What Determines an NFL Quarterback's Salary?

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1. Introduction

The NFL quarterback is thought of, by many, to be the most important position in all of sports. Likewise, quarterbacks are some of the highest-paid athletes in the world. With the rise of incredible young talent like Patrick Mahomes or Lamar Jackson, along with the consistent greatness of veteran legends like Tom Brady and Drew Brees, the NFL is flourishing. Because of this fortune and the corresponding record-high television ratings, new money is pouring into the league. Contracts are now reaching all-time highs for all positions on the field. Specifically, analysts have speculated that within the next year, Patrick Mahomes could become the NFL's first 200 million dollar man.

Quarterback signings have not come without controversy, however, with both football fans and analysts persistently questioning the logic behind some teams' financial decisions. For example, Derek Carr of the Oakland Raiders signed a 5 year 125,000,000 contract in 2017 and the raiders have yet to make the playoffs since he has been a starter. Excessively large contracts limit a team's ability to fill much-needed spots at other positions on the field, and with the NFL's hard salary cap, this can greatly hinder a team's ability to fill a roster. This raises the question, what factors determine how a quarterback is paid?

Using regression analysis, I attempted to answer the above query and clarify the determinants of a QB's salary. NFL team front offices, as well as quarterbacks themselves, will find this data useful.

2. Theory and Prior Research

Leeds and Kowalewski (1999) examine the impact of the salary cap and the collective bargaining agreement on NFL player salaries. They conclude the introduction of the collective bargaining agreement increased the performance to reward ratio for players, with more accomplished players able to receive better contracts. However, they illustrated the salary cap era overall produced greater income inequality between star players and their average/rookie counterparts. They further showed the weight of salary depended less on player position and more on starting role. A limitation of their work includes the lack of isolation for both player position and unique position-related performance statistics.

Berri and Simmons (2009) evaluated the role of race in compensation for quarterbacks. Using a quantile regression, they modeled quarterback performance and concluded while black quarterbacks were more likely to run the ball, and were more effective at doing so, they were not compensated for this additional skill. In addition, they found black quarterbacks received less compensation in the upper quartile of the salary distribution than their white counterparts. They conclude a significant negative coefficient on passing yards may be the root of salary based discrimination. Limitations of their study include, for example, erroneous variables such as appearances in Pro Bowls, which in the NFL, occur during the playoffs. Not only are the two teams in the Superbowl unable to participate in the Bowl, but due to the high risk of injury in the NFL, many who are invited to play do not actually participate.

Martin (1999) analyzes the salary determinants of NFL quarterbacks through a bargaining framework. He concludes a quarterback's salary is most impacted by his prior year win-loss record and total number of completions. An external factor associated with win percentage was also team revenue. A better team record increases revenues, and subsequently increases the value of the quarterback in the eyes of that team's front office. A limitation was the inability to account for other player's impacts on the quarterback's success, as the ability to win is a combination of multiple factors on offense, defense, and special teams.

3. Data and Variables

My data is a cross section of quarterback salaries regressed against age and five performance statistics. I analyzed the top 50 quarterbacks, based on NFL.com rankings, from each of the past three NFL seasons (2017, 2018, and 2019). I eliminated rookies who were not yet on the third year of their contract (all rookie contracts are three years in length and rookie salaries are determined by both their position and round taken in the draft - their salary is fixed for at least two years until negotiation can begin) for a total of 108 entries. Salaries from 2017 and 2018 were adjusted for inflation to reflect 2019 values using Bureau of Labor Statistics rates. All variables and expected signs are listed in Figure 1 below:

Figure 1: Variables

Variable	Description	Expected Sign
SALRY	"Cash Spent" value of QB's Salary (measured in $)	Dependent
AGE	Age of the Quarterback (measured in years)	+
CMP	Completion Percentage (measured as a %)	+
INT	Total Interceptions	−
QBR	Total Quarterback Rating (scale of 0-100)	+
TD	Total Touchdowns	+
YDS	Total Yards	+

Dependent Variable:

<u>SALRY</u>

The annual cash value of the quarterback's salary measured in U.S. dollars. Salary includes signing bonuses, roster bonuses, workout bonuses, restructure bonuses, option bonuses, and incentives. SALRY is not a measure of how much the quarterback costs against the salary cap. By including bonuses and incentives, SALRY is an accurate representation of the true salary a quarterback receives. All salaries were adjusted for inflation.

Independent Variables:

AGE

Age of the quarterback, measured in years. I chose age to assess whether older quarterbacks receive more than their younger counterparts. I predict an increase in age will correspond to an increase in salary for quarterbacks as it is a reflection of experience.

CMP

The quarterback's completion percentage, measured as a percent, and calculated by dividing the number of completed passes by the total number of passing attempts. It is a measure of a quarterback's passing accuracy. I predict a higher completion percentage will result in an increase in quarterback salary.

INT

The total number of interceptions thrown by the quarterback. Interceptions are a negative reflection of the quarterback's awareness. I predict a higher interception total will result in a lower quarterback salary.

QBR

Defined as "Total Quarterback Rating", it is a relatively new statistic created by ESPN to measure the overall performance of NFL quarterbacks in isolation of their team's success. It is calculated as a function of (AdjustedExpectedPointsAdded)/(ActionPlays) and is scaled from 0-100, with 100 being the best. It distributes more credit to the quarterback on plays more under his control and accounts for pass distance, time left in the game, the specific down, and the current score. I predict a higher QBR will result in a higher quarterback salary as it is a refined measurement of quarterback impact.

TD

The total number of touchdowns thrown by the quarterback. A common representation of a quarterback's prestige. I predict a higher touchdown total will result in a higher quarterback salary.

YDS

The total yards thrown for by a quarterback. A similar representation of a quarterback's prestige. I predict a greater number of yards thrown will result in a higher quarterback salary.

Descriptive statistics for all variables are shown below:

Figure 2: Descriptive Statistics

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Obs
SALRY	14274039	1.4E+07	70000000	219599.9	13283940	1.776065	7.612842	108
AGE	30.75926	30	42	21	4.702098	0.282696	2.348813	108
CMP	63.44722	63.8	74.6	46.4	5.297759	-0.54807	4.00778	108
INT	7.888889	6.5	30	0	5.07575	0.940104	4.746367	108
QBR	63.06852	62.2	117.5	16.3	24.24902	0.188139	2.254152	108
TD	16.25	18	39	0	10.55393	0.077321	1.763407	108
YDS	2614.694	2934	5129	265	1517.31	-0.168629	1.567329	108

4. Regression Analysis

After running the make_some_eqs program, I obtained 41 different regressions and have displayed them below:

Figure 3: Regression Results for SALRY

Eq Name:	A0	A01	A01A	A01SAF5	A01SBB5	A01SCF3	A01SDB3	A01SEF2	A01SFB2	A01SGF1	A01SHB1
Method:	STEPLS	STEPLS	LS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS
Dep. Var:	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY
C	-4.20294E+11	-4.20294E+11	-4.20287E+11	-99026170335	-4.30302E+11	26071474.61	-3.92834E+11	10934710.82	-1.01287E+11	10934710.82	-1.02423E+11
AGE	-1184508074	-1184508074	-1184506156	-1106924347	-1193395628		-1213783234		-1128765806		-1142896202
AGE^2	6286595.397	6286595.397	6286585.29	5885711.364	6348688.883		6470296.008		5999558.25		6079114.772
1/AGE	3.66443E+11	3.66443E+11	3.66442E+11	3.41929E+11	3.67844E+11		3.72796E+11		3.48976E+11		3.52594E+11
LOG(AGE)	36463339648	36463339648	36463280339	34037200206	36662645024		37218747100		34722960792		35123597033
CMP	-1487805410	-1487805410	-1487773394		-1525550059		-1344723582				
CMP^2	4150789.885	4150789.885	4150701.785		4244059.666		3748507.357				
1/CMP	1.71694E+12	1.71694E+12	1.7169E+12		1.76965E+12		1.55227E+12				
LOG(CMP)	87997714140	87997714140	87995789727		90474975074		79568218075				
INT	-2963605.453	-2963605.453	-2963610.916	-3039109.192	-2865497.539	-2664181.265	-2911178.424	-957719.0723	-2819236.033	-957719.0723	-2426949.742
INT^2	75335.48984	75335.48984	75335.71336	81949.43664	72113.4417	63875.68036	72967.60339		75109.55709		63276.21363
QBR	3500318.663	3500318.663	3500318.716	366815.4993	503080.294	-96687.85356					
QBR^2	-9155.005426	-9155.005426	-9155.016582								
1/QBR	-3640429279	-3640429279	-3640424558	-1330204845	-1586169046		-554574028.5				
LOG(QBR)	-210582657.7	-210582657.7	-210582483.8	-52508184.45	-65138111.74		-15292950.4		-4070789.082		
TD	-225544.9247	-225544.9247	-225542.5139			332462.3799					
TD^2	5276.27652	5276.27652	5276.235326								
YDS	-1804.695435	-1804.695435	-1804.508108	8476.334115							
YDS^2	0.834635	0.834635	0.834615		1.044882	0.824379	1.013587	1.194913	0.804812	1.194913	0.803399
1/YDS	5829622721	5829622721	5829544494			-4293151971					
LOG(YDS)	17411539.24	17411539.24	17411297.2		6114291.135		6246586.147		8102070.393		6285951.904
Obs	108	108	108	108	108	108	108	108	108	108	108
R-sq	0.4225	0.4225	0.4225	0.3983	0.4195	0.3171	0.4143	0.2677	0.3864	0.2677	0.3752
AdjR-sq	0.2898	0.2898	0.2898	0.3363	0.3248	0.2766	0.3261	0.2538	0.33	0.2538	0.3247
Akaike	35.4725	35.4725	35.4725	35.3284	35.3852	35.3809	35.3756	35.3766	35.3295	35.3766	35.329
Schwarz:	35.994	35.994	35.994	35.6015	35.7825	35.5547	35.7481	35.4511	35.5779	35.4511	35.5525
HQ	35.684	35.684	35.684	35.4391	35.5463	35.4514	35.5267	35.4069	35.4302	35.4069	35.4196
S.E.reg	11195136.18	11195136.18	11195136.18	10822133.54	10915281.72	11298647.42	10905189.9	11475098.33	10873236.74	11475098.33	10916060.69
MeanDep	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99
DW	2.1233	2.1233	2.1233	2.1765	2.1103	2.1033	2.1108	1.994	2.1241	1.994	2.0923
F-Stat	9.98E-05	9.98E-05	9.98E-05	1.60E-07	3.36E-06	6.36E-07	2.09E-06	7.85E-08	1.35E-07	7.85E-08	1.03E-07
LRam1	1.44E-05	1.44E-05	1.44E-05	3.51E-05	1.32E-05	0.004047	7.59E-05	0.030988	4.42E-05	0.030988	8.28E-06
LRam2	1.75E-05	1.75E-05	1.75E-05	3.18E-05	1.93E-05	0.000978	0.000124	0.009538	1.04E-05	0.009538	5.85E-07
LRam3	2.84E-05	2.84E-05	2.84E-05	9.59E-05	1.80E-05	0.002544	0.000254	0.013861	4.16E-05	0.013861	1.12E-06
LRam4	1.50E-05	1.50E-05	1.50E-05	0.000119	6.87E-06	0.004516	0.000176	0.014026	3.42E-05	0.014026	2.78E-06
FRam1	0.000113	0.000113	0.000113	9.99E-05	6.64E-05	0.005796	0.000270	0.034700	0.000113	0.034700	2.28E-05
FRam2	0.000180	0.000180	0.000180	0.000111	0.000118	0.001743	0.000511	0.011831	3.74E-05	0.011831	2.52E-06
FRam3	0.000336	0.000336	0.000336	0.000340	0.000137	0.004581	0.001106	0.017780	0.000148	0.017780	5.37E-06
FRam4	0.000256	0.000256	0.000256	0.000470	7.57E-05	0.008348	0.000957	0.018909	0.000144	0.018909	1.42E-05
BPG	0.085618	0.085618	0.085618	0.043758	0.029138	0.006336	0.051933	0.000405	0.011160	0.000405	0.018256
Gleisjer	0.007720	0.007720	0.007720	0.017398	0.005368	0.005405	0.009304	0.002126	0.003434	0.002126	0.011183
Harvey	0.023822	0.023822	0.023819	0.034938	0.131427	0.243102	0.221498	0.307603	0.022370	0.307603	0.015699
White SQ	0.119579	0.119579	0.119579	0.065516	0.037851	0.021662	0.078684	0.001999	0.030007	0.001999	0.026907
Wh L&SQ	NA	NA	NA	NA	NA	0.035650	NA	0.002568	NA	0.002568	NA
MaxVIF	35820824	35820824	35820824	3941416	33567788	13	32572547	2	3920177	2	3917934

Eq Name:	A02	A02SB1	A02SB3	A02SB5	A02SF1	A02SF3	A02SF5	A03	A04	A05	A05A
Method:	LS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS
Dep. Var:	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY	SALRY
C	9480398.309	-99065297751	-3.91403E+11	-3.91403E+11	-71410496.31	131643334.2	-1.0108E+11	-104449541.9	-163114333.6	989736632.1	352049610.9
AGE	157855.2815	-1104825614	-1153324246	-1153324246	5696666.957	5632343.529	-1136464013		5622420.803		-2352309.058
AGE^2		5873178.219	6135893.601	6135893.601	-88013.69781	-86647.69234	6060099.988		-86292.82122		
1/AGE		3.41359E+11	3.55234E+11	3.55234E+11			3.49306E+11			-5651518838	-2363984786
LOG(AGE)		33977757492	35423300602	35423300602			34854924966	12957777.33		-174724054.3	
CMP	-90641.94478	-43711.91957	-1362200248	-1362200248	-94955.87427	-1743222.904	-1912996.796		2866460.972		-1601315.547
CMP^2			3793979.939	3793979.939					-23925.44759		
1/CMP			1.5747E+12	1.5747E+12		-6124476693	-7111288100			-3456320509	-5596804457
LOG(CMP)			80662468150	80662468150				7503661.064		-55299334.48	
INT	-1099544.56	-2871558.644	-3083009.999	-3083009.999	-2626965.329	-2773202.042	-3228977.772		-3038155.38		-1074705.734
INT^2		75842.09865	80695.00563	80695.00563	65663.96347	69184.50909	86800.37958		79122.3536		
QBR	-53326.84809	-73087.27617	482531.878	482531.878	-75124.98478	-69283.10221	380238.4962		-17298.91697		-78540.72139
QBR^2									-465.915962		
1/QBR			-1567646380	-1567646380			-1412020161			-110079516	-142797856
LOG(QBR)			-63641125.73	-63641125.73			-54497324.4	-582061.5111		-1752704.111	
TD	237131.2372	12982.85351	17255.07539	17255.07539	181095.5251	225038.4159	35171.29908		372880.0369		208508.8318
TD^2									-3131.87395		
YDS	5305.842278	8322.46725	8527.382015	8527.382015	7052.801609	6743.070926	8203.503886		8045.536069		5895.583697
YDS^2									-0.28437		
1/YDS										7309145232	1408558201
LOG(YDS)								6017281.681		12781771.29	
Obs	108	108	108	108	108	108	108	108	108	108	108
R-sq	0.281	0.3883	0.4194	0.4194	0.3452	0.3532	0.4089	0.1813	0.354	0.2294	0.3115
AdjR-sq	0.2383	0.3252	0.3248	0.3248	0.2923	0.2938	0.3271	0.1495	0.2724	0.1671	0.2406
Akaike	35.4324	35.3449	35.3852	35.3852	35.3759	35.3821	35.3662	35.5253	35.4365	35.5388	35.4631
Schwarz:	35.6063	35.6181	35.7826	35.7826	35.5994	35.6305	35.7139	35.6494	35.7593	35.7623	35.7363
HQ	35.5029	35.4556	35.5464	35.5464	35.4665	35.4828	35.5072	35.5756	35.5674	35.6294	35.5739
S.E.reg	11593698.26	10911851.75	10915608.67	10915608.67	11175026.57	11163013.46	10896521.63	12250779.13	11331032.17	12123244.02	11576396.83
MeanDep	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99	14274038.99
DW	2.0483	2.1368	2.118	2.118	2.0967	2.0742	2.1508	1.9443	2.1001	1.9961	2.0389
F-Stat	6.86E-06	3.24E-07	3.37E-06	3.37E-06	8.28E-07	1.32E-06	1.27E-06	0.000347	1.79E-05	0.000844	4.38E-05
LRam1	0.002745	5.85E-05	2.74E-05	2.74E-05	0.000281	0.000509	9.80E-05	0.189158	0.000572	0.001544	3.07E-05
LRam2	0.000349	2.62E-05	5.01E-05	5.01E-05	0.000423	0.000836	8.07E-05	0.378343	0.001580	0.006425	3.44E-05
LRam3	0.000458	9.46E-05	3.65E-05	3.65E-05	0.001083	0.002406	0.000154	0.012711	0.004639	0.005122	8.02E-06
LRam4	0.001280	0.000104	1.31E-05	1.31E-05	0.000244	0.000252	9.62E-05	0.025163	0.001110	0.007835	1.01E-05
FRam1	0.004044	0.000157	0.000123	0.000123	0.000557	0.001017	0.000312	0.203032	0.001350	0.002625	8.87E-05
FRam2	0.000677	9.31E-05	0.000261	0.000261	0.000934	0.001838	0.000326	0.402944	0.003870	0.010743	0.000119
FRam3	0.000967	0.000336	0.000245	0.000245	0.002429	0.005248	0.000668	0.017959	0.011030	0.009640	3.92E-05
FRam4	0.002693	0.000418	0.000128	0.000128	0.000728	0.000821	0.000528	0.035632	0.003718	0.015272	5.62E-05
BPG	0.007073	0.040211	0.038442	0.038442	0.016379	0.004991	0.022397	0.810613	0.017089	0.887890	0.030393
Gleisjer	0.006364	0.013440	0.006204	0.006204	0.003767	0.000305	0.004304	0.696490	0.001708	0.923348	0.015131
Harvey	0.089128	0.049516	0.070666	0.070666	0.010658	0.001363	0.104533	0.713861	0.001458	0.750593	0.055613
White SQ	0.050069	0.074951	0.049746	0.049746	0.035483	0.014709	0.043200	0.795173	0.038929	0.924437	0.156345
Wh L&SQ	0.007121	NA	NA	NA	0.027426	0.029996	NA	0.690674	0.072319	NA	0.041804
MaxVIF	11	4149297	32683383	32683383	158	158	4177116	1	258	211	58

Figure 4: Regression Results for log(SALRY)

Eq Name:	A06	A06A	A06SAF5	A06SBB5	A06SCF3	A06SDB3	A06SEF2	A06SFB2	A06SGF1	A06SHB1
Method:	STEPLS	LS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS
Dep. Var:	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)
C	-15325.53047	-15325.53051	1559.069846	-11838.84284	22.394737	-11631.89018	22.394737	-11631.89018	16.701963	-11202.35965
AGE	-128.502919	-128.502918		-129.383507		-133.428269		-133.428269		-128.50887
AGE^2	0.69174	0.69174	-0.002927	0.696435	-0.002077	0.718185	-0.002077	0.718185		0.690862
1/AGE	38732.11152	38732.11147	-226.407934	39007.77921	-178.565533	40313.32237	-178.565533	40313.32237	-56.683465	38892.47755
LOG(AGE)	3904.465668	3904.465664		3931.660648		4057.417321		4057.417321		3911.802135
CMP	-23.713068	-23.713068		-7.242458						
CMP^2	0.074249	0.074249	0.013537	0.029057						
1/CMP	19750.78389	19750.78416	-12285.87205							
LOG(CMP)	1217.196407	1217.19642	-304.069459	224.948481		1.856335		1.856335		
INT	-0.180821	-0.180821		-0.181598		-0.180186		-0.180186		-0.187621
INT^2	0.006746	0.006746		0.006792		0.006892		0.006892		0.006901
QBR	0.816622	0.816622	0.709429	0.83434		0.822615		0.822615		0.848134
QBR^2	-0.002418	-0.002418	-0.002061	-0.002463		-0.002429		-0.002429		-0.002509
1/QBR	-684.722975	-684.722973	-604.981272	-702.52504		-690.265253		-690.265253		-694.210768
LOG(QBR)	-42.891036	-42.891036	-37.578267	-43.911368		-43.331224		-43.331224		-44.193205
TD	0.021723	0.021723	0.021165		0.133098		0.133098		0.064928	
TD^2	-0.000394	-0.000394			-0.001961		-0.001961			
YDS	0.002473	0.002473	0.001638	0.00232		0.001366		0.001366		0.001479
YDS^2	0	0	0	0		0		0		0
1/YDS	-226.721688	-226.721717								
LOG(YDS)	-1.379773	-1.379773	-0.794545	-0.852207						
Obs	108	108	108	108	108	108	108	108	108	108
R-sq	0.489	0.489	0.4148	0.4885	0.3552	0.4766	0.3552	0.4766	0.3266	0.4665
AdjR-sq	0.3716	0.3716	0.3338	0.3986	0.3302	0.4043	0.3302	0.4043	0.3138	0.3991
Akaike	3.1213	3.1213	3.1273	3.0482	3.0576	3.0156	3.0576	3.0156	3.0639	3.0163
Schwarz:	3.6428	3.6428	3.475	3.4704	3.1817	3.3633	3.1817	3.3633	3.1384	3.3391
HQ	3.3328	3.3328	3.2683	3.2194	3.1079	3.1566	3.1079	3.1566	3.0942	3.1472
S.E.reg	1.0569	1.0569	1.0882	1.034	1.0912	1.0291	1.0912	1.0291	1.1044	1.0335
MeanDep	15.8711	15.8711	15.8711	15.8711	15.8711	15.8711	15.8711	15.8711	15.8711	15.8711
DW	2.0247	2.0247	1.9299	2.0302	1.9959	2.1009	1.9959	2.1009	1.9834	2.1169
F-Stat	1.68E-06	1.68E-06	8.54E-07	6.36E-08	2.95E-09	9.25E-09	2.95E-09	9.25E-09	9.63E-10	7.45E-09
LRam1	0.037986	0.037986	0.555662	0.063186	0.754585	0.091181	0.754585	0.091181	0.061038	0.090613
LRam2	0.113112	0.113112	0.830814	0.168108	0.896371	0.236287	0.896371	0.236287	0.164889	0.217677
LRam3	NA	NA	0.843749	NA	0.953613	NA	0.953613	NA	0.272124	NA
LRam4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FRam1	0.064851	0.064851	0.585494	0.090777	0.761853	0.117979	0.761853	0.117979	0.066684	0.115371
FRam2	0.179919	0.179919	0.853943	0.230053	0.902749	0.292593	0.902749	0.292593	0.179240	0.269019
FRam3	NA	NA	0.873678	NA	0.958076	NA	0.958076	NA	0.295232	NA
FRam4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BPG	0.063215	0.063215	0.005087	0.035722	1.29E-05	0.037160	1.29E-05	0.037160	4.79E-06	0.029377
Gleisjer	0.009853	0.009853	0.000781	0.003074	1.95E-06	0.004831	1.95E-06	0.004831	1.42E-06	0.005127
Harvey	0.074325	0.074325	0.006685	0.008373	8.14E-05	0.002177	8.14E-05	0.002177	0.000912	0.004309
White SQ	0.072491	0.072491	0.012481	0.075227	0.000115	0.033070	0.000115	0.033070	9.97E-05	0.023259
Wh L&SQ	NA	NA	NA	NA	4.81E-05	NA	4.81E-05	NA	6.74E-06	NA
MaxVIF	35820824	35820824	31515	4059312	16	3987961	16	3987961	1	3958256

Eq Name:	A07	A07SB1	A07SB3	A07SB5	A07SF1	A07SF3	A07SF5	A08	A09	LINALL
Method:	LS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	STEPLS	LS
Dep. Var:	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	LOG(SALRY)	SALRY
C	-2.400217	-11896.6825	-11838.84273	-11838.84273	-17.626926	-12.078147	81.841293	12.01558	-2.647829	9480398.309
AGE		-135.849293	-129.383506	-129.383506				0.053411	0.584724	157855.2815
AGE^2		0.735916	0.696435	0.696435	-0.0038	-0.003614	-0.004292		-0.008395	-90641.94478
1/AGE		40585.88831	39007.77894	39007.77894						-1099544.56
LOG(AGE)	1.950667	4106.638895	3931.660621	3931.660621	9.147722	8.67131	10.196489			-53326.84809
CMP			-7.242458	-7.242458				0.018824	0.204613	237131.2372
CMP^2			0.029057	0.029057					-0.001504	5305.842278
1/CMP										
LOG(CMP)	1.383428	2.280784	224.948469	224.948469	1.85529	1.644497	1.503406			
INT		-0.144563	-0.181598	-0.181598				-0.008875	-0.153241	
INT^2		0.006065	0.006792	0.006792					0.005538	
QBR			0.83434	0.83434			0.590259	-0.001214	0.025362	
QBR^2			-0.002463	-0.002463			-0.001653		-0.00022	
1/QBR		-93.912917	-702.525039	-702.525039	-72.181487	-79.646163	-548.609396			
LOG(QBR)	0.077023	-2.026985	-43.911368	-43.911368	-1.410891	-1.617294	-32.649561			
TD						0.033849		0.026722	0.09993	
TD^2									-0.001578	
YDS			0.00232	0.00232				0.000279	0.000534	
YDS^2			0	0					0	
1/YDS							599.772593			
LOG(YDS)	0.731835	0.912297	-0.852207	-0.852207	0.704422	0.336224	1.318946			
Obs	108	108	108	108	108	108	108	108	108	108
R-sq	0.33	0.4443	0.4885	0.4885	0.3677	0.3806	0.395	0.3333	0.3914	0.281
AdjR-sq	0.304	0.387	0.3986	0.3986	0.3301	0.3372	0.3394	0.2937	0.3146	0.2383
Akaike	3.096	3.0201	3.0482	3.0482	3.0751	3.0731	3.0865	3.128	3.1479	35.4324
Schwarz:	3.2201	3.2932	3.4704	3.4704	3.2489	3.2717	3.3349	3.3019	3.4708	35.6063
HQ	3.1463	3.1308	3.2194	3.2194	3.1456	3.1536	3.1872	3.1985	3.2788	35.5029
S.E.reg	1.1123	1.0439	1.034	1.034	1.0912	1.0855	1.0836	1.1205	1.1038	11593698.26
MeanDep	15.8711	15.8711	15.8711	15.8711	15.8711	15.8711	15.8711	15.8711	15.8711	14274038.99
DW	1.859	1.9712	2.0302	2.0302	1.8877	1.9614	2.0077	1.921	1.9449	2.0483
F-Stat	1.99E-08	5.14E-09	6.36E-08	6.36E-08	1.73E-08	2.23E-08	7.24E-08	2.08E-07	1.69E-06	6.5789
LRam1	0.814756	0.909627	0.063186	0.063186	0.638180	0.490571	0.496339	0.072893	0.553998	8.9694
LRam2	0.799232	0.835296	0.168108	0.168108	0.786285	0.787303	0.591940	0.200219	0.788576	15.921
LRam3	0.124434	NA	NA	NA	0.120409	0.374572	0.348881	0.352258	0.924204	17.9146
LRam4	NA	NA	NA	NA	NA	NA	NA	NA	NA	17.9195
FRam1	0.820318	0.914996	0.090777	0.090777	0.651728	0.510289	0.520205	0.085161	0.581889	8.6596
FRam2	0.810925	0.853589	0.230053	0.230053	0.802198	0.804930	0.627451	0.228935	0.815025	7.8624
FRam3	0.147868	NA	NA	NA	0.150264	0.421859	0.405696	0.394789	0.938712	5.8939
FRam4	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.3766
BPG	0.000174	0.020804	0.035722	0.035722	0.001866	0.002677	0.001125	8.42E-05	0.002244	17.6839
Gleisjer	2.13E-05	0.001335	0.003074	0.003074	0.000196	0.000189	0.000130	1.40E-05	0.000317	17.948
Harvey	2.49E-05	0.000267	0.008373	0.008373	0.000816	0.000729	0.000174	0.000243	0.003057	10.9758
White SQ	0.000156	0.019494	0.075227	0.075227	0.001685	0.002921	0.001035	0.000718	0.005410	12.5878
Wh L&SQ	0.000299	NA	NA	NA	0.009387	0.007291	0.001725	0.000348	0.013091	27.2458
MaxVIF	1	3950126	4059312	4059312	37	38	11533	11	258	11

All linear equations, including the supersets, failed the Ramsey test. The log superset passed the Ramsey so the log equations will not have low power passes. When selecting from the log equations, I eliminated identical equations, and sorted the rest by top adjusted R^2 values and lowest Akaike, Schwarz, and HQ values. The highest adjusted R^2 value was 0.4043 and the lowest Akaike, Schwarz, and HQ values were 3.0156, 3.1384, and 3.0942 respectively. While equation A06SGF1 contained the lowest Schwarz and HQ values, A06SDB3 contained both the highest R^2 value, the lowest Akaike value, and similarly low Schwarz and HQ values. A06SDB3 also included 13 variables (including functional forms) to A06SGF1's two. Therefore, I chose equation A06SDB3 over A06SGF1. Figure 5 below shows the superset log equation A06 and my final equation A06SDB3.

Figure 5: Superset and Final Regression

Eq Name:	A06	A06SDB3
Method:	STEPLS	STEPLS
Dep. Var:	LOG(SALRY)	LOG(SALRY)
C	-15325.53047	-11631.89018
AGE	-128.502919	-133.428269
AGE^2	0.69174	0.718185
1/AGE	38732.11152	40313.32237
LOG(AGE)	3904.465668	4057.417321
CMP	-23.713068	
CMP^2	0.074249	
1/CMP	19750.78389	
LOG(CMP)	1217.196407	1.856335
INT	-0.180821	-0.180186
INT^2	0.006746	0.006892
QBR	0.816622	0.822615
QBR^2	-0.002418	-0.002429
1/QBR	-684.722975	-690.265253
LOG(QBR)	-42.891036	-43.331224
TD	0.021723	
TD^2	-0.000394	
YDS	0.002473	0.001366
YDS^2	0	0
1/YDS	-226.721688	
LOG(YDS)	-1.379773	
Obs	108	108
R-sq	0.489	0.4766
AdjR-sq	0.3716	0.4043
Akaike	3.1213	3.0156
Schwarz:	3.6428	3.3633
HQ	3.3328	3.1566
S.E.reg	1.0569	1.0291
MeanDep	15.8711	15.8711
DW	2.0247	2.1009
F-Stat	1.68E-06	9.25E-09
LRam1	0.037986	0.091181
LRam2	0.113112	0.236287
LRam3	NA	NA
LRam4	NA	NA
FRam1	0.064851	0.117979
FRam2	0.179919	0.292593
FRam3	NA	NA
FRam4	NA	NA
BPG	0.063215	0.037160
Gleisjer	0.009853	0.004831
Harvey	0.074325	0.002177
White SQ	0.072491	0.033070
Wh L&SQ	NA	NA
MaxVIF	35820824	3987961

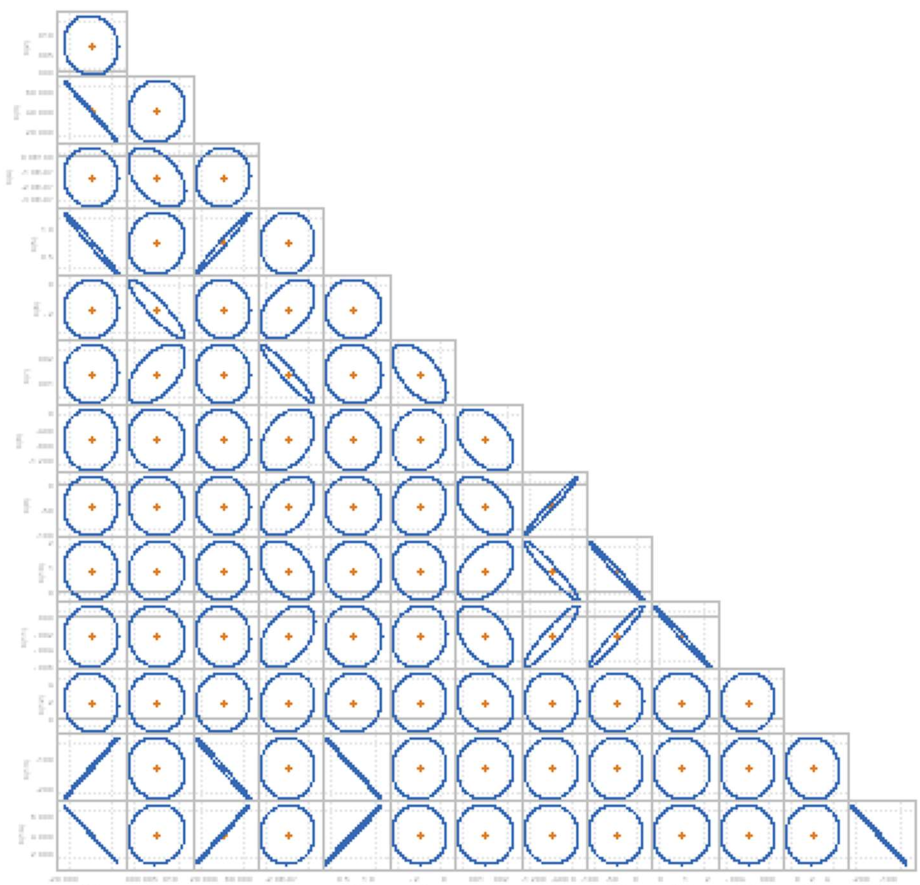
Dependent Variable: LOG(SALRY)
Method: Stepwise Regression
Date: 04/23/20 Time: 02:49
Sample: 1 108
Included observations: 108
Number of always included regressors: 1
Number of search regressors: 20
Selection method: Stepwise backwards
Stopping criterion: p-value forwards/backwards = 0.3/0.3

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
C	-11631.89	3680.135	-3.160724	0.0021
INT^2	0.006892	0.003041	2.266676	0.0257
1/AGE	40313.32	12576.00	3.205575	0.0018
YDS^2	-1.49E-07	8.11E-08	-1.834924	0.0697
AGE^2	0.718185	0.231242	3.105779	0.0025
INT	-0.180186	0.082765	-2.177085	0.0320
YDS	0.001366	0.000476	2.868345	0.0051
1/QBR	-690.2653	329.5260	-2.094722	0.0389
LOG(QBR)	-43.33122	23.39774	-1.851940	0.0672
QBR	0.822615	0.486233	1.691814	0.0940
QBR^2	-0.002429	0.001509	-1.609224	0.1109
LOG(CMP)	1.856335	1.375994	1.349086	0.1806
AGE	-133.4283	42.25077	-3.158008	0.0021
LOG(AGE)	4057.417	1270.557	3.193417	0.0019

R-squared	0.476644	Mean dependent var	15.87114
Adjusted R-squared	0.404265	S.D. dependent var	1.333263
S.E. of regression	1.029065	Akaike info criterion	3.015600
Sum squared resid	99.54354	Schwarz criterion	3.363284
Log likelihood	-148.8424	Hannan-Quinn criter.	3.156573
F-statistic	6.585385	Durbin-Watson stat	2.100906
Prob(F-statistic)	0.000000		

A06SDB3 passes the Ramsey on 2 terms, with the other two terms resulting in NA due to near singular matrix error, which I treat as neither a pass nor a fail. A06SDB3 has a potential multicollinearity problem as its Max VIF= 3987961. The confidence ellipses for A06SDB3 are shown in Figure 6. A06SDB3 uses multiple functional forms of the same variable (specifically for AGE, INT, and QBR). The multicollinearity between the functional forms and the constant terms is expected. All functional forms of AGE and the intercept C also exhibited multicollinearity. In the context of my data, I interpret the intercept as the minimum salary of an NFL quarterback with age and performance statistics of value 0. AGE is collinear with C because AGE increases over time as does the minimum salary value. Given the F-stat probability is 0, and the p-values for all but two of the independent variables are small and indicate significance, I will overlook A06SDB3's high Max VIF value.

Figure 6: Confidence Ellipses



Vertical C(2)-C(14); Horizontal C(1)-C(13)

To analyze the joint significance or insignificance of the variables in A06SDB3, I performed the Wald test. A06SDB3 is a subset of A06, so I used the output from A06 to confirm the excluded variables in A06SDB3. The Wald test in Figure 7 shows a high F-statistic probability of .9125, suggesting I can accept the maintained hypothesis that the excluded variables in A06SDB3 are jointly insignificant and can be excluded from the equation. I then performed the Wald test to confirm the significant variables in A06SDB3. The Wald test in Figure 8 shows a low F-statistic probability of 0, suggesting the independent variables in A06SDB3 are jointly significant and should be included.

Figure 7: Wald Test for Excluded Variables

Wald Test:
Equation: A06

Test Statistic	Value	df	Probability
F-statistic	0.342402	(6, 87)	0.9125
Chi-square	2.054413	6	0.9146

Null Hypothesis: C(2)=C(4)=C(6)=C(13)=C(16)=C(20)=C(21
)
Null Hypothesis Summary:

Figure 8: Wald Test for Significant Variables

Wald Test:
Equation: A06SDB3

Test Statistic	Value	df	Probability
F-statistic	6.585385	(13, 94)	0.0000
Chi-square	85.61001	13	0.0000

Null Hypothesis: C(2)=C(3)=C(4)=C(5)=C(6)=C(7)=C(8)=C(
9)=C(10)=C(11)=C(12)=C(13)=C(14)=0
Null Hypothesis Summary:

A06SDB3 fails the BPG, Gleisjer, Harvey, and White heteroskedasticity tests. To correct the misreported standard errors, I ran the Huber-White HAC test. Figure 9 shows A06SDB3 on the left and A06SDB3HAC on the right. After correction, QBR, which was previously significant at the .1 level, is now insignificant. 1/QBR remains significant at the .05 level, LOG(QBR) and YDS^2 remain significant at the .1 level, and the rest of the variables remain significant at the .01 level. The magnitudes of the coefficients for the independent variables were not changed after the correction. Assuming that the HAC standard errors are closer to the true standard errors, I will analyze A06SDB3HAC going forward.

Figure 9: Huber-White HAC Results

Dependent Variable: LOG(SALRY)
Method: Stepwise Regression
Date: 04/23/20 Time: 02:49
Sample: 1 108
Included observations: 108
Number of always included regressors: 1
Number of search regressors: 20
Selection method: Stepwise backwards
Stopping criterion: p-value forwards/backwards = 0.3/0.3

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
C	-11631.89	3680.135	-3.160724	0.0021
INT^2	0.006892	0.003041	2.266676	0.0257
1/AGE	40313.32	12576.00	3.205575	0.0018
YDS^2	-1.49E-07	8.11E-08	-1.834924	0.0697
AGE^2	0.718185	0.231242	3.105779	0.0025
INT	-0.180186	0.082765	-2.177085	0.0320
YDS	0.001366	0.000476	2.868345	0.0051
1/QBR	-690.2653	329.5260	-2.094722	0.0389
LOG(QBR)	-43.33122	23.39774	-1.851940	0.0672
QBR	0.822615	0.486233	1.691814	0.0940
QBR^2	-0.002429	0.001509	-1.609224	0.1109
LOG(CMP)	1.856335	1.375994	1.349086	0.1806
AGE	-133.4283	42.25077	-3.158008	0.0021
LOG(AGE)	4057.417	1270.557	3.193417	0.0019

R-squared	0.476644	Mean dependent var	15.87114
Adjusted R-squared	0.404265	S.D. dependent var	1.333263
S.E. of regression	1.029065	Akaike info criterion	3.015600
Sum squared resid	99.54354	Schwarz criterion	3.363284
Log likelihood	-148.8424	Hannan-Quinn criter.	3.156573
F-statistic	6.585385	Durbin-Watson stat	2.100906
Prob(F-statistic)	0.000000		

Dependent Variable: LOG(SALRY)
Method: Least Squares
Date: 04/25/20 Time: 01:50
Sample: 1 108
Included observations: 108
Huber-White-Hinkley (HC1) heteroskedasticity consistent standard errors and covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-11631.89	3035.693	-3.831709	0.0002
INT^2	0.006892	0.002422	2.846160	0.0054
1/AGE	40313.32	10393.84	3.878577	0.0002
YDS^2	-1.49E-07	8.05E-08	-1.848466	0.0677
AGE^2	0.718185	0.187161	3.837265	0.0002
INT	-0.180186	0.071370	-2.524684	0.0133
YDS	0.001366	0.000485	2.816206	0.0059
1/QBR	-690.2653	340.4198	-2.027688	0.0454
LOG(QBR)	-43.33122	25.22928	-1.717498	0.0892
QBR	0.822615	0.530909	1.549446	0.1246
QBR^2	-0.002429	0.001653	-1.469274	0.1451
LOG(CMP)	1.856335	1.383123	1.342133	0.1828
AGE	-133.4283	34.50147	-3.867322	0.0002
LOG(AGE)	4057.417	1044.857	3.883229	0.0002

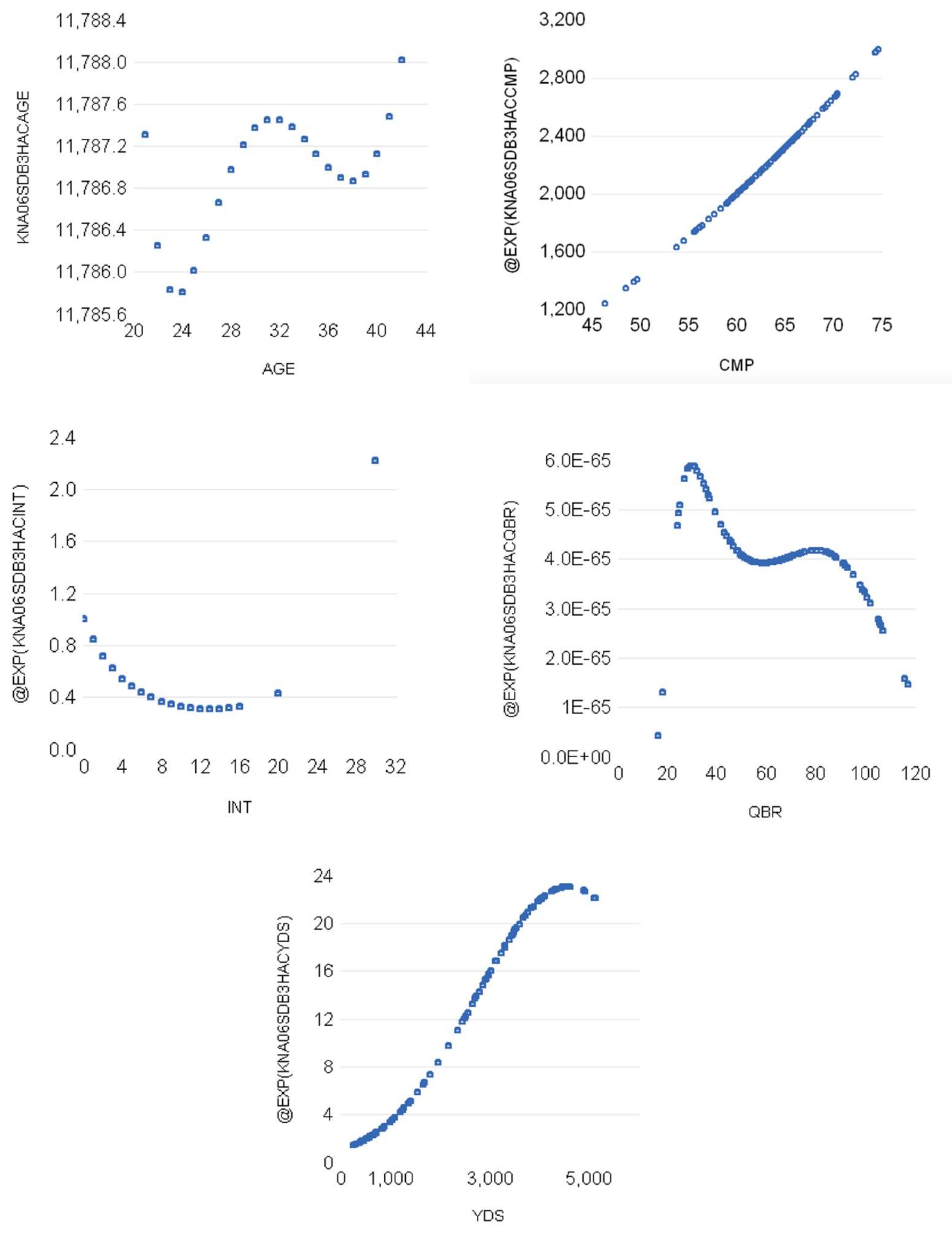
R-squared	0.476644	Mean dependent var	15.87114
Adjusted R-squared	0.404265	S.D. dependent var	1.333263
S.E. of regression	1.029065	Akaike info criterion	3.015600
Sum squared resid	99.54354	Schwarz criterion	3.363284
Log likelihood	-148.8424	Hannan-Quinn criter.	3.156573
F-statistic	6.585385	Durbin-Watson stat	2.100906
Prob(F-statistic)	0.000000	Wald F-statistic	11.22618
Prob(Wald F-statistic)	0.000000		

To further analyze the independent variables of A06SDB3HAC, I ran the slopes program. For all five variables (AGE, CMP, INT, QBR, YDS), the slope at the mean and the mean of the slopes are statistically significant at the .01 level. All variables excluding CMP have non-monotonic effects, as their minimum and maximum slopes are different signs. Figure 10 shows the slopes/elasticities results and Figure 11 shows the graphs. The graphs illustrate the univariate effect of the independent variables on SALRY.

Figure 10: Slopes and Elasticities Results

	SLOPE			SLOPE			SLOPE			SLOPE			SLOPE
AGE SL@M	766347.0		CMP SL@M	417628.9		INT SL@M	-1019712		QBR SL@M	39515.81		YDS SL@M	8398.747
AGE SL@M Pvalue	0.000000		CMP SL@M Pvalue	0.000000		INT SL@M Pvalue	0.000000		QBR SL@M Pvalue	0.000000		YDS SL@M Pvalue	0.000000
AGE mean	1056852.		CMP mean	413155.4		INT mean	-916230.4		QBR mean	-77561.22		YDS mean	5828.994
AGE mean Pvalue	0.000000		CMP mean Pvalue	0.000000		INT mean Pvalue	0.000000		QBR mean Pvalue	0.000000		YDS mean Pvalue	0.000000
AGE min	-30774004		CMP min	7139.244		INT min	-10414210		QBR min	-2817104		YDS min	-5290.969
AGE max	14975894		CMP max	2033267.		INT max	4882387.		QBR max	3096293.		YDS max	49327.45
	ELAST			ELAST			ELAST			ELAST			ELAST
AGE SL@M	1.651408		CMP SL@M	1.856335		INT SL@M	-0.563568		QBR SL@M	0.174597		YDS SL@M	1.538468
AGE mean	2.468482		CMP mean	1.856335		INT mean	-0.211713		QBR mean	-0.429742		YDS mean	0.859720

Figure 11: Graphs of AGE, CMP, INT, QBR, YDS



AGE

The graph of AGE shows varying effects on SALRY. Dividing it into four sections: there is an initial steep negative effect before age 24, followed by a positive effect until age 31, then another smaller decrease until age 38, then a final increase from age 38+. An explanation for the shape of the graph, using the four sections, is: younger players have to establish themselves before they earn big contracts (<24); established quarterbacks now are receiving better contracts (24-31); relatively older/ mid-30's aged quarterbacks are being replaced by younger stars (31-38), exceptions like Tom Brady or Drew Brees who are defying age and are compensated for their superior successes (38+). The slope at the mean is 766347, so for every year a quarterback gets older, salary would increase by $766,347, all else equal. This positive relationship matches my prediction.

CMP

The graph of CMP shows a positive linear relationship of CMP on SALRY. The slope at the mean is 417628.9, so for every percent increase in a quarterback's completion percentage, their salary would increase by $417,628.9, all else equal. This positive linear relationship matches my prediction.

INT

The graph of INT shows a negative effect on SALRY, leveling out at around 9 interceptions. The shape of the graph makes sense, as more interceptions continue to result in lower salary, and past a certain point, salary remains consistently low for quarterbacks who continue to throw picks. The slope at the mean is -1019712, so for every one additional interception thrown, salary would decrease, on average, by $1,019,712, all else equal. This negative relationship matches my prediction and emphasizes the importance of not throwing interceptions.

QBR

The graph of QBR shows varying effects. Based on my prediction, there should be a clear positive relationship between higher QBR and larger salary. There is potentially a data issue or an issue with the legitimacy of the performance statistic itself (which has actually drawn criticism). Despite the shape, the slope at the mean is still positive, with a value of 39515.81, so for every one unit increase in QBR, salary will increase by $39,515.81, all else equal.

YDS

The overall trend of the graph of YDS is positive and close to linear. The slope at the mean is 8398.747, so for every additional yard thrown, salary will increase by $8,398.75, all else equal. This positive relationship intuitively makes sense and matches my prediction.

5. Conclusion

The results of my regression analysis are satisfactory, as I have clarified many determinants of quarterback salary that agree with my predicted signs. The final regression A06SDB3HAC shows AGE, CMP, INT, QBR, and YDS are the most statistically significant factors in determining the salary of an NFL player. As expected, AGE, CMP, QBR, and YDS positively affect SALRY, while INT has a negative effect. In subsequent analysis and future research, I would consider using a larger data set for more accuracy. I would also consider substituting or adding additional variables to my data set to see if other performance metrics exhibit greater significance on quarterback salary.

While my results provide a good starting point for decision making, they cannot overcome front office incompetency, or help me understand why in 2017, Mike Glennon, who passed for only 833 yards, was earning more than Tom Brady. In my experience watching the NFL, teams who are underperforming will continue to overpay for average quarterbacks. I have yet to figure out whether that is just the nature of the position, if teams are exceedingly desperate, or if there are simply not enough good QB's to go around. I tend to believe it's the latter. Another interesting aspect of quarterback salaries that arose during my research was the effect of the NFL "hard cap" on contract formation. Contract workarounds through cash incentives, signing bonuses, and guarantees can help create immediate cap space and reduce the cap space toll through amortization over the life of the player's contract. A joint analysis exploring front office decision making and salary cap manipulation would be an interesting next step.

6. References

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7. Data Sources

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http://www.nfl.com/stats/

Salary Data:

https://www.spotrac.com/nfl/

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Inflation Data:

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