Economics

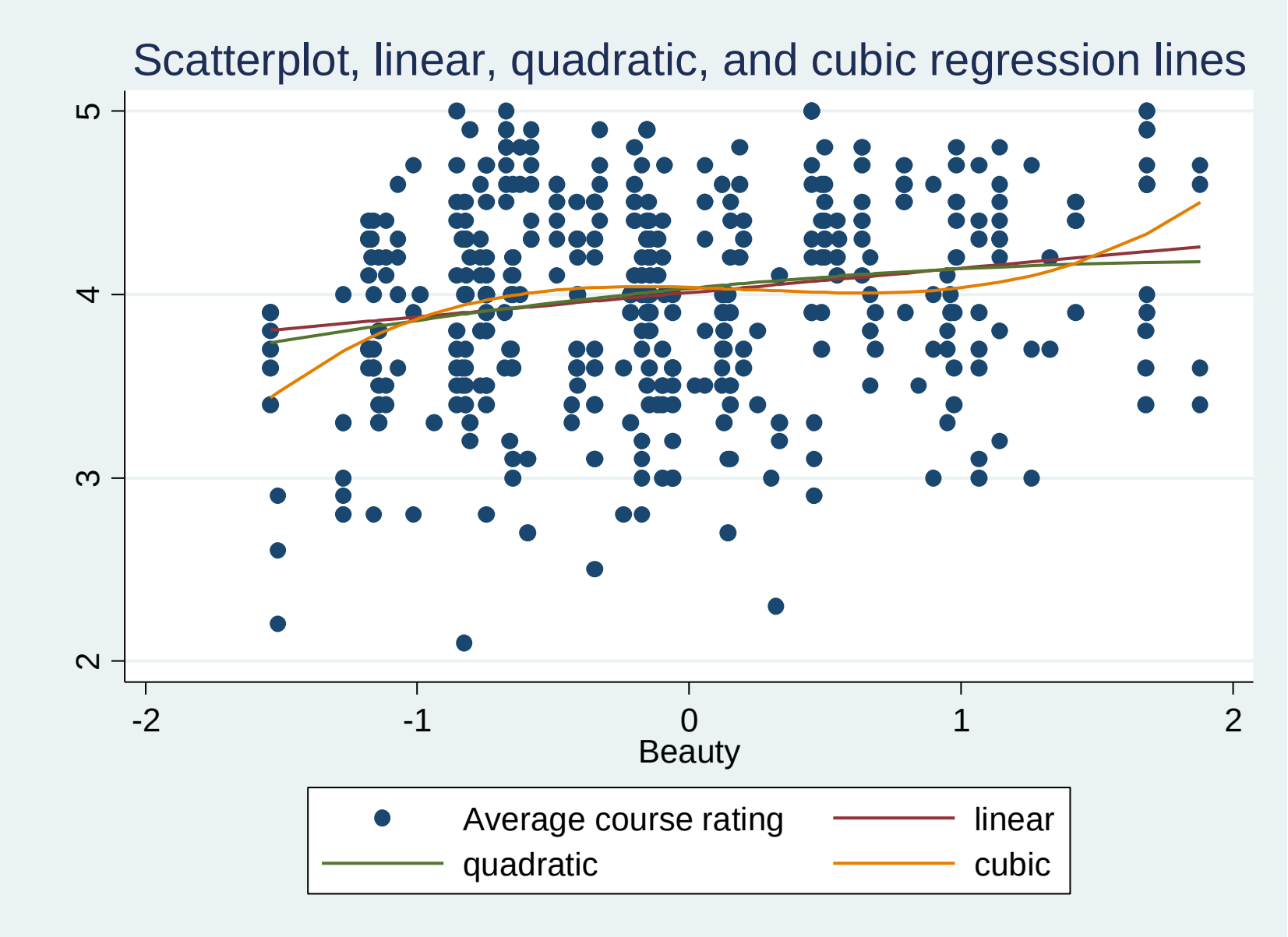
Lecture #5

Nonlinear Regression Functions III

Outline

1. Interactions
2. Application: Course evaluations and beauty
3. Nonlinearities: Summary and remarks about choice of specification

Nonlinear regression functions:
Course Evaluations, Beauty, and Sex



Questions:

1. Does the effect of *Beauty* differ between male and female instructors, holding constant course characteristics and other instructor characteristics (age, minority status, etc)?

2. Does age have a nonlinear effect on test scores?

3. Does the age-test score profile differ between male and female instructors?

Basic Linear specification

```
. reg courseevaluation btystdave male age minority
>       nonenglish tenuretrack lower onecredit, r;

Linear regression                               Number of obs =     463
                                                F(  8,   454) =   12.85
                                                Prob > F      =  0.0000
                                                R-squared     =  0.1577
                                                Root MSE      =  .51372
------------------------------------------------------------------------------
             |               Robust
courseeval~n |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   btystdave |   .1564742   .0301056     5.20   0.000     .0973106    .2156379
        male |   .1910459   .0529734     3.61   0.000     .0869425    .2951493
         age |  -.0024049   .0026586    -0.90   0.366    -.0076296    .0028198
    minority |  -.1595549   .0682725    -2.34   0.020    -.2937242   -.0253856
  nonenglish |  -.2344735   .0975351    -2.40   0.017    -.4261498   -.0427971
 tenuretrack |  -.0650419   .0579802    -1.12   0.263    -.1789848    .0489009
       lower |   .0046318   .0563316     0.08   0.935    -.1060712    .1153348
   onecredit |   .5964602   .1095069     5.45   0.000     .3812569    .8116634
       _cons |    4.06842   .1374566    29.60   0.000      3.79829     4.33855
------------------------------------------------------------------------------
```

Generating interaction terms in STATA:

```
gen male = 1-female;
gen bty_male = btystdave*male;
```

Additional nonlinear and interaction terms:

```
* NOTE: age2 = age*age is already defined in the data set;
gen bty2 = btystdave*btystdave;
gen bty3 = btystdave*btystdave*btystdave;
gen bty2_male = bty2*male;
gen bty3_male = bty3*male;
gen age_male = age*male;
gen age2_male = age2*male;
```

Linear with sex-beauty interaction

Linear regression

Number of obs	= 463
F(10, 452)	= 12.40
Prob > F	= 0.0000
R-squared	= 0.1830
Root MSE	= .50704

courseeval~n	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
btystdave	.0698874	.0403132	1.73	0.084	-.0093371	.1491119
male	-.6392078	.2560961	-2.50	0.013	-1.142495	-.135921
bty_male	.1741823	.0621973	2.80	0.005	.0519505	.2964141
age	-.0130934	.0044586	-2.94	0.003	-.0218555	-.0043313
age_male	.0178141	.0054475	3.27	0.001	.0071086	.0285196
minority	-.1379492	.0707575	-1.95	0.052	-.2770038	.0011053
nonenglish	-.2017403	.1025914	-1.97	0.050	-.4033556	-.0001251
tenuretrack	-.0616752	.0599482	-1.03	0.304	-.179487	.0561365
lower	.0001915	.0560525	0.00	0.997	-.1099644	.1103474
onecredit	.6557842	.109996	5.96	0.000	.4396172	.8719513
_cons	4.542915	.2178182	20.86	0.000	4.114853	4.970977

Benchmark nonlinear with no interactions

```
. reg courseevaluation btystdave bty2 bty3 male age age2 minority
>        nonenglish tenuretrack lower onecredit, r;
Linear regression                               Number of obs =     463
                                                F( 11,   451) =   10.32
                                                Prob > F      =  0.0000
                                                R-squared     =  0.1744
                                                Root MSE      =  .51028
------------------------------------------------------------------------------
             |               Robust
courseeval~n |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   btystdave |   .0245173   .0639067     0.38   0.701    -.1010746    .1501092
        bty2 |  -.0849377   .0416698    -2.04   0.042    -.1668289   -.0030466
        bty3 |   .0966194    .040416     2.39   0.017     .0171923    .1760465
        male |   .1871739    .053206     3.52   0.000     .0826114    .2917364
         age |   .0083595   .0246683     0.34   0.735    -.0401196    .0568385
        age2 |  -.0001186   .0002552    -0.46   0.642      -.00062    .0003829
    minority |  -.1594723   .0715312    -2.23   0.026    -.3000481   -.0188966
  nonenglish |  -.2752031   .1000263    -2.75   0.006    -.4717786   -.0786275
 tenuretrack |  -.0461931   .0618176    -0.75   0.455    -.1676795    .0752932
       lower |  -.0046437   .0564785    -0.08   0.935    -.1156373    .1063499
   onecredit |   .5620478   .1093743     5.14   0.000     .3471013    .7769943
       _cons |   3.865119    .596273     6.48   0.000       2.6933    5.036937
```

```
.  test bty2 bty3;

 ( 1)  bty2 = 0
 ( 2)  bty3 = 0

       F(  2,   451) =    3.43
            Prob > F =    0.0332

.  test age age2;

 ( 1)  age = 0
 ( 2)  age2 = 0

       F(  2,   451) =    0.76
            Prob > F =    0.4692
```

Nonlinear with nonlinear interactions (different nonlinear functions)

```
Linear regression                               Number of obs =     463
                                                F( 16,   446) =   13.02
                                                Prob > F      =  0.0000
                                                R-squared     =  0.2528
                                                Root MSE      =  .48815
```

(continued on next slide)

courseeval~n	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
btystdave	.049012	.0905383	0.54	0.589	-.1289226	.2269466
male	-2.697054	1.36349	-1.98	0.049	-5.376716	-.0173915
bty2	.0327519	.0499135	0.66	0.512	-.0653429	.1308467
bty3	.0029834	.0482024	0.06	0.951	-.0917486	.0977154
bty_male	-.0964114	.1194252	-0.81	0.420	-.3311174	.1382946
bty2_male	-.3005362	.0694863	-4.33	0.000	-.4370974	-.163975
bty3_male	.2458653	.0679643	3.62	0.000	.1122953	.3794352
age	-.0366662	.0541871	-0.68	0.499	-.1431599	.0698276
age2	.0002953	.0006123	0.48	0.630	-.000908	.0014987
age_male	.1126335	.061227	1.84	0.066	-.0076957	.2329627
age2_male	-.0009927	.0006737	-1.47	0.141	-.0023168	.0003313
minority	-.107427	.0757036	-1.42	0.157	-.256207	.041353
nonenglish	-.3249134	.1068987	-3.04	0.003	-.5350012	-.1148256
tenuretrack	.0255414	.0641215	0.40	0.691	-.1004764	.1515592
lower	-.0089454	.0565692	-0.16	0.874	-.1201207	.1022299
onecredit	.5742187	.1032149	5.56	0.000	.3713708	.7770666
_cons	4.905785	1.165435	4.21	0.000	2.615358	7.196212

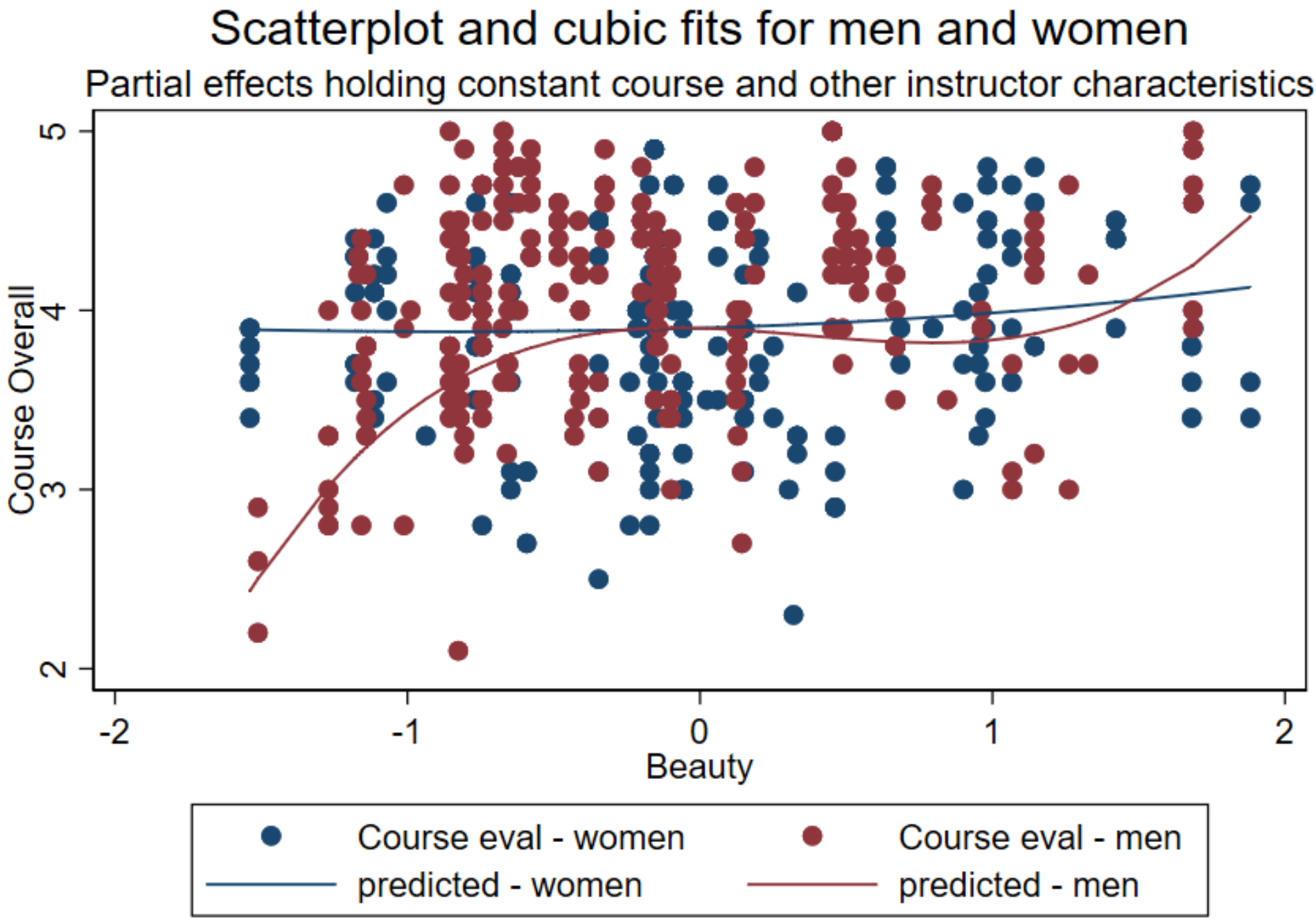
Tests of beauty nonlinearities and beauty-sex interactions

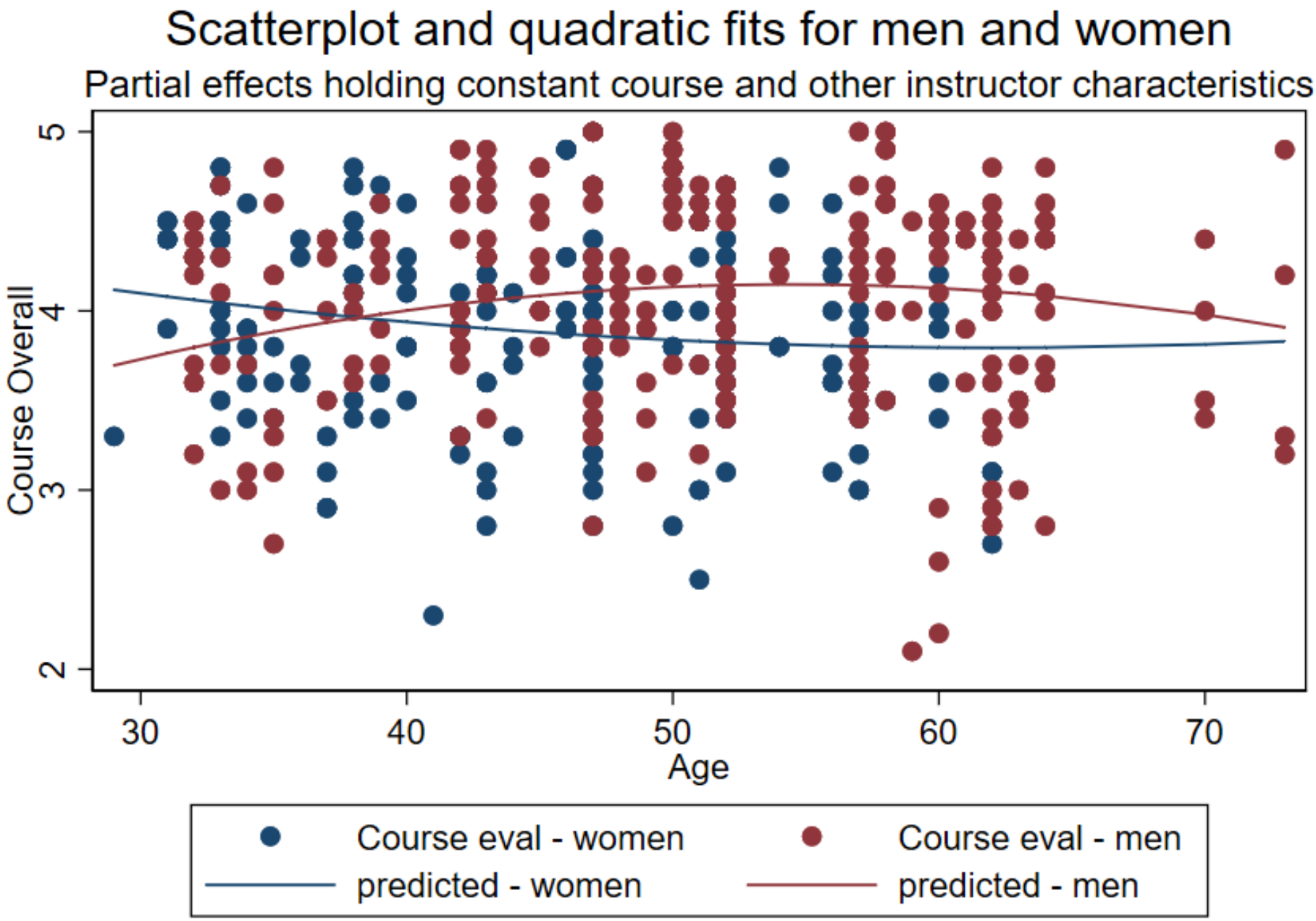
```
. test bty_male bty2_male bty3_male;

 ( 1)  bty_male = 0
 ( 2)  bty2_male = 0
 ( 3)  bty3_male = 0

       F(  3,   446) =   12.36
            Prob > F =    0.0000
```

```
. test bty2 bty3 bty2_male bty3_male;
 ( 1)  bty2 = 0
 ( 2)  bty3 = 0
 ( 3)  bty2_male = 0
 ( 4)  bty3_male = 0

       F(  4,   446) =    9.62
            Prob > F =    0.0000

. test btystdave bty2 bty3;
 ( 1)  btystdave = 0
 ( 2)  bty2 = 0
 ( 3)  bty3 = 0

       F(  3,   446) =    0.87
            Prob > F =    0.4549

. test bty2 bty3;
 ( 1)  bty2 = 0
 ( 2)  bty3 = 0

       F(  2,   446) =    0.23
            Prob > F =    0.7941
```

Tests of age nonlinearities and age-sex interactions

```
. test age age2 age_male age2_male;
 ( 1)  age = 0
 ( 2)  age2 = 0
 ( 3)  age_male = 0
 ( 4)  age2_male = 0

       F(  4,   446) =    3.82
            Prob > F =    0.0046

. test age_male age2_male;
 ( 1)  age_male = 0
 ( 2)  age2_male = 0

       F(  2,   446) =    7.41
            Prob > F =    0.0007

. test age2 age2_male;
 ( 1)  age2 = 0
 ( 2)  age2_male = 0

       F(  2,   446) =    2.63
            Prob > F =    0.0729
```


Scatterplot and cubic fits for men and women
Partial effects holding constant course and other instructor characteristics
Course Overall
5
4
3
2
-2
-1
0
1
2
Beauty
Course eval - women
Course eval - men
predicted - women
predicted - men


Scatterplot and quadratic fits for men and women
Partial effects holding constant course and other instructor characteristics
Course Overall
2
3
4
5
30
40
50
60
70
Age
Course eval - women
Course eval - men
predicted - women
predicted - men

Predicted changes for men with controls

```
. * change from beauty = -1.5 to -1;
. sca a1 = (-1) - (-1.5);
. sca b1 = (-1)*(-1) - (-1.5)*(-1.5);
. sca c1 = (-1)*(-1)*(-1) - (-1.5)*(-1.5)*(-1.5);

. lincom a1*btystdave + a1*bty_male + b1*bty2 + b1*bty2_male + c1*bty3 +
c1*bty3_male;
 ( 1)  .5 btystdave - 1.25 bty2 + 2.375 bty3 + .5 bty_male - 1.25 bty2_male +
2.375 bty3
> _male = 0

------------------------------------------------------------------------------
courseeval~n |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   .9020462   .1273947     7.08   0.000     .6516778    1.152415
------------------------------------------------------------------------------
```

Summary: nonlinear effect of *Beauty*, cubic specifications

Change in *Beauty*	Δ*CourseEval*	*Std. Error*
Undifferentiated (no *beauty*-*sex* interactions)		
from -1.5 to -1.0	0.39	0.10
from 0 to 0.5	-0.03	0.03
from 1.0 to 1.5	0.17	0.07
Men		
from -1.5 to -1.0	0.90	0.13
from 0 to 0.5	-0.06	0.04
from 1.0 to 1.5	0.23	0.07
Women		
from -1.5 to -1.0	-0.01	0.11
from 0 to 0.5	0.03	0.04
from 1.0 to 1.5	0.07	0.09

STATA do file for beauty example: lecture 6

```
clear
set scheme s1color
capture log close
*************************************************************
*  beauty_2_f18_lect6.do
*  Ec1123
*  nonlinear functions
*************************************************************
set more off
log using beauty_2_f18_lect6.txt, text replace
*************************************************************
* read in data
use hamermesh_beauty
desc
su
*
*************************************************************
*    Generate nonlinear terms
*************************************************************
gen bty2 = btystdave*btystdave
gen bty3 = btystdave*btystdave*btystdave
*
gen male = 1-female
gen bty_male = btystdave*male
gen bty2_male = bty2*male
gen bty3_male = bty3*male
*
* NOTE: age2 = age*age is already defined in the data set
gen age_male = age*male
gen age2_male = age2*male
```

```
*
*************************************************************
*    Regressions - different beauty effect, men v. women?
*************************************************************
*
* Benchmark regression - linear, no interactions
reg courseevaluation btystdave male age minority ///
       nonenglish tenuretrack lower onecredit, r
*
* include all interactions - linear only
reg courseevaluation btystdave male bty_male age age_male minority ///
       nonenglish tenuretrack lower onecredit, r
*
* Benchmark regression - nonlinear, no interactions
reg courseevaluation btystdave bty2 bty3 male age age2 minority ///
       nonenglish tenuretrack lower onecredit, r
 test bty2 bty3
 test age age2
*
* include all interactions - nonlinear
reg courseevaluation btystdave male bty2 bty3 ///
       bty_male bty2_male bty3_male ///
       age age2 age_male age2_male ///
       minority nonenglish tenuretrack lower onecredit, r
test bty_male bty2_male bty3_male
test bty2 bty3 bty2_male bty3_male
test btystdave bty2 bty3
test bty2 bty3
test age age2 age_male age2_male
test age_male age2_male
test age2 age2_male
*
* predicted changes for men with controls
* change from beauty = -1.5 to -1
```

```
sca a1 = (-1) - (-1.5)
sca b1 = (-1)*(-1) - (-1.5)*(-1.5)
sca c1 = (-1)*(-1)*(-1) - (-1.5)*(-1.5)*(-1.5)
sca a2 = (.5) - (0)
sca b2 = (.5)*(.5) - (0)*(0)
sca c2 = (.5)*(.5)*(.5) - (0)*(0)*(0)
sca a3 = (1.5) - (1)
sca b3 = (1.5)*(1.5) - (1)*(1)
sca c3 = (1.5)*(1.5)*(1.5) - (1)*(1)*(1)
* for women
lincom a1*btystdave + b1*bty2 + c1*bty3
lincom a2*btystdave + b2*bty2 + c2*bty3
lincom a3*btystdave + b3*bty2 + c3*bty3
* for men
lincom a1*btystdave + a1*bty_male + b1*bty2 + b1*bty2_male ///
 + c1*bty3 + c1*bty3_male
lincom a2*btystdave + a2*bty_male + b2*bty2 + b2*bty2_male ///
+ c2*bty3 + c2*bty3_male
lincom a3*btystdave + a3*bty_male + b3*bty2 + b3*bty2_male ///
+ c3*bty3 + c3*bty3_male
*
su courseevaluation if female==1
gen pred_bf = _b[btystdave]*btystdave + _b[bty2]*bty2 ///
+ _b[bty3]*bty3 + r(mean)
label var pred_bf "predicted - women"
su courseevaluation if female==0
gen pred_bm = pred_bf + _b[bty_male]*btystdave ///
    + _b[bty2_male]*bty2 + _b[bty3_male]*bty3
label var pred_bm "predicted - men"
gen ceval_f = courseevaluation if female==1
 label var ceval_f "Course eval - women"
gen ceval_m = courseevaluation if female==0
 label var ceval_m "Course eval - men"
twoway scatter ceval_f ceval_m pred_bf pred_bm btystdave, ///
```

```
 ms(0 0 i i) connect(. . l l) sort(btystdave) ///
 mc(navy maroon) lc(navy maroon) lw(vthick) ///
 title("Scatterplot and cubic fits for men and women") ///
 subtitle("Partial effects holding constant course and other instructor
characteristics") ///
 xtitle("Beauty") ytitle("Course Overall")
 graph export beauty_2f18b.png, replace
*
su courseevaluation if female==1
 sca mf = r(mean)
gen pred_af = _b[age]*age + _b[age2]*age2
 su pred_af if female==1
 replace pred_af = pred_af - r(mean) + mf
su courseevaluation if female==0
 sca mm = r(mean)
gen pred_am = (_b[age]+_b[age_male])*age + (_b[age2]+_b[age2_male])*age2
 su pred_am if female==0
 replace pred_am = pred_am - r(mean) + mm
*
label var pred_af "predicted - women"
label var pred_am "predicted - men"
twoway scatter ceval_f ceval_m pred_af pred_am age, ///
 ms(0 0 i i) connect(. . l l) sort(age) ///
 mc(navy maroon) lc(navy maroon) lw(vthick) ///
 title("Scatterplot and quadratic fits for men and women") ///
 subtitle("Partial effects holding constant course and other instructor
characteristics") ///
 xtitle("Age") ytitle("Course Overall")
 graph export beauty_2f18c.png, replace

************************************************************
log close
clear
exit
```