Proc LOGISTIC ROCs! Let's see how…

Colleen E McGahan
Lead Biostatistician, Surveillance & Outcomes Unit,
BC Cancer Agency, Vancouver

VanSUG/SUAVe Fall 2010

Receiver Operating Characteristic Curve

SUMMARY

- Brief overview of ROC curves
- ROC curve statements/options available in proc LOGISTIC
- Assumes use of SAS 9.2
- Assumes basic knowledge of logistic regression
- Does not cover model selection techniques

Introduction

- Logistic regression provides the estimated probability that the event of interest will happen.
- It can be used as a decision making tool whereby, given the probability of the event happening you decide to take action or not
- In order to do this, a probability cut-off is required – a probability higher than the cut-off you predict the event will happen, below the cut-off you predict the event won't happen.

- The accuracy of a predictive model can be assessed by comparing the predicted outcome with the actual known outcome.
- And the predicted outcome depends on the probability cut-off specified

For example,

Low grade breast cancer patients require radiation therapy (RT) after surgical removal of the tumour.

- Standard treatment: Whole breast
  - 4 to 6 weeks treatment
- New treatment: Partial breast
  - 1 week treatment
  - reduced side effects
  - takes 2 hours longer per patient to plan
  - some women are not suitable to receive a partial plan

The question is:

- Can these women be identified ahead of time so 2 hours is not spent on planning their treatment and they can make arrangements to be receiving treatment for 4-6 weeks.

Logistic Regression

- Model Outcome:
  - probability of not suitable for a Partial Plan
- Patient characteristics:
  - age
  - breast laterality
  - radiation dose volume
  - breast volume
  - surgical cavity volume
  - ratio of the surgical cavity volume to breast volume
  - ratio of radiation dose volume to breast volume
  - breast quadrant the tumour was located in
  - number of weeks between final breast surgery and the CT scan used for radiation planning purposes

Predictive Model Criteria

Want the predictive model to save planning a partial plan for at least 25% of patients that would not be suitable to have one.

Would accept a cost of not giving a partial plan to 5% of patients that could potentially receive one.

Probability cut-off for not suitable for Partial Plan = 0.2

PREDICTED OUTCOME	KNOWN OUTCOME: Not suitable	KNOWN OUTCOME: Suitable
Not suitable ($p \geq 0.2$)	TRUE POSITIVE rate=0.762 (n=48)	**FALSE POSITIVE rate=0.272** (n=72)
Suitable ($p < 0.2$)	FALSE NEGATIVE rate=0.238 (n=15)	TRUE NEGATIVE rate=0.728 (n=193)
	1	1

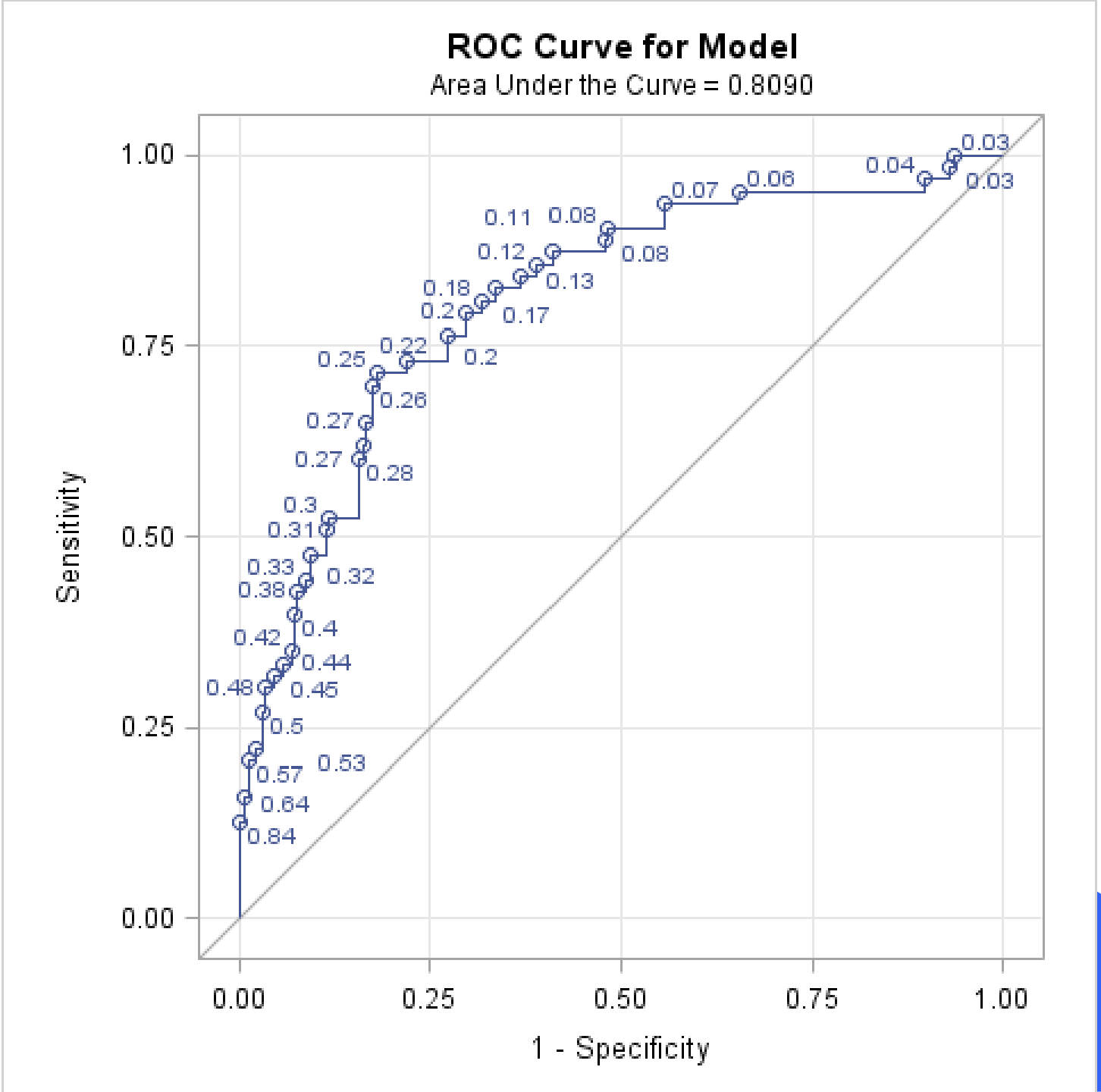
SENSITIVITY

Probability cut-off for not suitable for Partial Plan = 0.45

1-SPECIFICITY

PREDICTED OUTCOME	KNOWN OUTCOME: Not suitable	KNOWN OUTCOME: Suitable
Not suitable (p≥0.45)	TRUE POSITIVE rate=0.318 (n=20)	**FALSE POSITIVE rate=0.049** (n=13)
Suitable (p<0.45)	FALSE NEGATIVE rate=0.682 (n=43)	TRUE NEGATIVE rate=0.951 (n=252)
	1	1

SPECIFICITY


ROC Curve for Model
Area Under the Curve = 0.8090
Sensitivity
1 - Specificity
0.00
0.25
0.50
0.75
1.00
0.03
0.04
0.03
0.07
0.06
0.11
0.08
0.08
0.12
0.13
0.18
0.2
0.17
0.22
0.2
0.25
0.26
0.27
0.27
0.28
0.3
0.31
0.33
0.32
0.38
0.4
0.42
0.44
0.48
0.45
0.5
0.53
0.57
0.64
0.84

Proc LOGISTIC ROCs!
Let's see how…

Proc LOGISTIC ROCs!

- In order to produce a ROC curve in proc LOGISTIC, ODS graphics needs to be turned on.

```
ods graphics on;
```

The ROC curve can then be requested in the proc LOGISTIC statement using the PLOTS option.

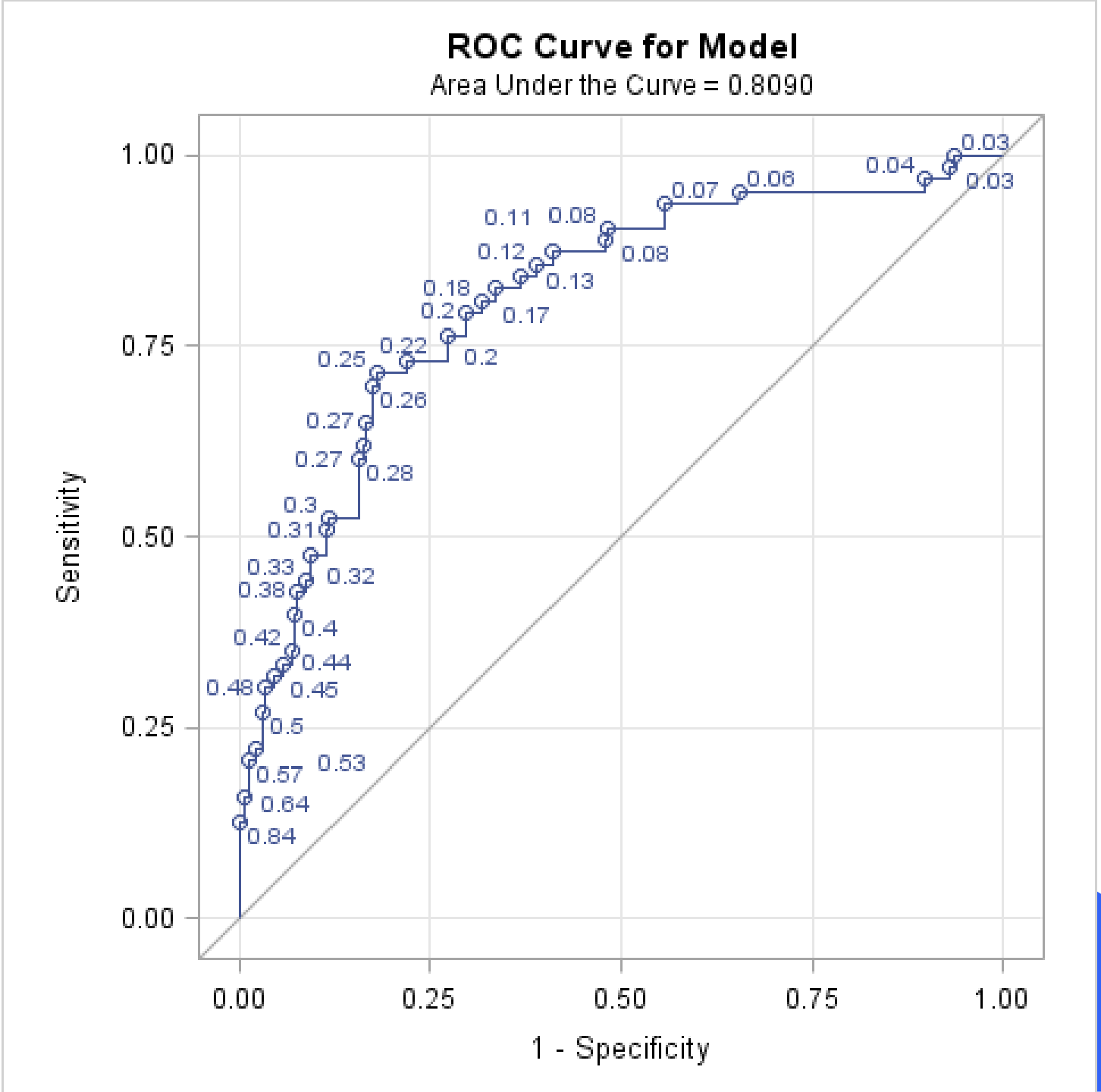
```
ods graphics on;
  proc logistic DATA=dset
      PLOTS(ONLY)=(ROC(ID=prob) EFFECT);
    CLASS quadrant / PARAM=glm;
    MODEL partplan = quadrant cavtobr;
  run;
```

The ONLY option suppresses the default plots and only the requested plots are displayed.

In this case only the ROC curve and the EFFECT plot will be displayed.

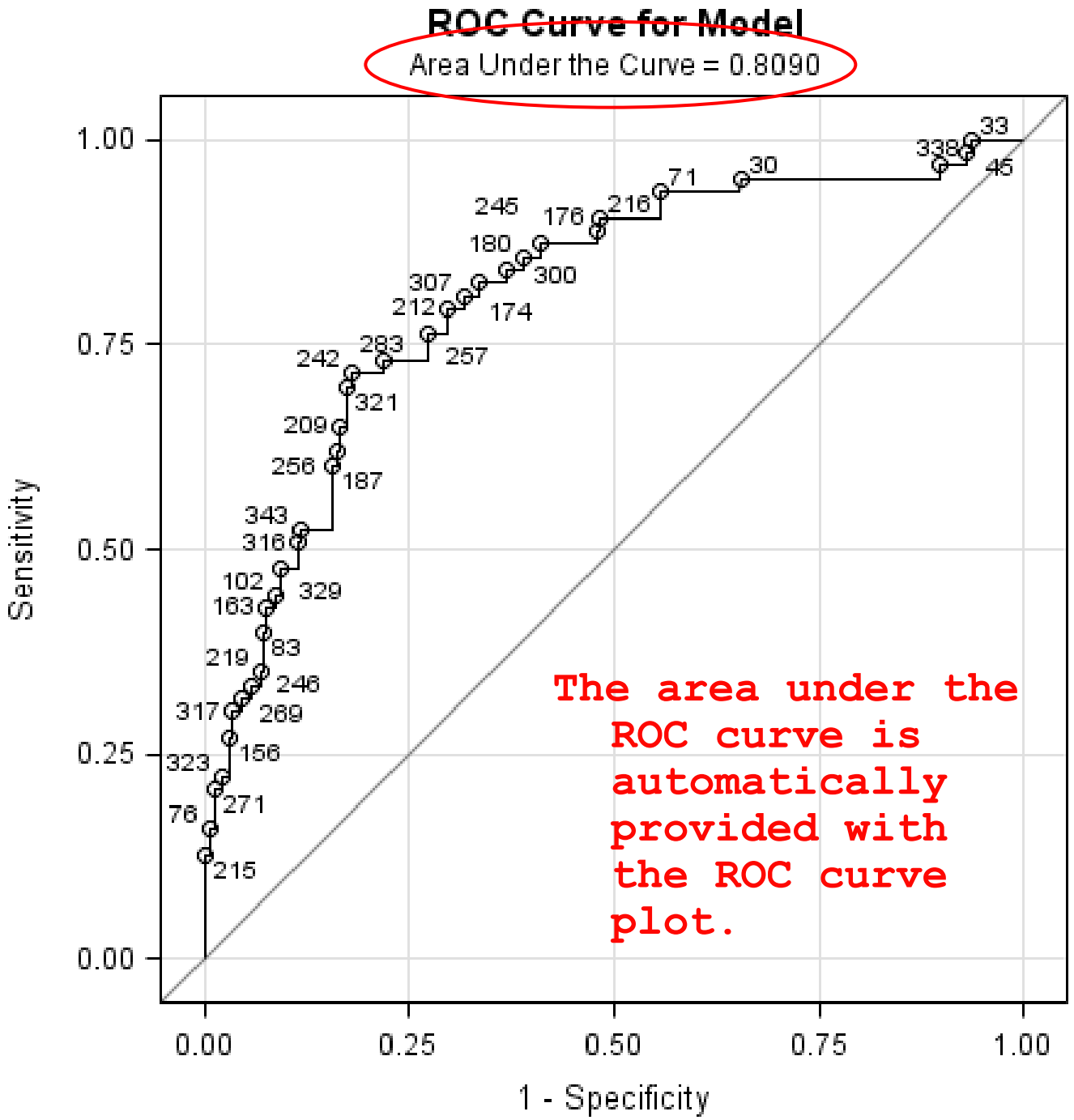
```
ods graphics on;
  proc logistic DATA=dset
       PLOTS(ONLY)=(ROC(ID=prob) EFFECT);
    CLASS quadrant / PARAM=glm;
    MODEL partplan = quadrant cavtobr;
  run;
```

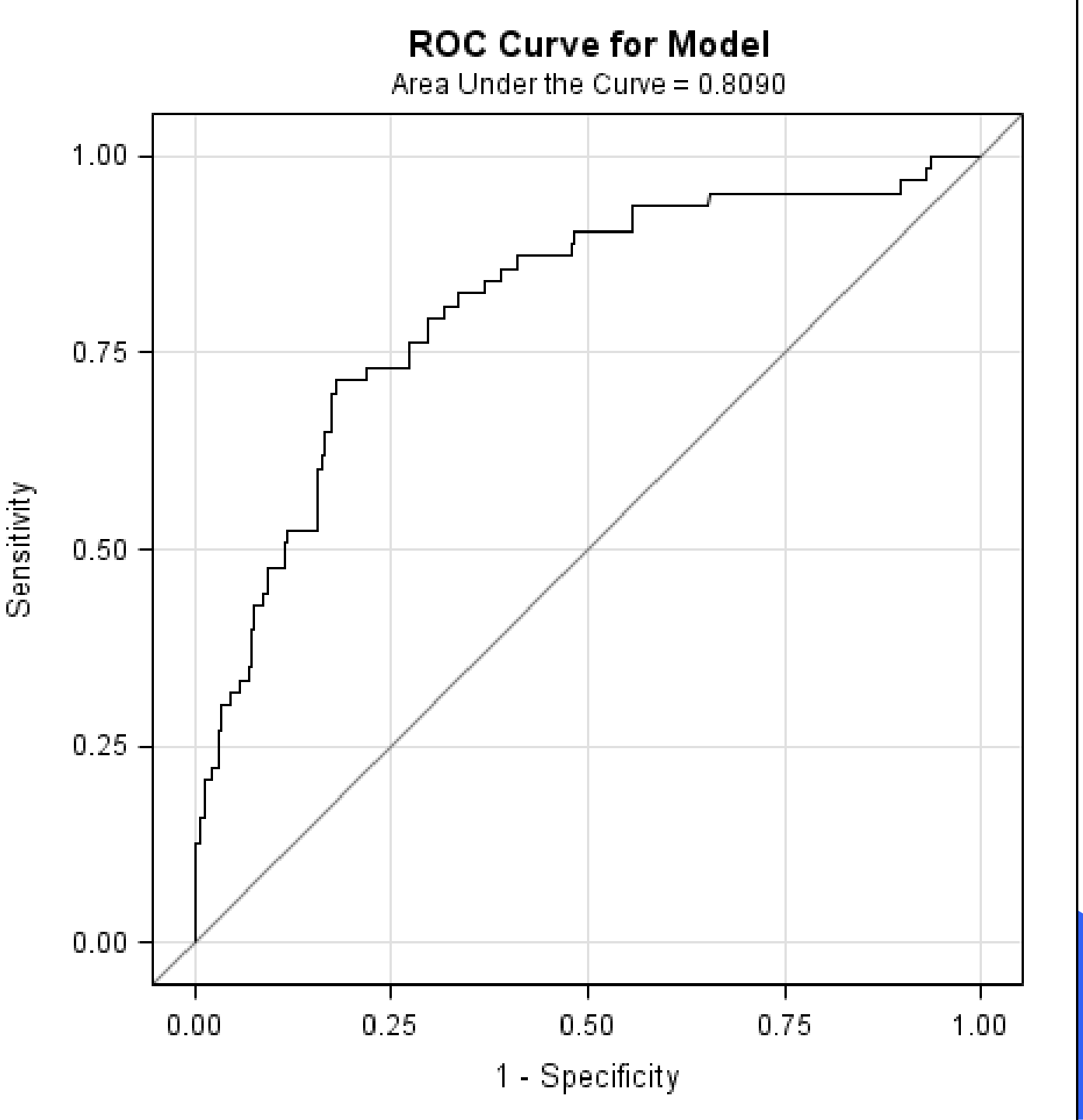
ID=prob option requests that the predicted probabilities are displayed on the ROC plot


ROC Curve for Model
Area Under the Curve = 0.8090
Sensitivity
1 - Specificity
0.00
0.25
0.50
0.75
1.00
0.03
0.04
0.03
0.07
0.06
0.11
0.08
0.08
0.12
0.13
0.18
0.2
0.17
0.22
0.2
0.25
0.26
0.27
0.27
0.28
0.3
0.31
0.33
0.32
0.38
0.4
0.42
0.44
0.48
0.45
0.5
0.53
0.57
0.64
0.84

```
ods graphics on;
  proc logistic DATA=dset
       PLOTS(ONLY)=(ROC(ID=casenum) EFFECT);
    CLASS quadrant / PARAM=glm;
    MODEL partplan = quadrant cavtobr;
  run;
```

- ID=prob option requests that the predicted probabilities are displayed on the ROC plot
- If instead you wanted the observation number displayed, ID=casenum could be used.


ROC Curve for Model
Area Under the Curve = 0.8090
Sensitivity
1 - Specificity
0.00
0.25
0.50
0.75
1.00
The area under the ROC curve is automatically provided with the ROC curve plot.


ROC Curve for Model
Area Under the Curve = 0.8090
Sensitivity
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
1 - Specificity

```
ods graphics on;
  proc logistic DATA=dset;
    CLASS quadrant / PARAM=glm;
    MODEL partplan = quadrant cavtobr /
                          OUTROC=dset_name;
  run;
```

The option OUTROC= produces an output dataset that holds all the data that is used to produce the ROC plot.

VIEWTABLE: Receiver Operating Characteristics

	Probability Level	No. of Correctly Predicted Events	No. of Correctly Predicted Nonevents	No. of Nonevents Predicted as Events	No. of Events Predicted as Nonevents	Sensitivity	1 - Specificity
1	0.9996098411	1	265	0	62	0.0158730159	0
2	0.9890844658	2	265	0	61	0.0317460317	0
3	0.9756835305	3	265	0	60	0.0476190476	0
4	0.9434518496	4	265	0	59	0.0634920635	0
5	0.9353801923	5	265	0	58	0.0793650794	0
6	0.9236486803	6	265	0	57	0.0952380952	0
7	0.8919756696	7	265	0	56	0.1111111111	0
8	0.8353664426	8	265	0	55	0.126984127	0
9	0.8003994659	8	264	1	55	0.126984127	0.0037735849
10	0.783013909	8	263	2	55	0.126984127	0.0075471698
11	0.7264493317	9	263	2	54	0.1428571429	0.0075471698
12	0.6431072195	10	263	2	53	0.1587301587	0.0075471698
13	0.6234507017	10	262	3	53	0.1587301587	0.0113207547
14	0.6044447286	11	262	3	52	0.1746031746	0.0113207547
15	0.5855376375	12	262	3	51	0.1904761905	0.0113207547
16	0.5700183463	13	262	3	50	0.2063492063	0.0113207547
17	0.568987181	13	261	4	50	0.2063492063	0.0150943396
18	0.5599176113	13	260	5	50	0.2063492063	0.0188679245
19	0.5499463684	13	259	6	50	0.2063492063	0.0226415094
20	0.5310464599	14	259	6	49	0.2222222222	0.0226415094
21	0.5069313824	14	258	7	49	0.2222222222	0.0264150943
22	0.5020175756	14	257	8	49	0.2222222222	0.0301886792
23	0.5000354978	15	257	8	48	0.2380952381	0.0301886792
24	0.4994565271	16	257	8	47	0.253968254	0.0301886792
25	0.4951223106	17	257	8	46	0.2698412698	0.0301886792
26	0.4930484167	17	256	9	46	0.2698412698	0.0339622642
27	0.4924959025	18	256	9	45	0.2857142857	0.0339622642
28	0.4760355107	19	256	9	44	0.3015873016	0.0339622642
29	0.4699692178	19	255	10	44	0.3015873016	0.0377358491
30	0.4679401888	19	254	11	44	0.3015873016	0.041509434

```
ods graphics on;
  proc logistic DATA=dset;
    CLASS quadrant / PARAM=glm;
    MODEL partplan = quadrant cavtobr /
                          OUTROC=dset_name;
  run;
```

If the PLOTS option is not specified the OUTROC= option will still produce a ROC curve.

But, the predicted probabilities or observation number will not be shown on the plot.

The OUTROC dataset is not provided if you only request the ROC curve using the PLOTS option.

```
ods graphics on;
Ods output classification=classification_table;
  proc logistic DATA=dset;
    CLASS quadrant / PARAM=glm;
    MODEL partplan = quadrant cavtobr /
                     OUTROC=dset_name
                     CTABLE PPROB=(.3 .5 to .9 by .1);
  run;
```

CTABLE with PPROB= option can be used to obtain the Classification Table

Can also request the classification table dataset with the ods output statement

If PPROB= is not specified then the default is to show classifications for probability cut-offs from 0 to 1 at intervals of .02

Output - (Untitled)

15:31 Sunday, November 14, 2010 110

Classification Table

Prob Level	Correct Event	Correct Non-Event	Incorrect Event	Incorrect Non-Event	Percentages Correct	Sensi-tivity	Speci-ficity	False POS	False NEG
0.300	28	227	38	35	77.7	44.4	85.7	57.6	13.4
0.500	13	256	9	50	82.0	20.6	96.6	40.9	16.3
0.600	10	262	3	53	82.9	15.9	98.9	23.1	16.8
0.700	9	263	2	54	82.9	14.3	99.2	18.2	17.0
0.800	8	263	2	55	82.6	12.7	99.2	20.0	17.3
0.900	6	265	0	57	82.6	9.5	100.0	0.0	17.7

VIEWTABLE: Classification Table

	Probability Level	Number of Correct Events	Number of Correct Nonevents	Number of Incorrect Events	Number of Incorrect Nonevents	Percentage of Correct Classification	Sensitivity in Percent	Specificity in Percent	Percentage of False Positive	Percentage of False Negative
1	0.300	28	227	38	35	77.7	44.4	85.7	57.6	13.4
2	0.500	13	256	9	50	82.0	20.6	96.6	40.9	16.3
3	0.600	10	262	3	53	82.9	15.9	98.9	23.1	16.8
4	0.700	9	263	2	54	82.9	14.3	99.2	18.2	17.0
5	0.800	8	263	2	55	82.6	12.7	99.2	20.0	17.3
6	0.900	6	265	0	57	82.6	9.5	100.0	0.0	17.7

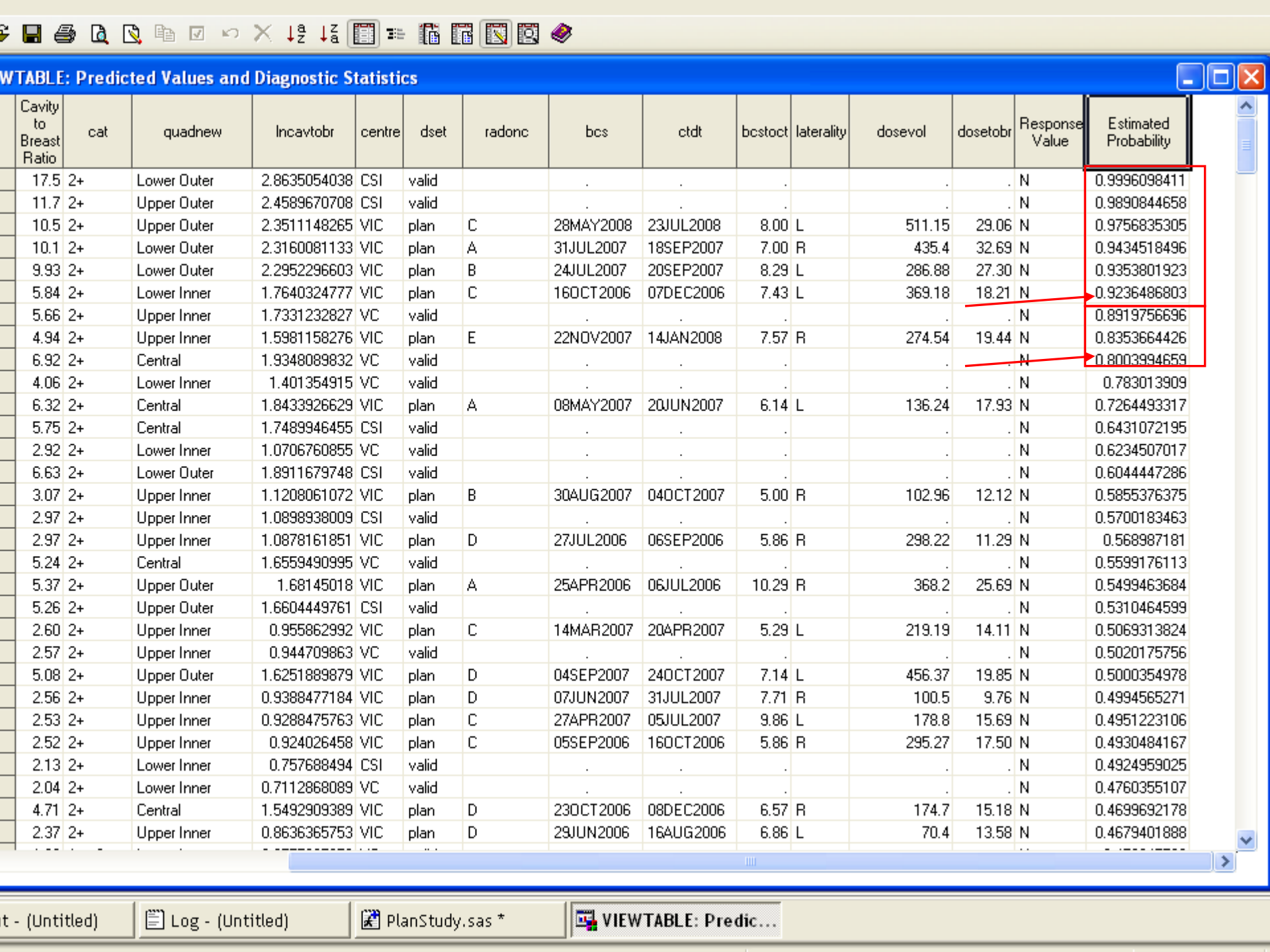
```
ods graphics on;
  proc logistic DATA=dset
   PLOTS(ONLY)=(ROC(ID=prob));
     CLASS quadrant / PARAM=glm;
    MODEL partplan = quadrant cavtobr /
                          OUTROC=dset_name
                          ROCEPS=0.1;
  run;
```

The ROCEPS= option requires a number between 0 and 1 which specifies the criterion for how you want the event probabilities grouped on the ROC curve or output into the OUTROC dataset.

(The default is 1E-8)

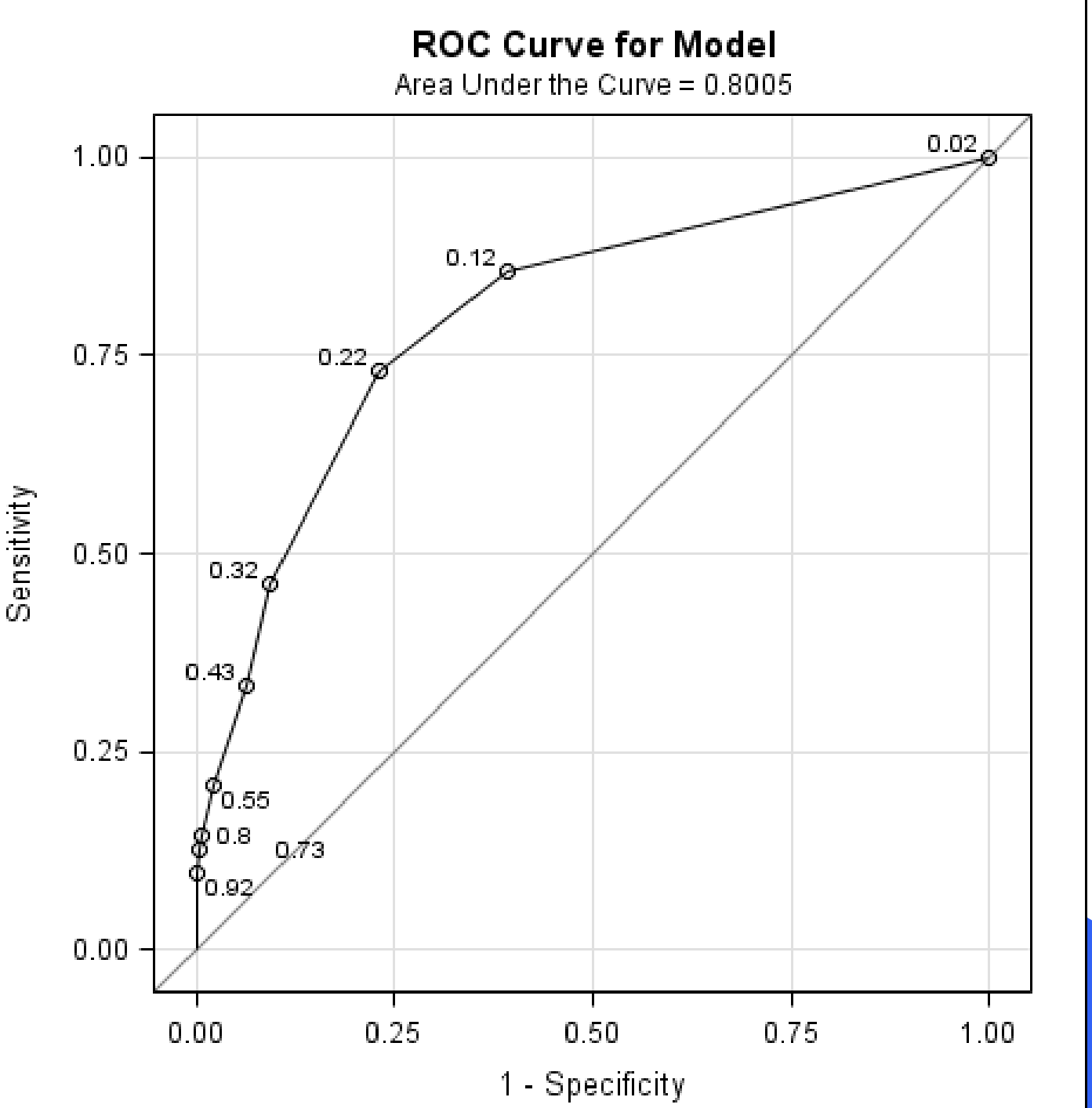
The AUC is adjusted accordingly.

- In each group, the difference between the largest and the smallest estimated event probabilities does not exceed the given value.
- The smallest estimated probability in each group serves as a cut point for predicting an event response.
- The OUTROC= option needs to be specified for ROCEPS= to have an effect



VIEWTABLE: Predicted Values and Diagnostic Statistics

Cavity to Breast Ratio	cat	quadnew	lncavtobr	centre	dset	radonc	bcs	ctdt	bcstoct	laterality	dosevol	dosetobr	Response Value	Estimated Probability
17.5	2+	Lower Outer	2.8635054038	CSI	valid		.	.	.		.	.	N	0.9996098411
11.7	2+	Upper Outer	2.4589670708	CSI	valid		.	.	.		.	.	N	0.9890844658
10.5	2+	Upper Outer	2.3511148265	VIC	plan	C	28MAY2008	23JUL2008	8.00	L	511.15	29.06	N	0.9756835305
10.1	2+	Lower Outer	2.3160081133	VIC	plan	A	31JUL2007	18SEP2007	7.00	R	435.4	32.69	N	0.9434518496
9.93	2+	Lower Outer	2.2952296603	VIC	plan	B	24JUL2007	20SEP2007	8.29	L	286.88	27.30	N	0.9353801923
5.84	2+	Lower Inner	1.7640324777	VIC	plan	C	16OCT2006	07DEC2006	7.43	L	369.18	18.21	N	0.9236486803
5.66	2+	Upper Inner	1.7331232827	VC	valid		.	.	.		.	.	N	0.8919756696
4.94	2+	Upper Inner	1.5981158276	VIC	plan	E	22NOV2007	14JAN2008	7.57	R	274.54	19.44	N	0.8353664426
6.92	2+	Central	1.9348089832	VC	valid		.	.	.		.	.	N	0.8003994659
4.06	2+	Lower Inner	1.401354915	VC	valid		.	.	.		.	.	N	0.783013909
6.32	2+	Central	1.8433926629	VIC	plan	A	08MAY2007	20JUN2007	6.14	L	136.24	17.93	N	0.7264493317
5.75	2+	Central	1.7489946455	CSI	valid		.	.	.		.	.	N	0.6431072195
2.92	2+	Lower Inner	1.0706760855	VC	valid		.	.	.		.	.	N	0.6234507017
6.63	2+	Lower Outer	1.8911679748	CSI	valid		.	.	.		.	.	N	0.6044447286
3.07	2+	Upper Inner	1.1208061072	VIC	plan	B	30AUG2007	04OCT2007	5.00	R	102.96	12.12	N	0.5855376375
2.97	2+	Upper Inner	1.0898938009	CSI	valid		.	.	.		.	.	N	0.5700183463
2.97	2+	Upper Inner	1.0878161851	VIC	plan	D	27JUL2006	06SEP2006	5.86	R	298.22	11.29	N	0.568987181
5.24	2+	Central	1.6559490995	VC	valid		.	.	.		.	.	N	0.5599176113
5.37	2+	Upper Outer	1.68145018	VIC	plan	A	25APR2006	06JUL2006	10.29	R	368.2	25.69	N	0.5499463684
5.26	2+	Upper Outer	1.6604449761	CSI	valid		.	.	.		.	.	N	0.5310464599
2.60	2+	Upper Inner	0.955862992	VIC	plan	C	14MAR2007	20APR2007	5.29	L	219.19	14.11	N	0.5069313824
2.57	2+	Upper Inner	0.944709863	VC	valid		.	.	.		.	.	N	0.5020175756
5.08	2+	Upper Outer	1.6251889879	VIC	plan	D	04SEP2007	24OCT2007	7.14	L	456.37	19.85	N	0.5000354978
2.56	2+	Upper Inner	0.9388477184	VIC	plan	D	07JUN2007	31JUL2007	7.71	R	100.5	9.76	N	0.4994565271
2.53	2+	Upper Inner	0.9288475763	VIC	plan	C	27APR2007	05JUL2007	9.86	L	178.8	15.69	N	0.4951223106
2.52	2+	Upper Inner	0.924026458	VIC	plan	C	05SEP2006	16OCT2006	5.86	R	295.27	17.50	N	0.4930484167
2.13	2+	Lower Inner	0.757688494	CSI	valid		.	.	.		.	.	N	0.4924959025
2.04	2+	Lower Inner	0.7112868089	VC	valid		.	.	.		.	.	N	0.4760355107
4.71	2+	Central	1.5492909389	VIC	plan	D	23OCT2006	08DEC2006	6.57	R	174.7	15.18	N	0.4699692178
2.37	2+	Upper Inner	0.8636365753	VIC	plan	D	29JUN2006	16AUG2006	6.86	L	70.4	13.58	N	0.4679401888


ROC Curve for Model
Area Under the Curve = 0.8005
Sensitivity
1 - Specificity
1.00
0.75
0.50
0.25
0.00
0.00
0.25
0.50
0.75
1.00
0.02
0.12
0.22
0.32
0.43
0.55
0.8
0.73
0.92

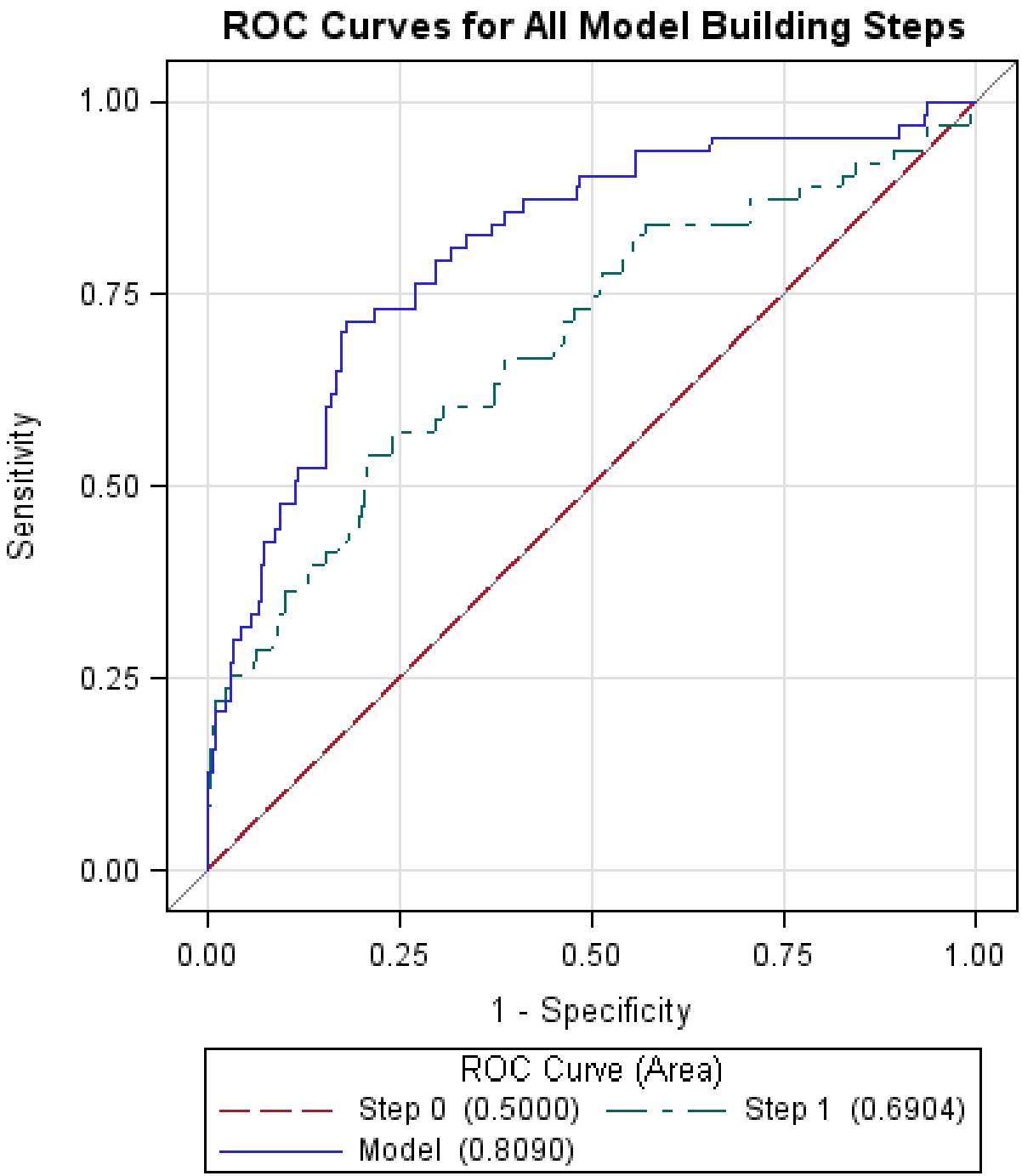
```
ods graphics on;
  proc logistic DATA=dset PLOTS(ONLY)=(ROC(ID=prob));
    CLASS quadrant / PARAM=glm;
    MODEL partplan = quadrant cavtobr /
                          SELECTION=forward;
  run;
```

If an automated model selection method is specified in the MODEL statement,

and a ROC plot has been requested in the PLOTS option,

or the OUTROC= option has been specified in the MODEL statement

then a ROC plot for the final selected model is provided as well as an overlaid plot of each of the ROC curves for each stage of the model selection process.



Although the PLOTS option requests predicted probabilities to be shown, it does not include them on this overlaid plot. One can imagine how messy it could get.

```
ods graphics on;
  proc logistic DATA=dset PLOTS(ONLY)=(ROC(ID=prob));
       CLASS quadrant / PARAM=glm;
       MODEL partplan = quadrant cavtobr / NOFIT;
       ROC 'Quadrant' quadrant;
       ROC 'Cavity to Breast Ratio' cavtobr;
  run;
```

- If an automated model selection process is not used then the ROC statement can be used to obtain a ROC curve for each predictor of interest
- A ROC curve in which all of them are overlaid is also provided
- Effects used in any of the ROC statements must be specified in the MODEL statement

```
ods graphics on;
  proc logistic DATA=dset PLOTS(ONLY)=(ROC(ID=prob));
       CLASS quadrant / PARAM=glm;
       MODEL partplan = quadrant cavtobr / NOFIT;
       ROC 'Quadrant' quadrant;
       ROC 'Cavity to Breast Ratio' cavtobr;
  run;
```

- The NOFIT option can be specified to instruct SAS to ignore fitting the model specified in the MODEL statement.
- A model for each of the specified ROC statements is fitted.
- An observation with a missing value for any of the variables specified in the MODEL statement is excluded, even if it is missing for a variable not specified in the ROC statement. This gives a common sample size for each ROC model.

SAS

File Edit View Tools Solutions Window Help

Results

- Results
  - Logistic: The SAS System
    - Model Information
    - Observations Summary
    - Response Profile
    - Class Level Information
    - Global Score
    - ROC Model: Quadrant
      - Convergence Status
      - Fit Statistics
      - Global Tests
      - Type 3 Tests
      - Parameter Estimates
      - Odds Ratios
      - ROC Curve
    - ROC Model: Cavity to Breast Volume Ra
      - Convergence Status
      - Fit Statistics
      - Global Tests
      - Parameter Estimates
      - Odds Ratios
      - ROC Curve
    - ROC Comparisons
      - ROC Curves
      - ROC Association Statistics

Output - (Untitled)

The SAS System 15:42 Friday, November

The LOGISTIC Procedure

Model Information

Data Set	WORK.TEMP
Response Variable	partplan Partial Plan Suitable
Number of Response Levels	2
Model	binary logit
Optimization Technique	Fisher's scoring

Number of Observations Read	347
Number of Observations Used	328

Response Profile

Ordered Value	partplan	Total Frequency
1	N	63
2	Y	265

Probability modeled is partplan='N'.

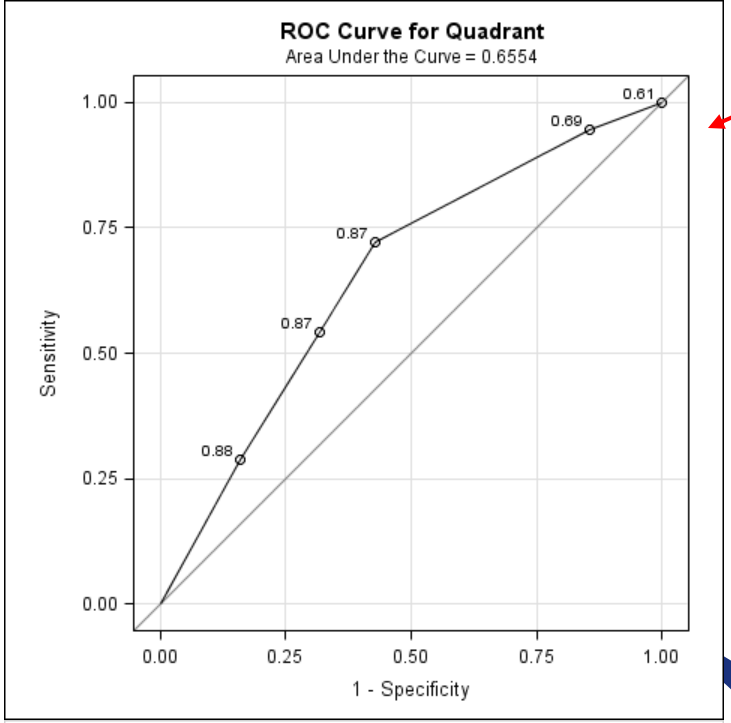
NOTE: 19 observations were deleted due to missing values for the response or explanat
variables.

Class Level Information

Class	Value	Design Variables				
quadrant	Central	1	0	0	0	0
	Lower Inner	0	1	0	0	0
	Lower Outer	0	0	1	0	0
	Upper Inner	0	0	0	1	0
	Upper Outer	0	0	0	0	1

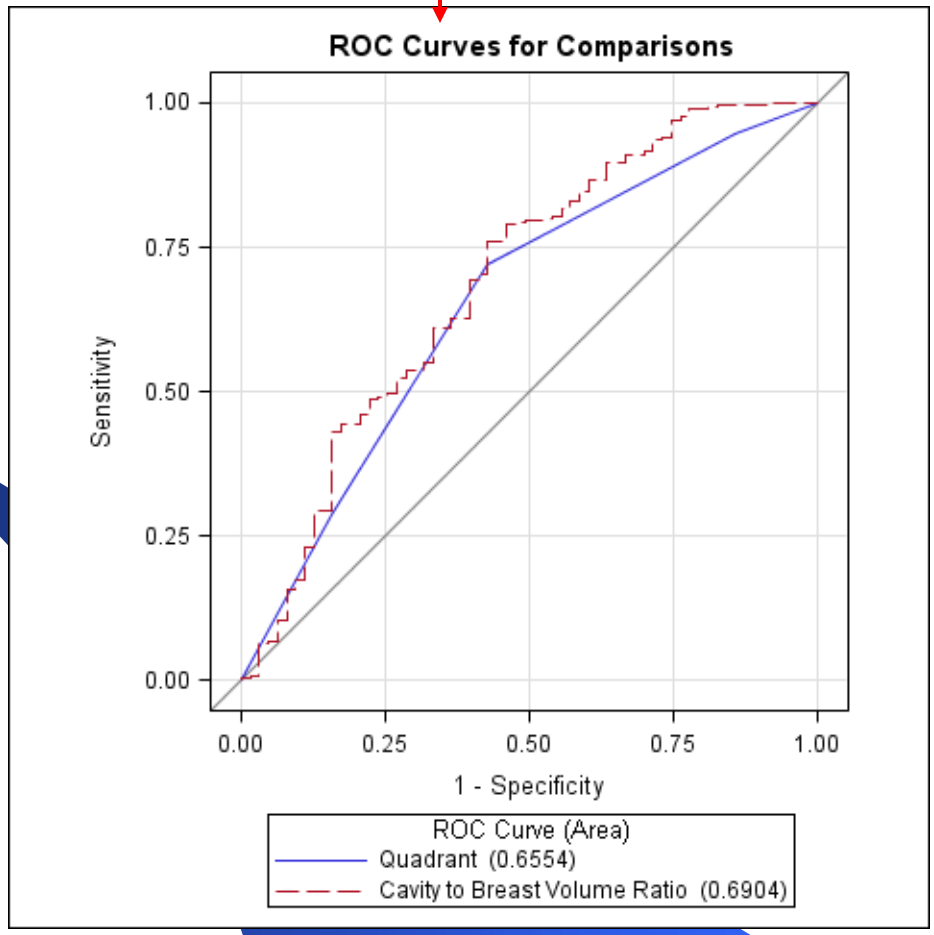
Score Test for Global Null Hypothesis

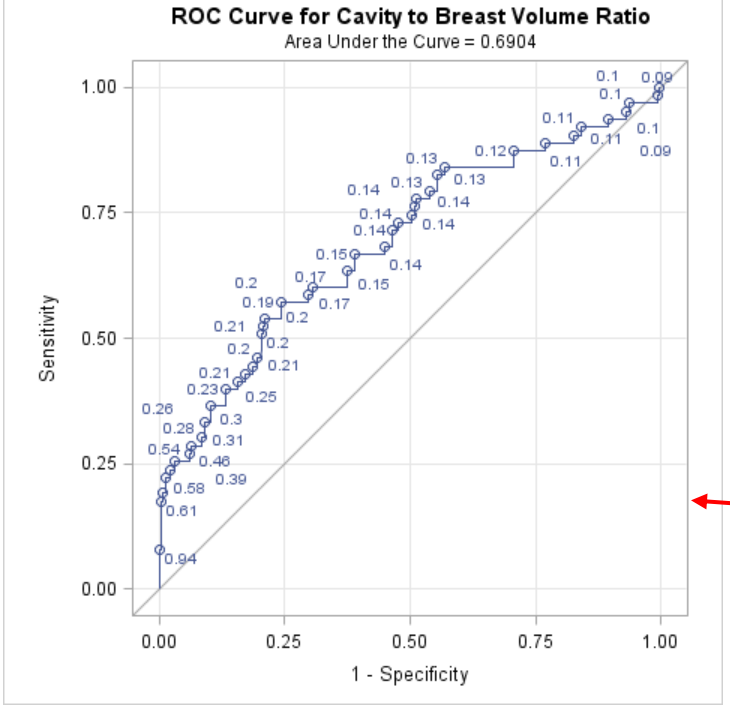
Chi-Square	DF	Pr > ChiSq
73.1051	5	<.0001



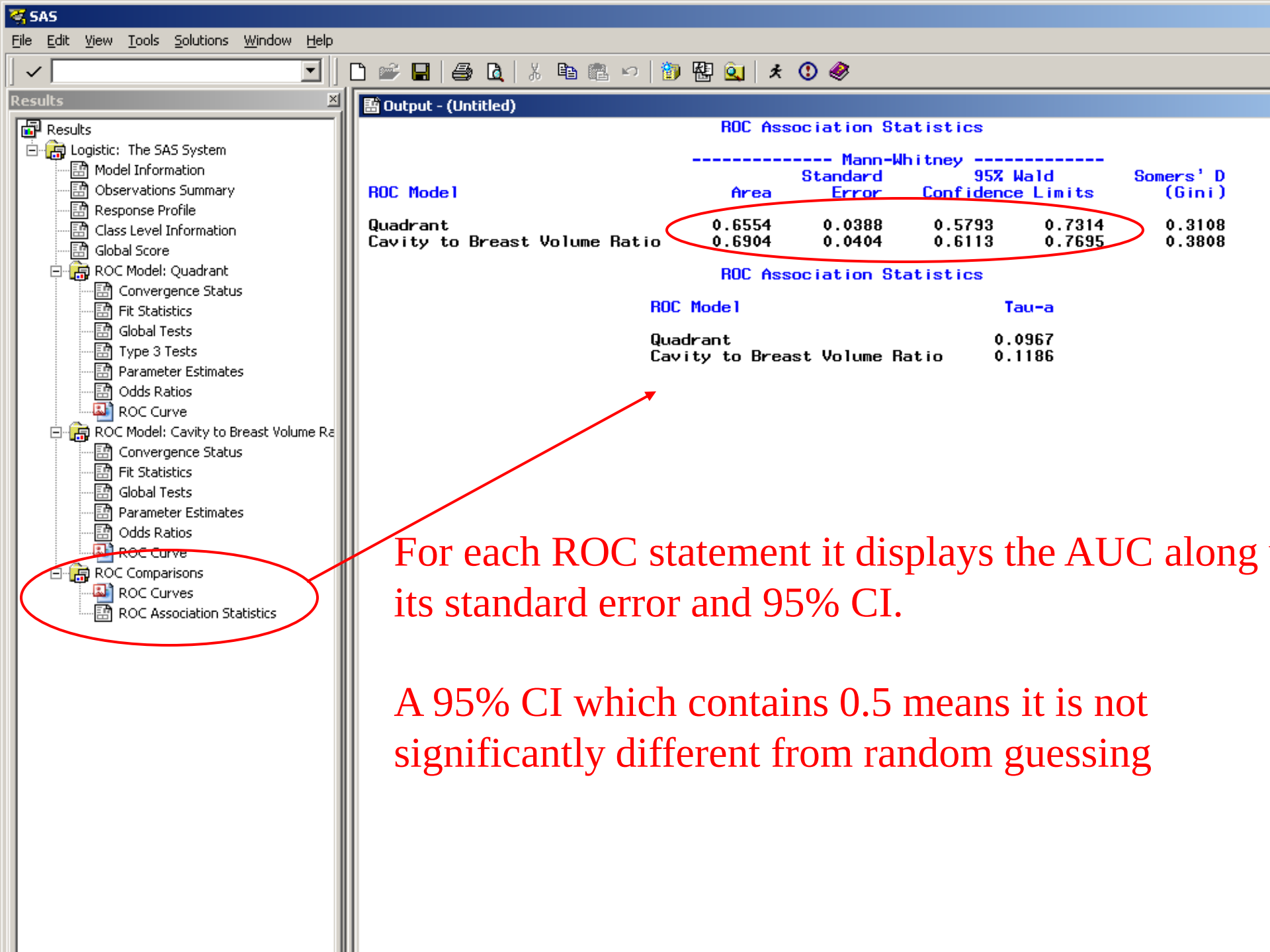
From 1st ROC statement

Overlaid plot of each ROC statement plot





From 2nd ROC statement


SAS
File Edit View Tools Solutions Window Help
Results
Results
Logistic: The SAS System
Model Information
Observations Summary
Response Profile
Class Level Information
Global Score
ROC Model: Quadrant
Convergence Status
Fit Statistics
Global Tests
Type 3 Tests
Parameter Estimates
Odds Ratios
ROC Curve
ROC Model: Cavity to Breast Volume Ra
Convergence Status
Fit Statistics
Global Tests
Parameter Estimates
Odds Ratios
ROC Curve
ROC Comparisons
ROC Curves
ROC Association Statistics
Output - (Untitled)
ROC Association Statistics
Mann-Whitney
ROC Model
Area
Standard Error
95% Wald Confidence Limits
Somers' D (Gini)
Quadrant 0.6554 0.0388 0.5793 0.7314 0.3108
Cavity to Breast Volume Ratio 0.6904 0.0404 0.6113 0.7695 0.3808
ROC Association Statistics
ROC Model
Tau-a
Quadrant 0.0967
Cavity to Breast Volume Ratio 0.1186
For each ROC statement it displays the AUC along
its standard error and 95% CI.
A 95% CI which contains 0.5 means it is not
significantly different from random guessing

```
ods graphics on;
  proc logistic DATA=dset
        PLOTS(ONLY)=(ROC(ID=prob))
        ROCOPTIONS(NODETAILS OUT=roc_dset);
      CLASS quadrant / PARAM=glm;
      MODEL partplan = quadrant cavtobr / NOFIT;
      ROC 'Quadrant' quadrant;
      ROC 'Cavity to Breast Ratio' cavtobr;
  run;
```

- ROCOPTIONS can be used to specify global options that apply to every ROC statement
- NODETAILS suppresses the model fitting information for models specified in the ROC statements
- OUT=<*dset name*> appends the ROC data for each ROC statement into one dataset (the alias for ROCOUT= in the MODEL statement)

```
ods graphics on;
  proc logistic DATA=dset
        PLOTS(ONLY)=(ROC(ID=prob))
        ROCOPTIONS(NODETAILS);
      CLASS quadrant / PARAM=glm;
      MODEL partplan = quadrant cavtobr cavvol brvol
                        / NOFIT;
      ROC 'Ratio' quadrant cavtobr;
      ROC 'Quadrant' quadrant;
      ROC 'Separate' quadrant cavvol brvol;
      ROCCONTRAST REFERENCE('Ratio') E ESTIMATE;
  run;
```

- ID=prob asks for probability cut-offs to be shown on the ROC curves
- Use NODETAILS as not interested in the model fitting information for each of the ROC statements
- Requesting 3 models each with a separate ROC statement

```
ods graphics on;
  proc logistic DATA=dset
        PLOTS(ONLY)=(ROC(ID=prob))
        ROCOPTIONS(NODETAILS);
      CLASS quadrant / PARAM=glm;
      MODEL partplan = quadrant cavtobr cavvol brvol
                       / NOFIT;
      ROC 'Ratio' quadrant cavtobr;
      ROC 'Quadrant' quadrant;
      ROC 'Separate' quadrant cavvol brvol;
      ROCCONTRAST REFERENCE('Ratio') E ESTIMATE;
  run;
```

- Using the ROCCONTRAST statement to compare the ROC curves specified by the ROC statements
- The ROC curve labelled 'Ratio' will be the REFERENCE comparison curve
- E requests the contrast coefficients to be displayed

Help

Output - (Untitled)

ROC Association Statistics

ROC	Area	Standard Error	95% Wald Confidence Limits		Somers' D (Gini)	Gamma	Tau-a
		Mann-Whitney					
Quadrant	0.6554	0.0388	0.5793	0.7314	0.3108	0.3936	0.0967
Ratio	0.8090	0.0315	0.7472	0.8707	0.6179	0.6179	0.1924
Addition	0.8025	0.0319	0.7400	0.8650	0.6050	0.6050	0.1883

ROC Contrast Coefficients

ROC Model	Row1	Row2
Quadrant	1	0
Ratio	-1	-1
Addition	0	1

ROC Contrast Test Results

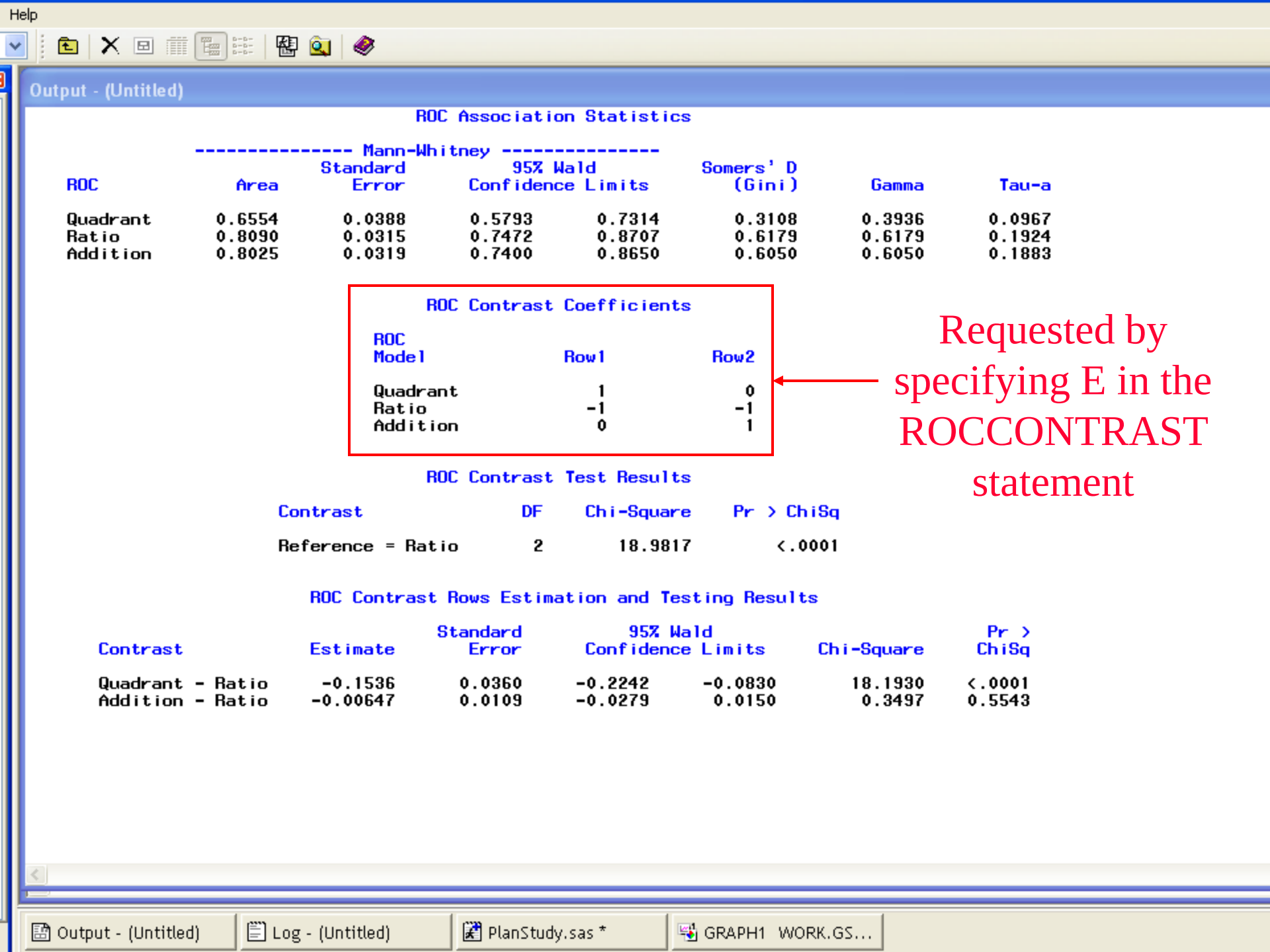
Contrast	DF	Chi-Square	Pr > ChiSq
Reference = Ratio	2	18.9817	<.0001

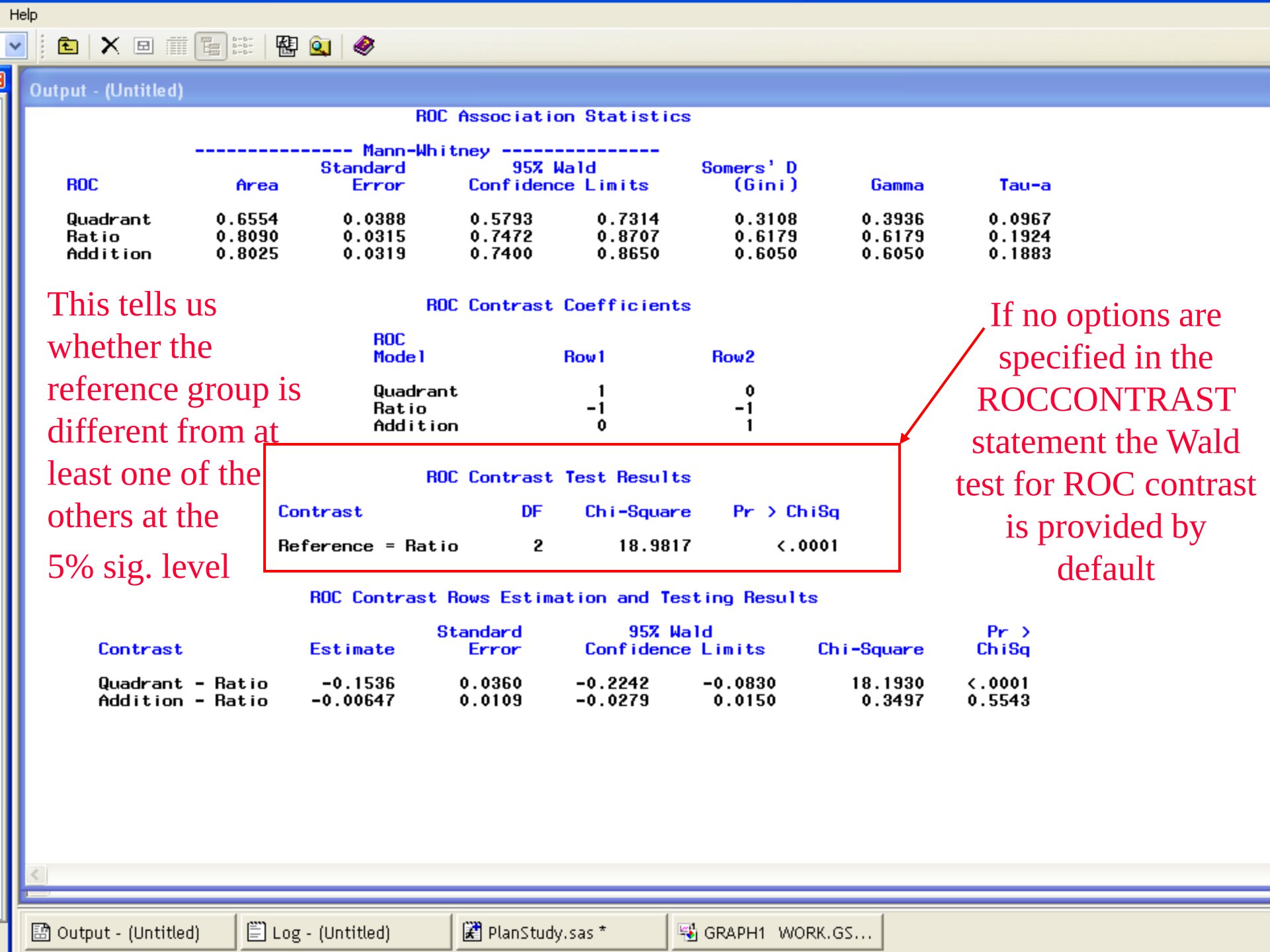
ROC Contrast Rows Estimation and Testing Results

Contrast	Estimate	Standard Error	95% Wald Confidence Limits		Chi-Square	Pr > ChiSq
Quadrant - Ratio	-0.1536	0.0360	-0.2242	-0.0830	18.1930	<.0001
Addition - Ratio	-0.00647	0.0109	-0.0279	0.0150	0.3497	0.5543

ROC Association Statistics produced when ROC statement are specified

Output - (Untitled) | Log - (Untitled) | PlanStudy.sas * | GRAPH1 WORK.GS...


Help
Output - (Untitled)
ROC Association Statistics
Mann-Whitney
ROC
Area
Standard Error
95% Wald Confidence Limits
Somers' D (Gini)
Gamma
Tau-a
Quadrant 0.6554 0.0388 0.5793 0.7314 0.3108 0.3936 0.0967
Ratio 0.8090 0.0315 0.7472 0.8707 0.6179 0.6179 0.1924
Addition 0.8025 0.0319 0.7400 0.8650 0.6050 0.6050 0.1883
ROC Contrast Coefficients
ROC Model
Row1
Row2
Quadrant 1 0
Ratio -1 -1
Addition 0 1
Requested by specifying E in the ROCCONTRAST statement
ROC Contrast Test Results
Contrast
DF
Chi-Square
Pr > ChiSq
Reference = Ratio 2 18.9817 <.0001
ROC Contrast Rows Estimation and Testing Results
Contrast
Estimate
Standard Error
95% Wald Confidence Limits
Chi-Square
Pr > ChiSq
Quadrant - Ratio -0.1536 0.0360 -0.2242 -0.0830 18.1930 <.0001
Addition - Ratio -0.00647 0.0109 -0.0279 0.0150 0.3497 0.5543
Output - (Untitled)
Log - (Untitled)
PlanStudy.sas *
GRAPH1 WORK.GS...


Help
Output - (Untitled)
ROC Association Statistics
Mann-Whitney
ROC
Area
Standard Error
95% Wald Confidence Limits
Somers' D (Gini)
Gamma
Tau-a
Quadrant 0.6554 0.0388 0.5793 0.7314 0.3108 0.3936 0.0967
Ratio 0.8090 0.0315 0.7472 0.8707 0.6179 0.6179 0.1924
Addition 0.8025 0.0319 0.7400 0.8650 0.6050 0.6050 0.1883
This tells us whether the reference group is different from at least one of the others at the 5% sig. level
ROC Contrast Coefficients
ROC Model
Row1
Row2
Quadrant 1 0
Ratio -1 -1
Addition 0 1
ROC Contrast Test Results
Contrast
DF
Chi-Square
Pr > ChiSq
Reference = Ratio 2 18.9817 <.0001
If no options are specified in the ROCCONTRAST statement the Wald test for ROC contrast is provided by default
ROC Contrast Rows Estimation and Testing Results
Contrast
Estimate
Standard Error
95% Wald Confidence Limits
Chi-Square
Pr > ChiSq
Quadrant - Ratio -0.1536 0.0360 -0.2242 -0.0830 18.1930 <.0001
Addition - Ratio -0.00647 0.0109 -0.0279 0.0150 0.3497 0.5543
Output - (Untitled)
Log - (Untitled)
PlanStudy.sas *
GRAPH1 WORK.GS...

```
ods graphics on;
  proc logistic DATA=dset
        PLOTS(ONLY)=(ROC(ID=prob))
        ROCOPTIONS(NODETAILS);
      CLASS quadrant / PARAM=glm;
      MODEL partplan = quadrant cavtobr cavvol brvol
                        / NOFIT;
      ROC 'Ratio' quadrant cavtobr;
      ROC 'Quadrant' quadrant;
      ROC 'Separate' quadrant cavvol brvol;
      ROCCONTRAST REFERENCE('Ratio') E ESTIMATE;
  run;
```

- ESTIMATE requests that the comparison be made between the REFERENCE ROC and each ROC statement
- ESTIMATE=ALLPAIRS could be used to do all pair comparisons

Help

Output - (Untitled)

ROC Association Statistics

ROC	Area	Standard Error	95% Wald Confidence Limits		Somers' D (Gini)	Gamma	Tau-a
		Mann-Whitney					
Quadrant	0.6554	0.0388	0.5793	0.7314	0.3108	0.3936	0.0967
Ratio	0.8090	0.0315	0.7472	0.8707	0.6179	0.6179	0.1924
Addition	0.8025	0.0319	0.7400	0.8650	0.6050	0.6050	0.1883

ROC Contrast Coefficients

ROC Model	Row1	Row2
Quadrant	1	0
Ratio	-1	-1
Addition	0	1

ROC Contrast Test Results

Contrast	DF	Chi-Square	Pr > ChiSq
Reference = Ratio	2	18.9817	<.0001

ROC Contrast Rows Estimation and Testing Results

Contrast	Estimate	Standard Error	95% Wald Confidence Limits		Chi-Square	Pr > ChiSq
Quadrant - Ratio	-0.1536	0.0360	-0.2242	-0.0830	18.1930	<.0001
Addition - Ratio	-0.00647	0.0109	-0.0279	0.0150	0.3497	0.5543

Output produced by specifying the ESTIMATE option in the ROCCONTRAST statement

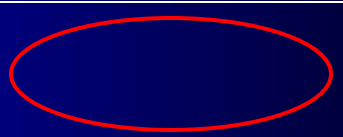
Output - (Untitled) | Log - (Untitled) | PlanStudy.sas * | GRAPH1 WORK.GS...

Using a validation dataset

- The dataset that model is determined from is often called the ‘test’ dataset.
- The model can then be applied to a ‘validation’ dataset to see how well it performs on the validation dataset
- This can be done using the SCORE statement in proc logistic

```
ods graphics on;
  proc logistic DATA=dset OUTMODEL=model_name;
       CLASS quadrant / PARAM=glm;
       MODEL partplan = quadrant cavtobr;
  run;
  proc logistic INMODEL=model_name;
       SCORE DATA=partplan OUT=score_dset CLM
             OUTROC=score_roc;
  run;
```

- OUTMODEL



SUMMARY

- Using PLOTS= option to:
  - Produce ROC curve/AUC
  - Show predicted probs/observation # on plot
- Using OUTROC= option to:
  - Produce ROC curve/AUC
  - Obtaining ROC plot dataset
  - Utilise ROCEPS= option
- Using automated model selection process to obtain overlaid ROC plots for each model selection process

Output - (Untitled)

Type 3 Analysis of Effects

Effect	DF	Wald Chi-Square	Pr > ChiSq
quadrant	4	29.1317	<.0001
cav_breast_ratio	1	32.5279	<.0001

Analysis of Maximum Likelihood Estimates

Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept		1	-3.4610	0.4697	54.2957	<.0001
quadrant	Central	1	0.1326	0.5459	0.0590	0.8081
quadrant	Lower Inner	1	1.9773	0.6096	10.5215	0.0012
quadrant	Lower Outer	1	-0.6308	0.6847	0.8486	0.3569
quadrant	Upper Inner	1	1.7165	0.4698	13.3508	0.0003
quadrant	Upper Outer	0	0	.	.	.
cav_breast_ratio		1	0.6814	0.1195	32.5279	<.0001

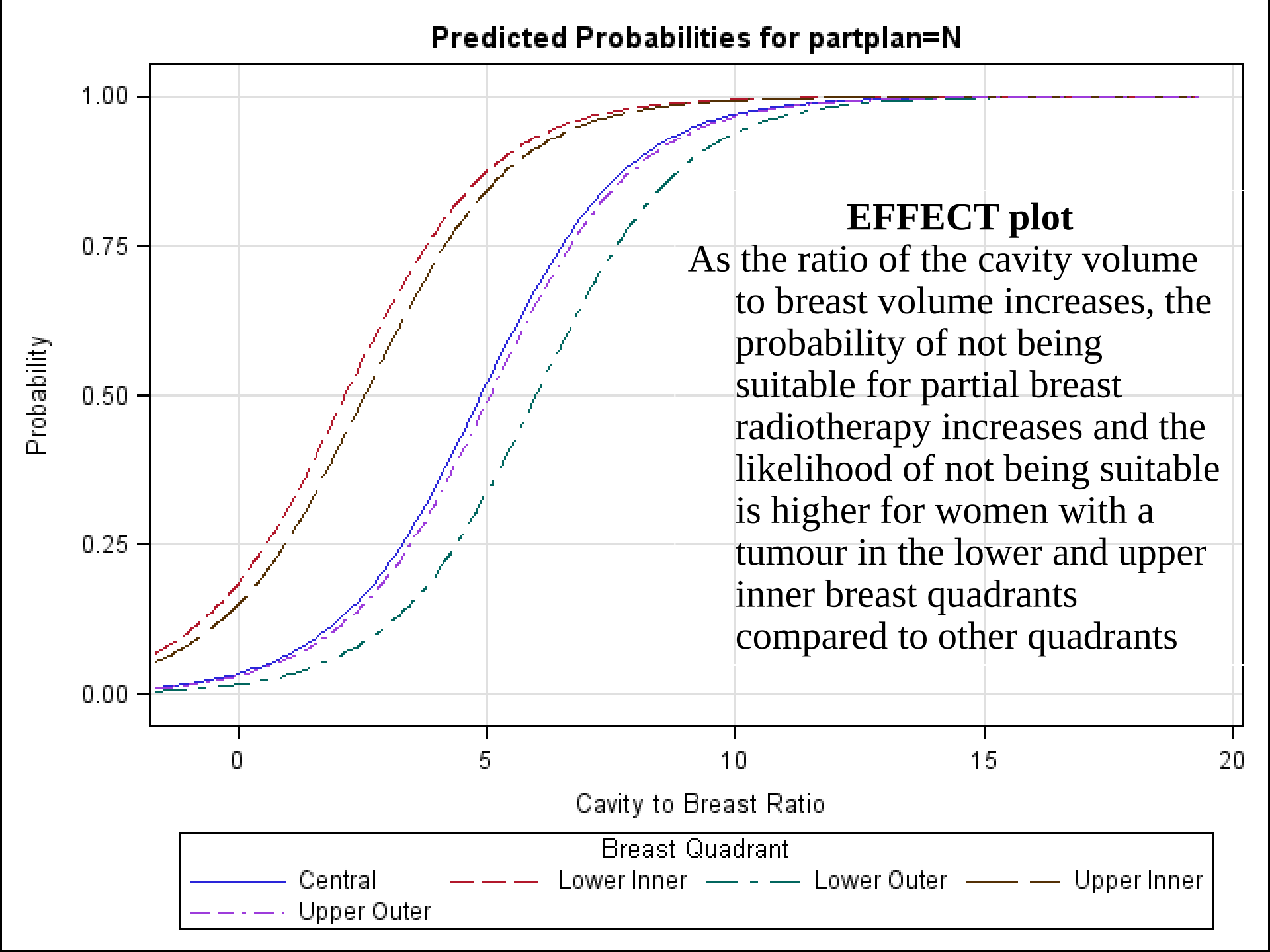
Odds Ratio Estimates

Effect				Point Estimate	95% Wald Confidence Limits	
quadrant	Central	vs	Upper Outer	1.142	0.392	3.329
quadrant	Lower Inner	vs	Upper Outer	7.223	2.187	23.857
quadrant	Lower Outer	vs	Upper Outer	0.532	0.139	2.037
quadrant	Upper Inner	vs	Upper Outer	5.565	2.216	13.974
cav_breast_ratio				1.977	1.564	2.498

Association of Predicted Probabilities and Observed Responses

Percent Concordant	80.9	Somers' D	0.618
Percent Discordant	19.1	Gamma	0.618
Percent Tied	0.0	Tau-a	0.192
Pairs	16695	c	0.809

Output - (Untitled) | Log - (Untitled) | PlanStudy.sas * | VIEWTABLE: Predict... | VIEWTABLE: Receiv... | VIEW


Predicted Probabilities for partplan=N
1.00
0.75
0.50
0.25
0.00
Probability
0
5
10
15
20
Cavity to Breast Ratio
Breast Quadrant
Central
Lower Inner
Lower Outer
Upper Inner
Upper Outer
EFFECT plot
As the ratio of the cavity volume to breast volume increases, the probability of not being suitable for partial breast radiotherapy increases and the likelihood of not being suitable is higher for women with a tumour in the lower and upper inner breast quadrants compared to other quadrants

```
ods graphics on;
  proc logistic DATA=dset PLOTS(ONLY)=(ROC(ID=prob));
    CLASS quadrant / PARAM=glm;
    MODEL partplan = quadrant cav_vol /
                          OUTROC=dset_name;
  run;
```

If the ROC curve is requested in the PLOTS option but the OUTROC= option is not specified then the OUTROC dataset will not be provided.