.85 and a marginal effect coefficient of -0.05. This result indicates that a one unit increase in the number of forwards on a full roster leads to a 5% decrease in the predicted probability of signing a UFA. The win percentage results show that the *Hypothesis 4* was accepted. This confirmed hypothesis is relevant to the study because it suggests that a team that wins more in the previous season will have a lower likelihood of signing a UFA than a team that wins less in the previous season. This result likely stems from the concept that a team that wins more games in a prior season is unlikely to be exploring the possibility of signing new players to their already successful team. The results for *fwdsonfullros* make sense within the context of the study because if a team has a higher number of forwards occupying roster spaces it is unlikely that they would need to sign additional players.

The appeal of this model lies in its statistical success, which can be viewed in Appendix G. The model's sensitivity was 98.77% and its specificity was 55.56%, and the total number of correctly classified predicted dependent variables was 94.44%. Of all the tested models, this model had the greatest statistical success by approximately 20% in comparison with the previous models. Although the model was not perfect, its success is the best indicator of the accuracy of the questions being asked in the study.

Approach 5

The final approach was conducted with the use of a negative binomial regression, which accounts for the log of the expected count as a function of the predictor variables. The initial negative binomial regressions were run, and then the models' average marginal effects were computed.

The first negative binomial regression used *numfasgn* against each of the examined seasons, each of the examined teams, *tmfwdcap*, *tmdefcap*, and *tmstinctx*. The average marginal effects are displayed in Table 5. Continuous variables use the sample averages for each continuous variable. Dummy variable marginal effects at their sample means are computed by calculating the difference in the probabilities evaluated at (dummy variables = 1 minus the probability when dummy variables = 0). This regression provides results for the variation that exists across the different teams and seasons, which is something that could not be evaluated under the probit models and therefore is indicative of these models' relevance to the study.

Table 5: Approach 5 Negative Binomial Regression Results (All Seasons)

		Delta-method				
Variables	**dy/dx**	**Std. Err.**	**z**	**P>z**	**[95% conf.**	**Interval]**
1.d1213	30.644	8.854	3.460	0.001	13.291	47.997
1.d1314	30.323	9.017	3.360	0.001	12.651	47.995
1.d1415	33.318	9.657	3.450	0.001	14.389	52.246
1.d1516	33.036	9.640	3.430	0.001	14.142	51.931
1.d1617	34.914	10.036	3.480	0.001	15.244	54.583
1.darizona	2.368	2.382	0.990	0.320	-2.300	7.037
1.dboston	-1.560	1.070	-1.460	0.145	-3.656	0.537
1.dbuffalo	-1.514	0.787	-1.920	0.054	-3.056	0.028
1.dcalgary	-1.920	0.809	-2.370	0.018	-3.506	-0.334
1.dcarolina	0.433	1.562	0.280	0.782	-2.629	3.495
1.dchicago	-1.769	1.048	-1.690	0.091	-3.823	0.284
1.dcolorado	-0.023	1.705	-0.010	0.989	-3.364	3.318
1.dcolumbus	-2.379	0.954	-2.490	0.013	-4.249	-0.508
1.ddallas	-0.312	2.017	-0.150	0.877	-4.265	3.641
1.ddetroit	-0.915	1.292	-0.710	0.479	-3.447	1.617
1.dedmonton	-1.377	0.852	-1.620	0.106	-3.047	0.292
1.dflorida	1.827	3.230	0.570	0.572	-4.504	8.157
1.dlosangeles	-2.527	0.531	-4.750	0.000	-3.568	-1.485
1.dminnesota	-0.824	0.963	-0.860	0.392	-2.711	1.063
1.dmontreal	-2.695	0.899	-3.000	0.003	-4.456	-0.933
1.dnashville	-0.693	1.352	-0.510	0.608	-3.344	1.958
1.dnewjersey	2.339	1.549	1.510	0.131	-0.697	5.375
1.dynyislanders	0.021	1.107	0.020	0.985	-2.148	2.190
1.dnyrangers	0.167	1.245	0.130	0.893	-2.273	2.608
1.dottawa	-2.024	0.513	-3.950	0.000	-3.029	-1.019
1.dphiladelphia	-0.422	1.691	-0.250	0.803	-3.736	2.892
1.dpittsburgh	1.504	2.259	0.670	0.506	-2.923	5.931
1.dsanjose	-1.935	0.665	-2.910	0.004	-3.238	-0.632
1.dstlouis	1.335	1.755	0.760	0.447	-2.104	4.774
1.dtampabay	-1.254	1.766	-0.710	0.478	-4.715	2.207
1.dtoronto	-0.113	1.020	-0.110	0.912	-2.112	1.887
1.dvancouver	-1.498	0.645	-2.320	0.020	-2.761	-0.235
1.dwashington	-0.289	1.097	-0.260	0.792	-2.438	1.861
1.dwinnipeg	-1.785	0.760	-2.350	0.019	-3.275	-0.296
tmfwdcap	0.000	0.000	1.520	0.128	-0.000	0.000
tmdefcap	0.000	0.000	1.990	0.047	0.000	0.000
tmstinctx	0.104	0.147	0.710	0.480	-0.185	0.393

Observations = 180

Note: dy/dx for factor levels is the discrete change from the base level.

Eleven of the team dummy variables were statistically significant and each of the five seasons were also statistically significant. The dummy variable for the Anaheim Ducks and the dummy variable for the 2011-2012 season are not shown in the models because they serve as reference variables. The statistically significant teams' and seasons' marginal effects coefficients indicate how unrestricted free agency signings are dispersed over time. These results suggest that there are factors that are unique to the composition of each teams' roster across the six seasons that in turn effect the probability of signing an UFA for a particular season. Leaguewide preferences and behaviors with regard to signing UFAs is thus inconsistent across the six-season period of time. The results allude to the dynamic nature of the NHL free agent market and its competitiveness. The market is never the same as the prior year, and team's desires to sign players also vary annually.

Tmdefcap was statistically significant at the 5% level with a z-score of 1.99 and a near zero marginal effects coefficient. This indicates that the average predicted count of the number of unrestricted free agent signings is about zero when holding *tmdefcap* at its mean and all other explanatory variables constant, across the five included seasons. Despite its statistical significance, this result implies that a one unit increase in *tmdefcap* is predicted to have a near zero effect on the number of unrestricted free agent signings, holding the other variables constant.

For the next part of this process, ten more negative binomial regressions were run to examine results that are specific to the individual seasons included in the study. For each season, two different models were used. The first model was the same as the model depicted in Table 5, but it did not include all five dummy season variables, rather it only included the one season being examined. The second model used the same variables as the first and *totalfa* was added.

Appendix H and Appendix I provide the results for the marginal effects on the negative binomial regression for the 2012-2013 season. In both models, every season except for the 2013-2014 season was statistically significant and indicated a positive effect on the predicted count of the number of unrestricted free agent signings, holding the other variables constant. Despite the lack of significance for one season, these results emphasize the evolving nature of the free agent market. Each free agency window is comprised of a different number of players, and different team objectives; thus, the data highlights how UFA signings experience variance annually.

A common theme in these models was that over the five years, Los Angeles, Montreal, Ottawa, San Jose, Vancouver, and Winnipeg all consistently showed statistical significance. However, their marginal effects produced negative results, resulting in these teams having a negative effect on the predicted probability on the number of unrestricted free agents signed for that specific season. With no degree of certainty, these results could be indicative of issues that these teams were experiencing under their individual cap space, position-specific cap space, or even the local income tax of the state or province in which they play. It is possible that these teams were struggling to sign unrestricted free agents for these reasons.

The results from the model that included the *totalfa* variable were the least surprising as the total number of unrestricted free agents available proved to be statistically significant and have a positive impact on the number of unrestricted free agent signings. Appendix I reveals that a season with a one unit increase in total unrestricted free agents available is predicted to have 0.03 more unrestricted free agent signings. When the number of available players increased, the likelihood of more players signing increased.

Conclusion

In the modern NHL, competitive balance in the league is likely a result of the league's salary cap and free agent market. A widely accepted concept regarding the strength of NHL rosters revolves around the belief that signing the correct free agents, based on teams' roster needs and financial boundaries, will provide a competitive advantage in the long run. Despite a wide variety of studies that focus on free agency, salary caps, and competitive balance in professional sports, several lack statistical support of the factors that alter the free agency market in the NHL. The goal of this paper was to answer the question: *What were the factors that affected unrestricted free agent signings in the NHL between the 2011-2012 and 2016-2017 seasons?*

The study conducted in this paper contributes to modern sport econometric analysis. The results collected from the models aim to provide a steppingstone for monitoring movement in the NHL's free agency market. The models also contribute probability-centered assessments of the NHL's free agent market, an approach that has not been widely used in a field that favors linear based assessments. The results from the models indicate that unrestricted free agency signings in the NHL, and the variation depicted across the six seasons, stem from teams' position-specific salary cap space, teams' position-specific needs, and the number of unrestricted free agents available during a free agency window.

Despite the evidence that suggests salary cap space, position-specific needs, and the number of UFAs available are the primary predictors of UFA signings in the NHL, the models from the study reveal that there are in fact, other explanatory variables that independently influence probability predictions of UFA signings. In fact, a pattern in the models reveals that a team’s history of qualifying for the Stanley Cup Playoffs does positively affect the probability that teams sign five or more UFAs. There is also consistent evidence that suggests that teams’ points percentages in the regular-season standings positively affect the probability of signing UFAs. Although there could be several reasons that these two variables have consistently recorded effects on UFA signings, the primary reason could be a result of competitive human nature in the field of professional sports. This means that franchises want to field teams that are going to produce wins, playoff appearances, and championships. Not only do teams want to win, but players do too; thus, it is not surprising to see that these variables are significant in this study. The NHL is a competitive league, and it is likely that everyone involved desires to win.

Finally, the nonbinomial linear regression models provided results that the probit models could not. These models enabled the study to include dummy variables for the twenty-nine of the thirty NHL teams and five of the six seasons being examined. The significance of these models highlights the fact that the likelihood of signing UFAs is not consistent for teams on a yearly basis. The focal point of these models is that there are several different strategies and needs that are deployed by organizations’ management when it comes to constructing their rosters and pursuing unrestricted free agents. This reality alludes to the understanding that at the NHL level, rosters vary on a yearly basis. However, this model is limited because it cannot account for additional factors such as changes within the coaching staff, player production, and general gameplay and management strategies that are specific to each team in each season.

Upon the conclusion of this study, it is necessary to reexamine the initial hypotheses. To a degree of surprise, teams' cap space did not positively affect the probability of signing unrestricted free agents, nor was it statistically significant in the models (*Hypothesis 1*). Average spending on defensemen proved to be statistically significant, but only had a minimal marginal effected probability of signing UFAs. The defenseman dummy variable that was used to quantify teams' needs at the defense position was not statistically significant (*Hypothesis 2*). State and provincial income taxes did not record any statistical significance in the probit models but did so in the negative binomial regressions (*Hypothesis 3*). While it is possible that a player may weigh this factor in their decision to sign with a team, there is no concrete evidence provided by the models that indicate this is a regular occurrence. Win percentages and teams' points percentages did reveal statistical significance in the predicted probability of signing UFAs (*Hypothesis 4*). Lastly, qualifying as a playoff team showed statistical significance with a predicted probability of 22% regarding signing five or more UFAs (*Hypothesis 5*).

The results from this study and the limitations of the models make it possible to question whether the determinants of signing unrestricted free agents are based on established criteria by teams' management groups that are objective, subjective, or a combination of the two. Regardless of what the statistical results from these models provide, it is likely that there is no definitive answer to what elements affect unrestricted free agent signings in the NHL. There are numerous variables that could play a role in the question at hand, and it is likely that several of them are unaccounted for in this study and many of them cannot be obtained because of subjective biases. This concept is a reality at the NHL level because evaluations on teams and players are two-fold. Quantitative analysis is an essential tool for evaluations, but it is not the sole factor (Tarter, 2017). Statistics are used hand-in-hand with subjective opinions to assess the worth of a team or player.

Although this study provided statistically backed conclusions about the determinants of unrestricted free agent signings in the NHL between the 2011-2012 and 2016-2017 seasons, further research is necessary in order to definitively establish the factors that play a role in the question at hand. Future studies in the field could analyze the role that player positional gameplay statistics and teams' subjective criteria tendencies on player evaluations have on free agent signings. Moreover, future research could track individual player movement across the free agent market throughout their careers in order to classify the quantitative factors that determine a player's ability to sign a contract. This research could also apply to inquiries about the determinants of contract value for NHL players. To provide concrete answers to these questions, future research in this field should study these variables over a longer period of time and include player-specific statistics.

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Appendices

Appendix A: OLS Regression Pairwise Correlation Test of Variables

Pairwise Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) signplyr	1.000									
(2) tmcapspace	0.063	1.000								
(3) tmfwdcap	-0.052	-0.622	1.000							
(4) tmdefcap	-0.028	-0.488	0.183	1.000						
(5) avg$fwdpsz	-0.375	-0.067	0.212	0.095	1.000					
(6) avg$defpsz	-0.461	-0.023	0.164	0.122	0.774	1.000				
(7) fwddummy	-0.030	0.561	-0.779	-0.155	0.041	0.100	1.000			
(8) defdummy	-0.041	0.402	-0.148	-0.774	-0.035	0.020	0.144	1.000		
(9) ufafwdsaval	0.719	0.089	-0.077	-0.079	-0.365	-0.648	-0.034	-0.054	1.000	
(10) ufadefaval	0.655	0.046	-0.080	-0.092	-0.376	-0.753	-0.060	-0.042	0.949	1.000
(11) fwdsonfullros	-0.453	-0.200	0.148	0.111	0.222	0.388	-0.039	-0.033	-0.581	-0.543
(12) defonfullros	-0.276	-0.264	0.136	0.384	0.163	0.276	-0.056	-0.264	-0.396	-0.377
(13) tmptspct	-0.021	-0.408	0.447	0.391	0.008	-0.016	-0.403	-0.396	-0.007	0.011
(14) tmstinctx	0.063	-0.015	-0.030	0.103	-0.015	-0.037	0.085	-0.093	0.047	0.048
(15) plyofftm	0.022	-0.430	0.434	0.427	0.000	0.000	-0.374	-0.389	0.000	0.000
(16) avghomeatt	0.022	-0.422	0.351	0.324	-0.021	-0.005	-0.240	-0.180	0.012	0.005
(17) champrate	0.004	-0.178	0.038	0.065	0.000	0.000	-0.001	-0.006	0.000	0.000
(18) winpct	-0.117	-0.467	0.337	0.288	0.055	-0.195	-0.376	-0.283	-0.014	0.115

Appendix B: OLS Regression Results

Variables	(1) OLS_Regression
tmcapspace	-0.00
	(0)
tmfwdcap	0.00
	(0)
tmdefcap	0.00
	(0)
avg$fwdpsz	-0.00***
	(0)
avg$defpsz	0.00**
	(0)
fwddummy	.003
	(.055)
defdummy	.006
	(.052)
ufafwdsaval	.004***
	(.001)
ufadefaval	.002
	(.003)
fwdsonfullros	-.012
	(.009)
defonfullros	.006
	(.012)
tmptspct	-.004
	(.003)
tmstinctx	.002
	(.003)
plyofftm	.061
	(.055)
avghomeatt	-0.00
	(0)
champrate	-.03
	(.272)
_cons	-.357
	(1.105)
Observations	180
R-squared	.565

Note: Standard errors are in parentheses. Negative zero coefficient values indicate marginally uninfluential presence.
**** p<.01, ** p<.05, * p<.1*

Appendix C: Descriptive Statistics for OLS Regression

Summary Statistics for OLS Model

Variable	Obs.	Mean	Std. Dev.	Min	Max
signplyr	180	.9	.301	0	1
tmcapspace	180	3879663.9	6514890	-14483929	24544723
tmfwdcap	180	34359127	5995872.4	17673677	49761667
tmdefcap	180	19248836	4707279.8	7153627	33149762
avg$fwdpsz	180	34359128	1270635.5	32739266	36067948
avg$defpszn	180	19248836	575498.84	18546696	20042854
fwddummy	180	.456	.499	0	1
defdummy	180	.494	.501	0	1
ufafwdsaval	180	165.5	52.302	53	206
ufadefaval	180	89.5	29.853	31	127
fwdsonfullros	180	15.956	2.41	10	23
defonfullros	180	8.822	1.695	5	14
tmptspct	180	55.759	8.653	29.3	75
tmstinctx	180	8.251	5.486	0	25.75
plyofftm	180	.533	.5	0	1
avghomeatt	180	17556.717	2262.669	11265	22623
champrate	180	.055	.068	0	.307
winpct	180	.465	.116	.183	.683

Observations = 180
F (16, 163) = 13.21
Prob > F = 0.00
R-squared = 0.5645

Appendix D: Approach 1 Classification Table

	True		
Classified	**D**	**~D**	**Total**
+	48	30	78
-	37	65	102
Total	85	95	180

Note: Classified + if predicted Pr(D) >= 0.5

Note: True D defined as signplyr5orm ! = 0

Sensitivity	Pr (+ | D)	56.47%
Specificity	Pr (- | ~D)	68.42%
Positive predictive value	Pr (D | +)	61.54%
Negative predictive value	Pr (~D | -)	63.73%
Correctly classified		**62.78%**

Appendix E: Approach 2 Classification Table

	True		
Classified	**D**	**~D**	**Total**
+	63	32	95
-	22	63	85
Total	85	95	180

Note: Classified + if predicted Pr(D) >= 0.5

Note: True D defined as signplyr5orm ! = 0

Sensitivity	Pr (+ | D)	74.12%
Specificity	Pr (- | ~D)	66.32%
Positive predictive value	Pr (D | +)	66.32%
Negative predictive value	Pr (~D | -)	74.12%
Correctly classified		**70.00%**

Appendix F: Approach 3 Classification Table

	True		
Classified	**D**	**~D**	**Total**
+	48	27	75
-	37	68	105
Total	85	95	180

Note: Classified + if predicted Pr(D) >= 0.5

Note: True D defined as signplyr5orm ! = 0

Sensitivity	Pr (+ | D)	56.47%
Specificity	Pr (- | ~D)	71.58%
Positive predictive value	Pr (D | +)	64.00%
Negative predictive value	Pr (~D | -)	64.76%
Correctly classified		**64.44%**

Appendix G: Approach 4 Classification Table

	True		
Classified	**D**	**~D**	**Total**
+	160	8	168
-	2	10	12
Total	162	18	180

Note: Classified + if predicted Pr(D) >= 0.5

Note: True D defined as signplyr ! = 0

Sensitivity	Pr (+ | D)	98.77%
Specificity	Pr (- | ~D)	55.56%
Positive predictive value	Pr (D | +)	95.24%
Negative predictive value	Pr (~D | -)	83.33%
Correctly classified		**94.44%**

Appendix H: Approach 5 Negative Binomial Regression (2012-13 Season without *totalfa*)

		Delta-method				
Variables	**dy/dx**	**Std. Err.**	**z**	**P>z**	**[95% conf.**	**Interval]**
1.d1213	0.804	0.409	1.970	0.049	0.003	1.606
1.darizona	11.448	9.188	1.250	0.213	-6.561	29.457
1.dboston	3.225	4.544	0.710	0.478	-5.682	12.132
1.dbuffalo	-0.036	1.807	-0.020	0.984	-3.577	3.506
1.dcalgary	-1.634	1.022	-1.600	0.110	-3.637	0.368
1.dcarolina	4.014	4.364	0.920	0.358	-4.540	12.567
1.dchicago	3.320	4.773	0.700	0.487	-6.035	12.675
1.dcolorado	6.740	6.918	0.970	0.330	-6.820	20.299
1.dcolumbus	0.275	2.873	0.100	0.924	-5.355	5.906
1.ddallas	13.993	15.579	0.900	0.369	-16.542	44.528
1.ddetroit	5.616	6.029	0.930	0.352	-6.201	17.434
1.dedmonton	-1.120	1.105	-1.010	0.311	-3.285	1.046
1.dflorida	23.708	23.990	0.990	0.323	-23.312	70.728
1.dlosangeles	-2.470	0.637	-3.870	0.000	-3.719	-1.220
1.dminnesota	1.318	2.205	0.600	0.550	-3.003	5.640
1.dmontreal	-5.241	1.352	-3.880	0.000	-7.891	-2.591
1.dnashville	4.511	4.480	1.010	0.314	-4.269	13.291
1.dnewjersey	4.519	3.129	1.440	0.149	-1.613	10.651
1.dynyislanders	2.341	2.709	0.860	0.387	-2.969	7.651
1.dnyrangers	3.160	3.137	1.010	0.314	-2.988	9.309
1.dottawa	-2.057	0.756	-2.720	0.006	-3.539	-0.576
1.dphiladelphia	9.755	9.882	0.990	0.324	-9.614	29.124
1.dpittsburgh	15.027	13.048	1.150	0.249	-10.547	40.601
1.dsanjose	-1.801	0.840	-2.140	0.032	-3.447	-0.154
1.dstlouis	9.360	7.095	1.320	0.187	-4.545	23.265
1.dtampabay	11.657	14.430	0.810	0.419	-16.625	39.939
1.dtoronto	-0.704	1.008	-0.700	0.485	-2.680	1.272
1.dvancouver	-2.544	0.737	-3.450	0.001	-3.988	-1.100
1.dwashington	3.080	2.898	1.060	0.288	-2.599	8.759
1.dwinnipeg	-3.272	0.633	-5.170	0.000	-4.512	-2.032
tmfwdcap	0.000	0.000	0.080	0.939	-0.000	0.000
tmdefcap	-0.000	0.000	-0.050	0.958	-0.000	0.000
tmstinctx	0.680	0.270	2.520	0.012	0.151	1.210

Observations = 180

Note: dy/dx for factor levels is the discrete change from the base level.

Appendix I: Approach 5 Negative Binomial Regression (2012-13 Season with *totalfa*)

		Delta-method				
Variables	**dy/dx**	**Std. Err.**	**Z**	**P>z**	**[95% conf.**	**Interval]**
totalfa	0.037	0.003	10.570	0.000	0.030	0.044
1.d1213	2.097	0.406	5.160	0.000	1.301	2.894
1.darizona	2.780	2.952	0.940	0.346	-3.006	8.566
1.dboston	-1.237	1.395	-0.890	0.375	-3.972	1.497
1.dbuffalo	-1.433	0.912	-1.570	0.116	-3.221	0.354
1.dcalgary	-1.979	0.870	-2.280	0.023	-3.684	-0.275
1.dcarolina	0.654	1.949	0.340	0.737	-3.167	4.475
1.dchicago	-1.476	1.289	-1.150	0.252	-4.002	1.049
1.dcolorado	0.395	2.170	0.180	0.855	-3.858	4.649
1.dcolumbus	-2.193	1.185	-1.850	0.064	-4.514	0.129
1.ddallas	0.398	2.746	0.140	0.885	-4.985	5.780
1.ddetroit	-0.551	1.638	-0.340	0.737	-3.761	2.659
1.dedmonton	-1.379	0.998	-1.380	0.167	-3.335	0.576
1.dflorida	2.644	4.140	0.640	0.523	-5.471	10.758
1.dlosangeles	-2.545	0.623	-4.090	0.000	-3.765	-1.324
1.dminnesota	-0.606	1.058	-0.570	0.567	-2.680	1.468
1.dmontreal	-3.078	0.983	-3.130	0.002	-5.005	-1.150
1.dnashville	-0.416	1.637	-0.250	0.799	-3.625	2.792
1.dnewjersey	2.527	1.938	1.300	0.192	-1.272	6.326
1.dynyislanders	0.152	1.268	0.120	0.905	-2.333	2.637
1.dnyrangers	0.352	1.375	0.260	0.798	-2.344	3.047
1.dottawa	-2.072	0.613	-3.380	0.001	-3.273	-0.871
1.dphiladelphia	0.044	2.136	0.020	0.984	-4.143	4.230
1.dpittsburgh	2.324	3.017	0.770	0.441	-3.588	8.237
1.dsanjose	-1.938	0.712	-2.720	0.007	-3.334	-0.542
1.dstlouis	1.836	2.197	0.840	0.403	-2.470	6.141
1.dtampabay	-0.790	2.172	-0.360	0.716	-5.047	3.467
1.dtoronto	-0.257	1.208	-0.210	0.832	-2.624	2.111
1.dvancouver	-1.653	0.850	-1.950	0.052	-3.318	0.012
1.dwashington	-0.073	1.354	-0.050	0.957	-2.726	2.580
1.dwinnipeg	-2.044	0.861	-2.370	0.018	-3.732	-0.357
tmfwdcap	0.000	0.000	0.750	0.453	-0.000	0.000
tmdefcap	0.000	0.000	1.740	0.081	-0.000	0.000
tmstinctx	0.163	0.175	0.930	0.353	-0.180	0.506

Observations = 180

Note: dy/dx for factor levels is the discrete change from the base level.