Background

Data for 5000 customers have been collected by Universal Bank, a relatively young bank growing rapidly in terms of overall customer acquisition. The data collected includes customer demographic information like age and income, their relationship with the bank if they are mortgage holders or have securities accounts, as well as customer's responses to the last personal loan campaign.

As per the bank, the majority of their customers are liability customers (or depositors) and the number of asset customers (or borrowers) is very small. The bank is looking for ways of converting its liability customers to personal customers, while retaining them as depositors too.

In the marketing campaign run by the bank last year for its liability customers, it witnessed a healthy conversion rate. Encouraged with this, bank wants to formulate campaigns with better target marketing.

To this end, a logistic regression model needs to be built which can classify whether a new customer will be accepting the loan offer.

Exploratory Data Analysis

All collected variables have been classified under 2 categories – Categorical and Numeric Variables

Categorical variables	**Numeric Variables**
Education	Age
Family	Experience
Personal Loan	Income
Securities Account	CCAvg
CD Account	Mortgage
Online	
CreditCard	

Exploratory Data Analysis has been performed to identify patterns with the help of Minitab. Statistical tools like Mean, Standard Deviation, Median, Skewness, distribution analysis, different types of charts and graphs have been used to try to portray picture of a typical Universal Bank customer.

Statistics

Variable	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum	Skewness
Age	45.338	0.162	11.463	23.000	35.000	45.000	55.000	67.000	-0.03
Experience	20.105	0.162	11.468	-3.000	10.000	20.000	30.000	43.000	-0.03
Income	73.774	0.651	46.034	8.000	39.000	64.000	98.000	224.000	0.84
CCAvg	1.9379	0.0247	1.7477	0.0000	0.7000	1.5000	2.5000	10.0000	1.60
Mortgage	56.50	1.44	101.71	0.00	0.00	0.00	101.00	635.00	2.10

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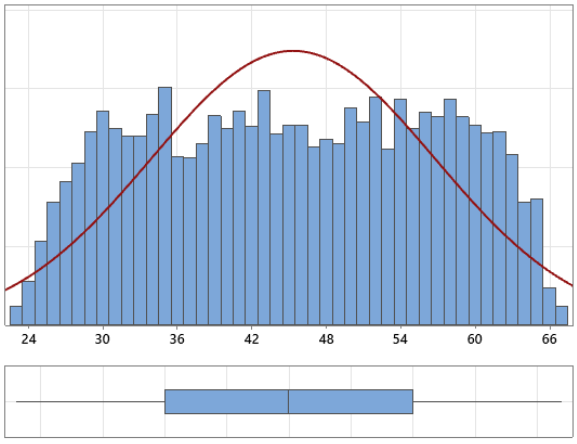
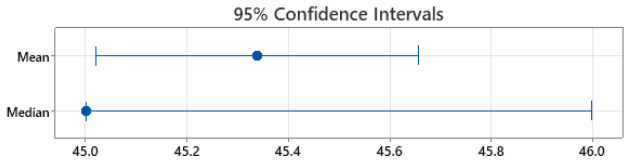
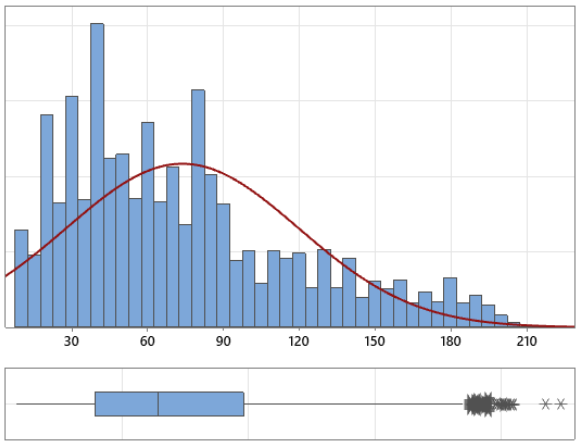
Summary Report for Age

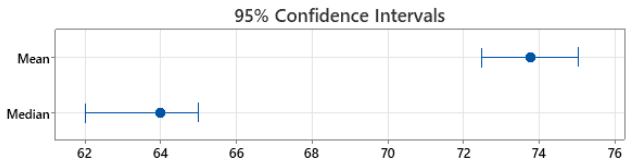




Anderson-Darling Normality Test	
A-Squared	50.64
P-Value	<0.005
Mean	45.338
StDev	11.463
Variance	131.404
Skewness	-0.02934
Kurtosis	-1.15307
N	5000
Minimum	23.000
1st Quartile	35.000
Median	45.000
3rd Quartile	55.000
Maximum	67.000
95% Confidence Interval for Mean	
45.021	45.656
95% Confidence Interval for Median	
45.000	46.000
95% Confidence Interval for StDev	
11.243	11.692

Summary Report for Income





Anderson-Darling Normality Test	
A-Squared	105.87
P-Value	<0.005
Mean	73.774
StDev	46.034
Variance	2119.104
Skewness	0.841339
Kurtosis	-0.044244
N	5000
Minimum	8.000
1st Quartile	39.000
Median	64.000
3rd Quartile	98.000
Maximum	224.000
95% Confidence Interval for Mean	
72.498	75.050
95% Confidence Interval for Median	
62.000	65.000
95% Confidence Interval for StDev	
45.149	46.954

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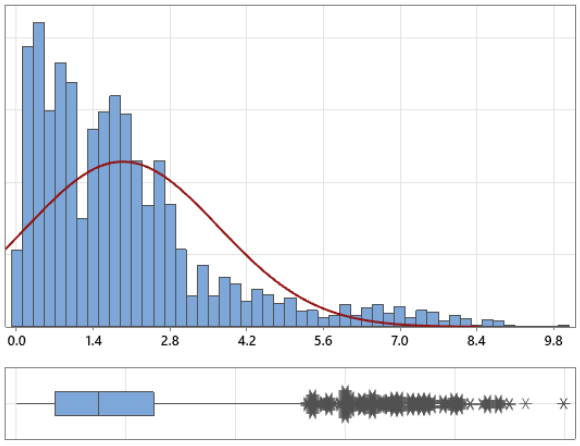
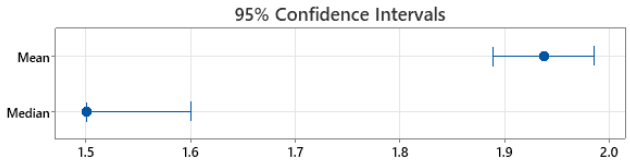
Summary Report for CCAvg





Anderson-Darling Normality Test

A-Squared	203.05
P-Value	<0.005
Mean	1.9379
StDev	1.7477
Variance	3.0543
Skewness	1.59844
Kurtosis	2.64671
N	5000
Minimum	0.0000
1st Quartile	0.7000
Median	1.5000
3rd Quartile	2.5000
Maximum	10.0000

95% Confidence Interval for Mean

1.8895	1.9864

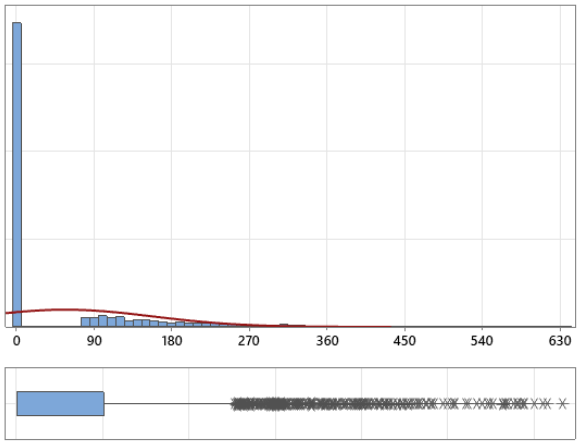
95% Confidence Interval for Median

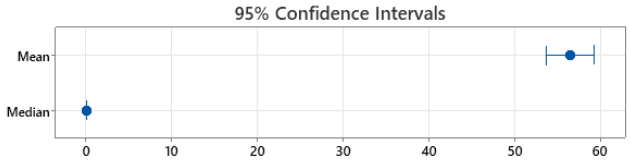
1.5000	1.6000

95% Confidence Interval for StDev

1.7141	1.7826

Summary Report for Mortgage





Anderson-Darling Normality Test

A-Squared	776.18
P-Value	<0.005
Mean	56.499
StDev	101.714
Variance	10345.698
Skewness	2.10400
Kurtosis	4.75680
N	5000
Minimum	0.000
1st Quartile	0.000
Median	0.000
3rd Quartile	101.000
Maximum	635.000

95% Confidence Interval for Mean

53.679	59.319

95% Confidence Interval for Median

0.000	0.000

95% Confidence Interval for StDev

99.759	103.748

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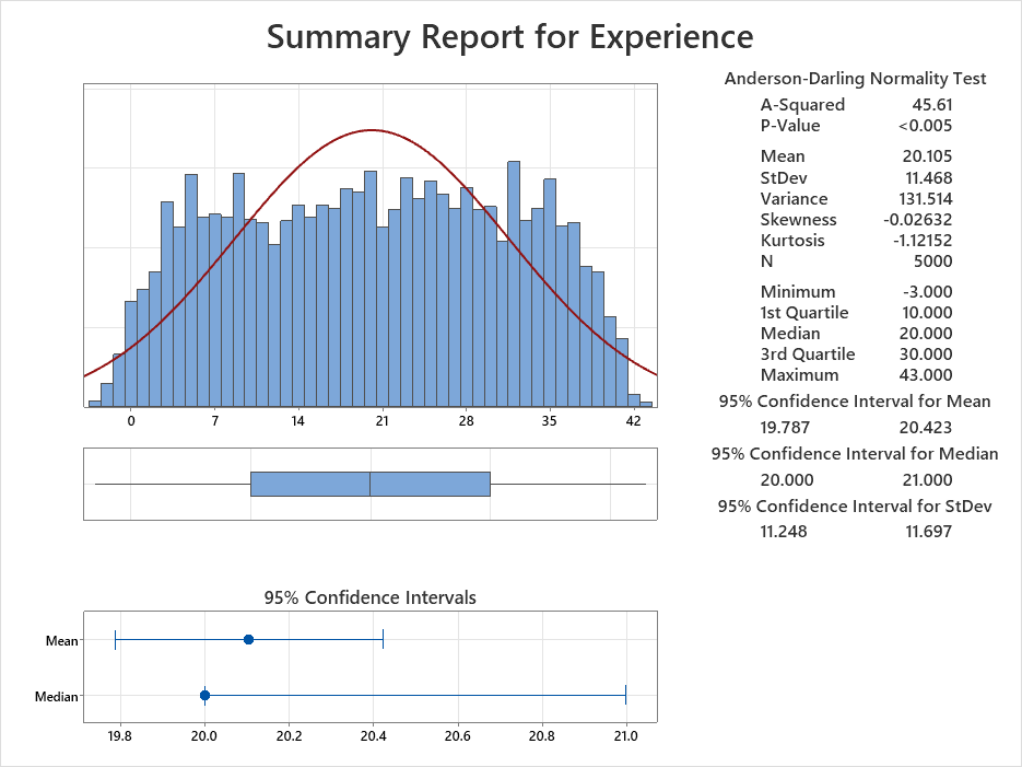

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Tally for Discrete Variables: Education, Family, Personal Loan, Securities Account, CD Account, Online, CreditCard

Tally

Education	Count	Percent
1	2096	41.92
2	1403	28.06
3	1501	30.02
N=	5000	

Family	Count	Percent
1	1472	29.44
2	1296	25.92
3	1010	20.20
4	1222	24.44
N=	5000	

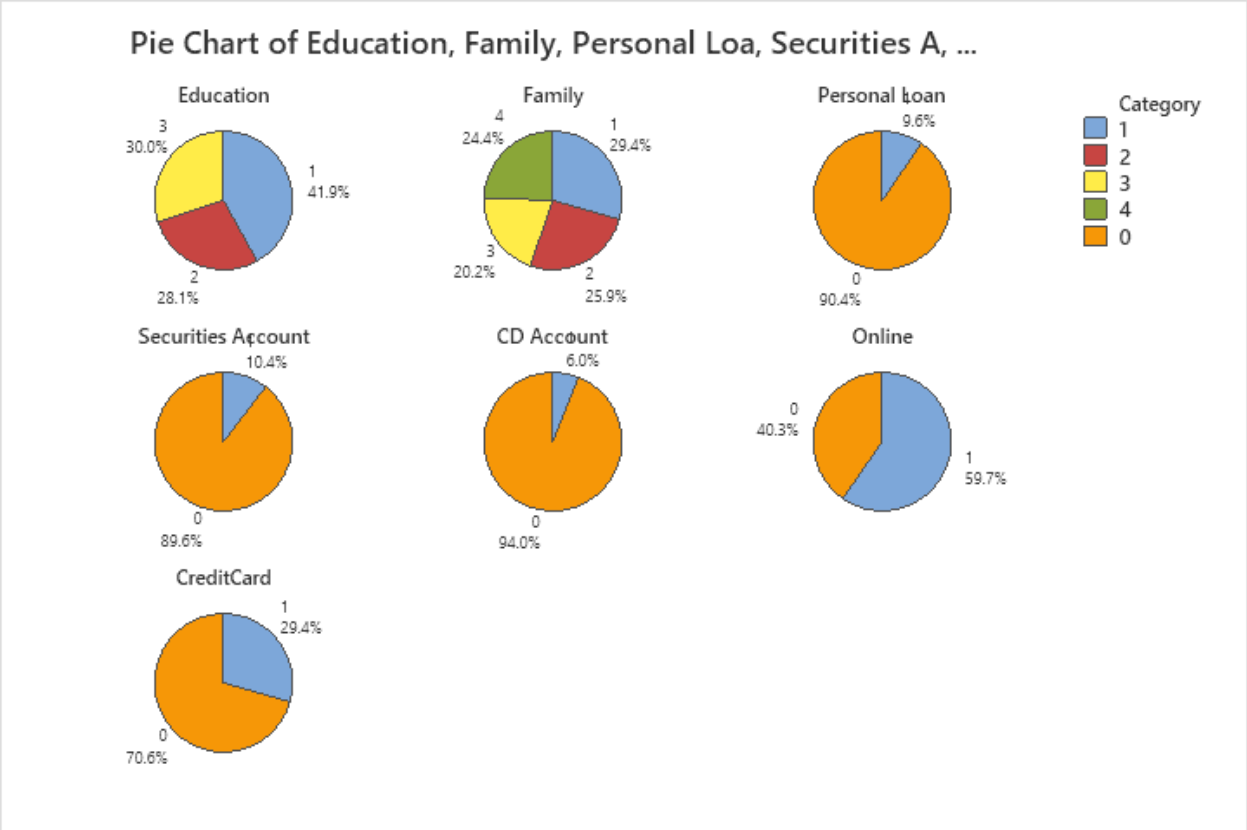
Personal Loan	Count	Percent
0	4520	90.40
1	480	9.60
N=	5000	

Securities Account	Count	Percent
0	4478	89.56
1	522	10.44
N=	5000	

CD Account	Count	Percent
0	4698	93.96
1	302	6.04
N=	5000	

Online	Count	Percent
0	2016	40.32
1	2984	59.68
N=	5000	

CreditCard	Count	Percent
0	3530	70.60
1	1470	29.40
N=	5000	



As per the analysis, it can be said that an average customer is of around 45 years of age having a professional experience of about 20 years. Almost 42% of the customers are undergrads. Also, a typical customer earns around $64,000 in annual income and has an average monthly credit card spending of approx. $1,500. Since income and credit card monthly spending data is right-skewed, we found median to be a better representative. Further, around 70% of the customers are without any mortgage.

As far as relationship with the bank is concerned, 1/10th of the customers have Securities Account with the bank while 6% hold Bank Certificate of Deposit. Further, 30 out of 100 people use Credit Card issued by Universal Bank. And it might also be interesting to note that more than 90% of the customers rejected the personal loan offered to them in the last campaign.

Linear Probability Model

We can try to predict whether a customer will accept the Personal Loan or not given certain conditions using a Linear Probability Model.

Personal Loan has been kept as response variable with continuous predictors being Income, Family, CCAvg, Mortgage, Age and Experience, while categorical predictors are Education and CD Account with confidence level as 95%.

Linear Regression model determined through Minitab are as below.

Regression Equation

Education	CD Account	
1	0	Personal Loan = -0.2072 + 0.003105 Income + 0.02996 Family + 0.01256 CCAvg + 0.000079 Mortgage - 0.00563 Age + 0.00616 Experience
1	1	Personal Loan = 0.0590 + 0.003105 Income + 0.02996 Family + 0.01256 CCAvg + 0.000079 Mortgage - 0.00563 Age + 0.00616 Experience
2	0	Personal Loan = -0.0596 + 0.003105 Income + 0.02996 Family + 0.01256 CCAvg + 0.000079 Mortgage - 0.00563 Age + 0.00616 Experience
2	1	Personal Loan = 0.2065 + 0.003105 Income + 0.02996 Family + 0.01256 CCAvg + 0.000079 Mortgage - 0.00563 Age + 0.00616 Experience
3	0	Personal Loan = -0.0494 + 0.003105 Income + 0.02996 Family + 0.01256 CCAvg + 0.000079 Mortgage - 0.00563 Age + 0.00616 Experience
3	1	Personal Loan = 0.2167 + 0.003105 Income + 0.02996 Family + 0.01256 CCAvg + 0.000079 Mortgage - 0.00563 Age + 0.00616 Experience

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-0.2072	0.0700	-2.96	0.003	
Income	0.003105	0.000097	32.12	0.000	1.86
Family	0.02996	0.00291	10.30	0.000	1.05
CCAvg	0.01256	0.00245	5.12	0.000	1.73
Mortgage	0.000079	0.000033	2.41	0.016	1.05
Age	-0.00563	0.00275	-2.04	0.041	93.66
Experience	0.00616	0.00275	2.24	0.025	93.56
Education					
2	0.14753	0.00823	17.93	0.000	1.28
3	0.15773	0.00821	19.22	0.000	1.33
CD Account					
1	0.2662	0.0140	19.07	0.000	1.04

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.230614	38.84%	38.73%	38.49%

Adjusted R-square of the model is 38.73% which implies the goodness of the fit. Also p-value for all variables is lesser than 0.05, which is our α, denoting that they are significant for our model. However, variables Age and Experience have VIF (Variance Inflation Factor) is 93.66 and 93.56, respectively, which is very high. This shows there is multi-collinearity between these two variables. Also p-value for Age is 0.041 which is very close to α, and that of Experience is 0.025.

To alleviate the problem of multi-collinearity, we tried fitting regression line by removing first only Age, then only Experience and then both Age and Experience. After considering adjusted R-square and

complexity of the line equations, we determined it's best to remove both Age and Experience as predictor variables. Resulting regression models are as below :

Regression Equation

Education	CD Account		
1	0	Personal Loan =	-0.3350 + 0.003110 Income + 0.02940 Family + 0.01217 CCAvg + 0.000079 Mortgage
1	1	Personal Loan =	-0.0676 + 0.003110 Income + 0.02940 Family + 0.01217 CCAvg + 0.000079 Mortgage
2	0	Personal Loan =	-0.1896 + 0.003110 Income + 0.02940 Family + 0.01217 CCAvg + 0.000079 Mortgage
2	1	Personal Loan =	0.0778 + 0.003110 Income + 0.02940 Family + 0.01217 CCAvg + 0.000079 Mortgage
3	0	Personal Loan =	-0.1815 + 0.003110 Income + 0.02940 Family + 0.01217 CCAvg + 0.000079 Mortgage
3	1	Personal Loan =	0.0860 + 0.003110 Income + 0.02940 Family + 0.01217 CCAvg + 0.000079 Mortgage

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-0.3350	0.0109	-30.71	0.000	
Income	0.003110	0.000097	32.21	0.000	1.85
Family	0.02940	0.00290	10.12	0.000	1.04
CCAvg	0.01217	0.00245	4.97	0.000	1.72
Mortgage	0.000079	0.000033	2.41	0.016	1.05
Education					
2	0.14539	0.00818	17.78	0.000	1.27
3	0.15357	0.00794	19.33	0.000	1.24
CD Account					
1	0.2674	0.0140	19.15	0.000	1.04

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.230756	38.74%	38.65%	38.44%

As can be seen from the above model, the adjusted R-square is 38.65% which is not very different from our earlier adjusted R-square of 38.73%, however VIF for all variables is close to 1 implying problem of multi-collinearity is not there anymore.

On the other hand, there are certain disadvantages while applying linear probability model to predict a categorical variable. Few of these shortcomings are :

1. It ignores the limitations of dependent variable, i.e. it might produce outcomes or predictions which are outside the possible range of values of dependent variable.
2. It lacks all the restrictions on the range of predicted values of the outcome.

For example, in the above case Personal Loan is a binary dependent variable with only two possible outcomes – 0 and 1 (No and Yes), but the model can predict values other than 0 and 1. It may even produce negative values.

Logistic Regression Model

Considering the shortcomings of fitting a Linear Probability model to a binary dependent variable, we have tried fitting a Logistic Regression Model to predict if the customer is like to accept the offer of a Personal Loan (which is our response variable) keeping Income, Family, CCAvg, Mortgage, Age and Experience as continuous predictors and Education and CD Account as categorical predictors.

Regression Equation

P(1) = exp(Y')/(1 + exp(Y'))

Education	CD Account	
1	0	Y' = -13.16 + 0.06005 Income + 0.6124 Family + 0.1561 CCAvg + 0.000793 Mortgage - 0.02479 Age + 0.03307 Experience
1	1	Y' = -10.64 + 0.06005 Income + 0.6124 Family + 0.1561 CCAvg + 0.000793 Mortgage - 0.02479 Age + 0.03307 Experience
2	0	Y' = -9.210 + 0.06005 Income + 0.6124 Family + 0.1561 CCAvg + 0.000793 Mortgage - 0.02479 Age + 0.03307 Experience
2	1	Y' = -6.692 + 0.06005 Income + 0.6124 Family + 0.1561 CCAvg + 0.000793 Mortgage - 0.02479 Age + 0.03307 Experience
3	0	Y' = -9.143 + 0.06005 Income + 0.6124 Family + 0.1561 CCAvg + 0.000793 Mortgage - 0.02479 Age + 0.03307 Experience
3	1	Y' = -6.626 + 0.06005 Income + 0.6124 Family + 0.1561 CCAvg + 0.000793 Mortgage - 0.02479 Age + 0.03307 Experience

Coefficients

Term	Coef	SE Coef	Z-Value	P-Value	VIF
Constant	-13.16	1.79	-7.35	0.000	
Income	0.06005	0.00289	20.75	0.000	2.62
Family	0.6124	0.0751	8.15	0.000	1.29
CCAvg	0.1561	0.0433	3.61	0.000	1.50
Mortgage	0.000793	0.000587	1.35	0.177	1.04
Age	-0.0248	0.0662	-0.37	0.708	102.11
Experience	0.0331	0.0658	0.50	0.615	101.93
Education					
2	3.946	0.264	14.92	0.000	2.69
3	4.012	0.261	15.38	0.000	2.73
CD Account					
1	2.518	0.243	10.38	0.000	1.07

Odds Ratios for Continuous Predictors

	Odds Ratio	95% CI
Income	1.0619	(1.0559, 1.0679)
Family	1.8449	(1.5923, 2.1375)
CCAvg	1.1689	(1.0739, 1.2724)
Mortgage	1.0008	(0.9996, 1.0019)
Age	0.9755	(0.8568, 1.1107)
Experience	1.0336	(0.9086, 1.1758)

Odds Ratios for Categorical Predictors

Level A	Level B	Odds Ratio	95% CI
Education			
2	1	50.4659	(30.1319, 84.5220)
3	1	52.6993	(31.8727, 87.1345)
3	2	1.0443	(0.7309, 1.4920)
CD Account			
1	0	12.7615	(7.9391, 20.5130)

Odds ratio for level A relative to level B

Model Summary

Deviance R-Sq	Deviance R-Sq(adj)	AIC	AICc	BIC	Area Under ROC Curve
61.47%	61.19%	1238.33	1238.38	1303.50	0.9585

Goodness-of-Fit Tests

Test	DF	Chi-Square	P-Value
Deviance	4990	1218.33	1.000
Pearson	4990	18577.70	0.000
Hosmer-Lemeshow	8	67.96	0.000

Analysis of Variance

		Wald Test	
Source	DF	Chi-Square	P-Value
Regression	9	563.65	0.000
Income	1	430.67	0.000
Family	1	66.47	0.000
CCAvg	1	13.01	0.000
Mortgage	1	1.82	0.177
Age	1	0.14	0.708
Experience	1	0.25	0.615
Education	2	262.34	0.000
CD Account	1	107.73	0.000

Adjusted deviance R-square is 61.2% which indicates that the model explains approximately 61.2% of deviance in the response. But coming to p-values, it is also seen that predictors Age and Experience have high p-values of 0.708 and 0.615 respectively, which are more than 0.05 level of significance. This implies that these variables are not significant while predicting the value of dependent variable. Also the VIF for both Age and Experience is more than 100 suggesting multi-collinearity between the two.

Hence, we would go ahead with fitting another model with the variables Age and Experience.

The revised model is as below :

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Regression Equation

P(1) = exp(Y')/(1 + exp(Y'))

Education	CD Account		
1	0	Y' =	-13.58 + 0.06003 Income + 0.6102 Family + 0.1505 CCAvg + 0.000766 Mortgage
1	1	Y' =	-11.05 + 0.06003 Income + 0.6102 Family + 0.1505 CCAvg + 0.000766 Mortgage
2	0	Y' =	-9.644 + 0.06003 Income + 0.6102 Family + 0.1505 CCAvg + 0.000766 Mortgage
2	1	Y' =	-7.110 + 0.06003 Income + 0.6102 Family + 0.1505 CCAvg + 0.000766 Mortgage
3	0	Y' =	-9.599 + 0.06003 Income + 0.6102 Family + 0.1505 CCAvg + 0.000766 Mortgage
3	1	Y' =	-7.065 + 0.06003 Income + 0.6102 Family + 0.1505 CCAvg + 0.000766 Mortgage

Coefficients

Term	Coef	SE Coef	Z-Value	P-Value	VIF
Constant	-13.585	0.557	-24.39	0.000	
Income	0.06003	0.00288	20.85	0.000	2.60
Family	0.6102	0.0751	8.12	0.000	1.29
CCAvg	0.1505	0.0431	3.49	0.000	1.49
Mortgage	0.000766	0.000587	1.31	0.192	1.04
Education					
2	3.941	0.264	14.91	0.000	2.69
3	3.986	0.258	15.46	0.000	2.67
CD Account					
1	2.533	0.242	10.47	0.000	1.07

Odds Ratios for Continuous Predictors

	Odds Ratio	95% CI
Income	1.0619	(1.0559, 1.0679)
Family	1.8408	(1.5888, 2.1327)
CCAvg	1.1625	(1.0682, 1.2650)
Mortgage	1.0008	(0.9996, 1.0019)

Odds Ratios for Categorical Predictors

Level A	Level B	Odds Ratio	95% CI
Education			
2	1	51.4596	(30.6541, 86.3863)
3	1	53.8331	(32.4738, 89.2410)
3	2	1.0461	(0.7319, 1.4953)
CD Account			
1	0	12.5961	(7.8393, 20.2392)

Odds ratio for level A relative to level B

Model Summary

Deviance R-Sq	Deviance R-Sq(adj)	AIC	AICc	BIC	Area Under ROC Curve
61.41%	61.19%	1236.17	1236.20	1288.31	0.9584

Goodness-of-Fit Tests

Test	DF	Chi-Square	P-Value
Deviance	4992	1220.17	1.000
Pearson	4992	17577.49	0.000
Hosmer-Lemeshow	8	69.22	0.000

Analysis of Variance

		Wald Test	
Source	DF	Chi-Square	P-Value
Regression	7	564.87	0.000
Income	1	434.70	0.000
Family	1	66.00	0.000
CCAvg	1	12.18	0.000
Mortgage	1	1.71	0.192
Education	2	263.07	0.000
CD Account	1	109.63	0.000

In the newer Logistic regression model, adjusted deviance R-square is 61.19% which is same as the one we had in the previous model. VIF for all the variables are low and close to 1 indicating non-collinearity among variables, however p-value for one of the variables Mortgage is 0.192 which is more than the level of significance of 0.05. This suggests that Mortgage as a predictor is not significant enough to cause variation in the dependent variable.

We will try to build another model by removing the variable Mortgage and see if it is a better model than the previous one.

Logistic Regression model to predict Personal Loan with continuous predictors Income, Family and CCAvg and categorical variables Education and CD Account is as below :

Regression Equation

P(1) = exp(Y')/(1 + exp(Y'))

Education	CD Account	
1	0	Y' = -13.55 + 0.06041 Income + 0.6138 Family + 0.1453 CCAvg
1	1	Y' = -11.01 + 0.06041 Income + 0.6138 Family + 0.1453 CCAvg
2	0	Y' = -9.632 + 0.06041 Income + 0.6138 Family + 0.1453 CCAvg
2	1	Y' = -7.086 + 0.06041 Income + 0.6138 Family + 0.1453 CCAvg
3	0	Y' = -9.589 + 0.06041 Income + 0.6138 Family + 0.1453 CCAvg
3	1	Y' = -7.043 + 0.06041 Income + 0.6138 Family + 0.1453 CCAvg

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Coefficients

Term	Coef	SE Coef	Z-Value	P-Value	VIF
Constant	-13.554	0.555	-24.41	0.000	
Income	0.06041	0.00287	21.06	0.000	2.59
Family	0.6138	0.0751	8.17	0.000	1.29
CCAvg	0.1453	0.0429	3.39	0.001	1.48
Education					
2	3.921	0.263	14.90	0.000	2.67
3	3.965	0.257	15.45	0.000	2.65
CD Account					
1	2.546	0.242	10.52	0.000	1.07

Odds Ratios for Continuous Predictors

	Odds Ratio	95% CI
Income	1.0623	(1.0563, 1.0683)
Family	1.8475	(1.5946, 2.1406)
CCAvg	1.1564	(1.0631, 1.2579)

Odds Ratios for Categorical Predictors

Level A	Level B	Odds Ratio	95% CI
Education			
2	1	50.4659	(30.1319, 84.5220)
3	1	52.6993	(31.8727, 87.1345)
3	2	1.0443	(0.7309, 1.4920)
CD Account			
1	0	12.7615	(7.9391, 20.5130)

Odds ratio for level A relative to level B

Model Summary

Deviance R-Sq	Deviance R-Sq(adj)	AIC	AICc	BIC	Area Under ROC Curve
61.36%	61.17%	1235.87	1235.89	1281.49	0.9584

Goodness-of-Fit Tests

Test	DF	Chi-Square	P-Value
Deviance	4993	1221.87	1.000
Pearson	4993	18208.73	0.000
Hosmer-Lemeshow	8	52.06	0.000

Analysis of Variance

		Wald Test	
Source	DF	Chi-Square	P-Value
Regression	6	566.01	0.000
Income	1	443.67	0.000
Family	1	66.77	0.000
CCAvg	1	11.46	0.001
Education	2	263.17	0.000
CD Account	1	110.57	0.000

This seems to be an optimal Binary Logistic Regression model. P-value of Regression is 0 which is lesser than α of 0.05 suggesting this model is statistically significant in predicting whether a customer will be accepting Personal Loan. P-values for all variables are also lesser than 0.05 indicating they are significant for the model. Adjusted deviance R-square suggests that 61.17% deviance in response variable can be explained with the model. VIF values for all variables are extremely low which means there is no issue of multi-collinearity among various predictors.

Odds ratio for all three continuous predictors is more than 1 implying better the chances of customer accepting Personal Loans with increase in income, family size or average monthly spending on credit cards. Coming to categorical predictors, customer with Advanced/Professional qualification is approximately 53 times and customer having a Graduate qualification is almost 50 times more likely to accept the loan as compared to customer with Undergrad qualification. Similarly, a customer already having a CD account with the bank is 12 times more like to accept the loan than customers who don't.

As far as goodness of fit is concerned, P-value for Deviance is 1 which is greater than 0.05 level of significance. This means there is not enough statistical evidence that to conclude that the model does not fit the data.

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