Epidemiology/Biostats VHM 812/802 Course
Winter 2015, Atlantic Veterinary College, PEI
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Lecture 2a: Model building I

Index **Page**

- Exercises
  - Today – Review Exercise 1
  - Home work for Friday
    - Exercise 2 in "Linear Regression Exercises"

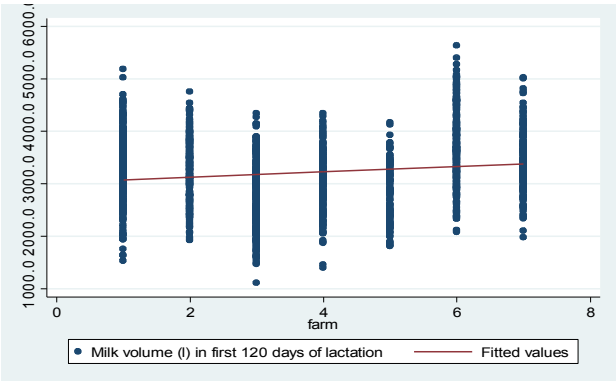
Predictors (X variables)

- categorical
  - nominal / ordinal – must be recoded
    - indicator
    - hierarchical
- continuous
  - scaling
  - assumption of linearity

Categorical predictors

- predictors with more that two levels should not be used as numeric

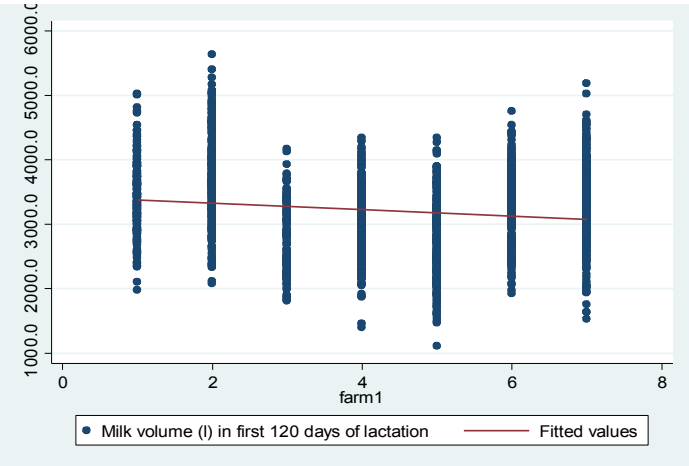
```
. table farm, c(mean milk120)

-------------------------

     farm | mean(milk120)
----------+--------------
        1 |        3357.8
        2 |        3279.3
        3 |        2778.6
        4 |        3032.5
        5 |        2838.2
        6 |        3730.6
        7 |        3435.8
-------------------------
```




```
------------------------------------------------------------------------------
     milk120 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        farm |   50.90872   8.848643     5.75   0.000       33.552     68.26543
       _cons |   3026.143   37.27521    81.18   0.000     2953.028     3099.259
------------------------------------------------------------------------------
```

```
list farm milk120 farm1
```

	farm	milk120	farm1
1.	1	3357.8	7
2.	2	3279.3	6
3.	3	2778.6	5
4.	4	3032.5	4
5.	5	2838.2	3
6.	6	3730.6	2
7.	7	3435.8	1



milk120	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
farm1	-50.90872	8.848643	-5.75	0.000	-68.26543	-33.552
_cons	3433.413	41.84204	82.06	0.000	3351.339	3515.487

Indicator variables

- convert nominal or ordinal variables to a set of dichotomous variables
- one level is referent (or baseline) level

herd	hrd1	hrd2	hrd3
1	1	0	0
2	0	1	0
3	0	0	1

- choice of referent level
  - biological sense
  - reasonable sample size
  - ease of interpretation
  - Stata by default selects first category
    - see *fvvarlist*
    - contrasts command
- all in / all out
- changing coding – no effect on overall model fit
  - same R^2 etc.

- example – parity as an ordinal variable
  - convert parity to 4 level categorical variable (parity_c4)
  - regular coding

parity	parity_c4	parity_c4_0	parity_c4_1	parity_c4_2	parity_c4_3
1	0	1	0	0	0
2	1	0	1	0	0
3	2	0	0	1	0
4	3	0	0	0	1
5	3	0	0	0	1
6	3	0	0	0	1
7	3	0	0	0	1

  - regress milk120 parity_c4 (indicator variables)

	Avg milk120	Regular coding	Hierarchical coding
parity_c4_0	2639.7		
parity_c4_1	3347.9	708.2	
parity_c4_2	3429.5	789.8	
parity_c4_3	3471.4	831.8	
intercept		2639.7	

- hierarchical dummy variables
  - measure effect moving up one level
  - only applicable to ordinal variables

disease	dz0	dz1	dz2
negative	1	0	0
mild	1	1	0
severe	1	1	1

  - hierarchical coding

parity	parity_h0	parity_h1	parity_h2	parity_h3
1	1	0	0	0
2	1	1	0	0
3	1	1	1	0
4+	1	1	1	1

  - regress milk120 parity_h1 parity_h2 parity_h3
    - same using contrasts command -see do-file

	Avg milk120	Regular coding	Hierarchical coding
parity_c4_0	2639.7		
parity_c4_1	3347.9	708.2	708.2
parity_c4_2	3429.5	789.8	81.6
parity_c4_3	3471.4	831.8	41.9
intercept		2639.7	2639.7

Continuous predictors

Improving "interpretability" of X variables

- scaling X variables
  - limited range of plausible values
    - effects only the constant (not the coefficient for the variable – slope)
    - subtract min. plausible value (e.g. parity)

```
. regress milk120 parity
...output omitted
------------------------------------------------------------------------------
     milk120 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      parity |    178.347   11.01266    16.19   0.000     156.7455    199.9484
       _cons |    2727.08   34.33991    79.41   0.000     2659.722    2794.438
------------------------------------------------------------------------------
```

```
. gen parity_1=parity-1

. reg milk120 parity_1
....output omitted
------------------------------------------------------------------------------
     milk120 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    parity_1 |    178.347   11.01266    16.19   0.000     156.7455    199.9484
       _cons |   2905.427   25.23474   115.14   0.000     2855.928    2954.925
------------------------------------------------------------------------------
```

  - subtract mean (centring)
    - helps with quadratic and interaction terms

```
. reg milk120 c.herd_size##c.herd_size, vsquish

      Source |       SS       df       MS              Number of obs =    1536
-------------+------------------------------           F(  2,  1533) =  111.15
       Model |  94747175.1     2  47373587.5           Prob > F      =  0.0000
    Residual |   653393017  1533  426218.537           R-squared     =  0.1266
-------------+------------------------------           Adj R-squared =  0.1255
       Total |   748140192  1535  487387.748           Root MSE      =  652.85

------------------------------------------------------------------------------
             milk120 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------------+--------------------------------------------------------------
           herd_size |   28.73126   1.993023    14.42   0.000     24.82192     32.6406
c.herd_size#c.herd_size |  -.0608255   .0041101   -14.80   0.000    -.0688875   -.0527634
               _cons |   66.06488   231.8877     0.28   0.776    -388.7858    520.9155
------------------------------------------------------------------------------
```

```
. reg milk120 c.hrdsz_ctr##c.hrdsz_ctr, vsquish

      Source |       SS       df       MS              Number of obs =    1536
-------------+------------------------------           F(  2,  1533) =  111.15
       Model |  94747175.1     2  47373587.5           Prob > F      =  0.0000
    Residual |   653393017  1533  426218.537           R-squared     =  0.1266
-------------+------------------------------           Adj R-squared =  0.1255
       Total |   748140192  1535  487387.748           Root MSE      =  652.85

------------------------------------------------------------------------------
             milk120 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------------+--------------------------------------------------------------
          hrdsz_ctr |  -1.803116   .2847073    -6.33   0.000    -2.361573   -1.244659
c.hrdsz_ctr#c.hrdsz_ctr |  -.0608255   .0041101   -14.80   0.000    -.0688875   -.0527634
               _cons |   3445.547   22.80494   151.09   0.000     3400.815    3490.279
------------------------------------------------------------------------------
```

- scale of measurement (eg grams or kg)
  - avoid very small regression coefficients

- Example: herd size (mean=251; min=125; max=333)

```
. reg milk120 herd_size
------------------------------------------------------------------------------
     milk120 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   herd_size |    -.49048   .2891242    -1.70   0.090    -1.057601    .0766405
       _cons |   3338.164   74.69789    44.69   0.000     3191.643    3484.685
------------------------------------------------------------------------------

. gen herdsz_100=herd_size/100 /*rescale herd_size so coef are larger*/

. reg milk120 herdsz_100

------------------------------------------------------------------------------
     milk120 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  herdsz_100 |  -49.04796   28.91242    -1.70   0.090      -105.76    7.664098
       _cons |   3338.164   74.69789    44.69   0.000     3191.643    3484.685
------------------------------------------------------------------------------
```

Linearity

- assumption about nature of relationship between X and Y
  - Note: the following are all discussed in more detail under Model Building (Chapter 15)

Detecting non-linearity – in final model

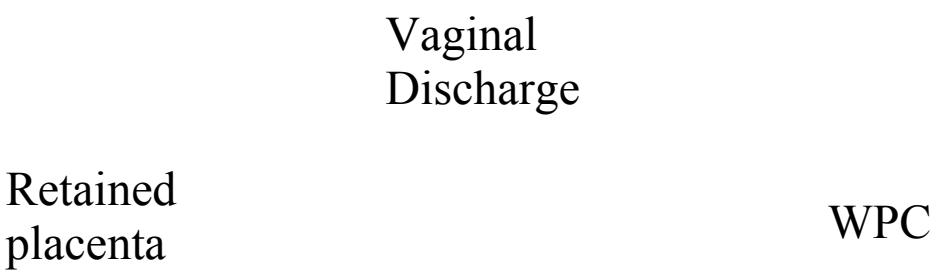
- plot residuals vs fitted values
  - simultaneous evaluation of all predictors
- plot of residuals vs predictor

Detecting non-linearity – before / during model building

- smoothed scatter plot of outcome vs predictor
- explore polynomial functions of X
- transformation of X
- categorization of predictor
  - indicator dummy variable
  - hierarchical dummy variable
  - compare categorical and linear variables

Detecting confounding (VER 13.5)

- review
  - components: Y (outcome), E (exposure) and Z (measured or unmeasured confounder)
  - criteria
    - Z must be a risk factor of Y (in E-,because risk must not be caused by E->Y))
    - Z must be associated with E
      - cohort – start follow up period
        - if constant during follow up -> look for unconditional assoc. Z->E
      - case-control – in controls (represent source population if no selection bias)
    - Z must not be the result of E or the result of Y
  - causal model



- assessment of confounding
  - when three criteria are met
  - difference between crude and adjusted effect/association changes substantially
    - e.g. 20-30%
- example - change in regression coefficient

```
. reg wpc vag_disch              /* vag_disch adds 10 days, P=0.04 */

------------------------------------------------------------------------------
         wpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   vag_disch |   11.99647   5.846716     2.05   0.040     .5282858    23.46465
       _cons |   68.17426   1.334494    51.09   0.000     65.55669    70.79184
------------------------------------------------------------------------------

. reg wpc rp                     /* rp adds 13 days, P=0.008 */

------------------------------------------------------------------------------
         wpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          rp |    11.7344   4.434231     2.65   0.008     3.036767    20.43203
       _cons |   67.68842   1.364298    49.61   0.000     65.01239    70.36446
------------------------------------------------------------------------------

. reg wpc rp vag_disch        /* vag_disch no sig. ,  rp is a confounder */

------------------------------------------------------------------------------
         wpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          rp |    10.2397   4.540774     2.26   0.024     1.333087    19.14632
   vag_disch |   9.066942     5.9819     1.52   0.130    -2.666406    20.80029
       _cons |   67.35756   1.381095    48.77   0.000     64.64857    70.06654
------------------------------------------------------------------------------
```

Confounding and collinearity

- confounding => collinearity
  - example: bwt – smoking (only for example, not for model building)
    - cig_2, cig_3 on bwt
  - two models
    - 1) E = cig_2
    - 2) E = cig_3
  - causal diagrams / criteria

- Model 1
  - cig_3 is not a confounder
  - cig_3 highly correlated with cig_2 -> keep cig_2
- Model 2
  - cig_2 meets (partially) confounding criteria
  - change of coefficient?

Detecting and modeling interaction

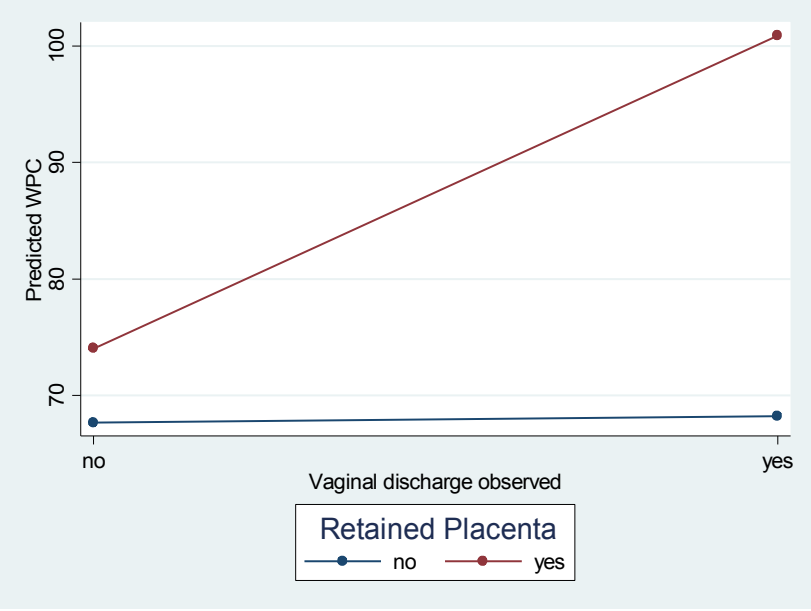
- cross-product term
  - eg. retpla and vag_disch
  - retpla*vag_disch

- interpreting coefficients (VER 14.7)
- examples 14.9, 14.10 and 14.11

Interaction between 2 dichotomous predictors

```
. reg wpc i.vag_disch##rp

      Source |       SS       df       MS              Number of obs =    1574
-------------+------------------------------           F(  3,  1570) =    4.53
       Model |  35915.9774     3  11971.9925           Prob > F      =  0.0036
    Residual |  4152174.58  1570  2644.69719           R-squared     =  0.0086
-------------+------------------------------           Adj R-squared =  0.0067
       Total |  4188090.56  1573  2662.48605           Root MSE      =  51.427

------------------------------------------------------------------------------
         wpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
 1.vag_disch |   .5429296   7.265382     0.07   0.940    -13.70794     14.7938
       1.rp |   6.339794   4.914322     1.29   0.197    -3.299531    15.97912
            |
vag_disch#rp |
       1 1  |   26.34867   12.77367     2.06   0.039     1.293414    51.40392
            |
       _cons |   67.66861   1.387883    48.76   0.000     64.94631    70.39091
------------------------------------------------------------------------------
```

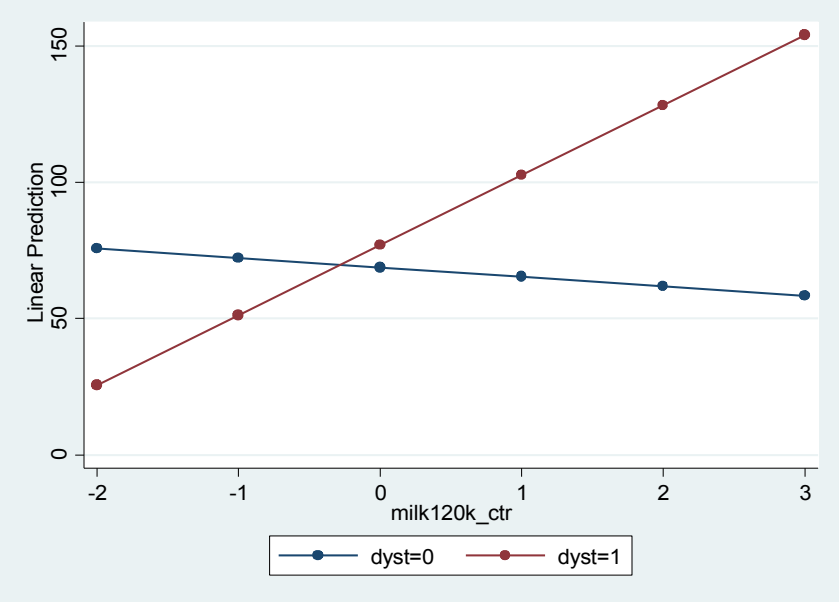
```
. margins vag_disch#rp

Adjusted predictions                                  Number of obs   =       1574
Model VCE    : OLS

Expression   : Linear prediction, predict()

------------------------------------------------------------------------------
             |            Delta-method
             |     Margin   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
vag_disch#rp |
      no#no  |   67.66861   1.387883    48.76   0.000     64.94631    70.39091
     no#yes  |    74.0084    4.71427    15.70   0.000     64.76147    83.25533
     yes#no  |   68.21154   7.131589     9.56   0.000      54.2231    82.19998
    yes#yes  |      100.9   9.389173    10.75   0.000     82.48336    119.3166
------------------------------------------------------------------------------

. marginsplot, legend(title("Retained Placenta")) noci ytitle("Predicted WPC")
title("")
```



Interaction between a dichotomous and a continuous predictor

```
. reg wpc i.dyst##c.milk120k_ctr
```

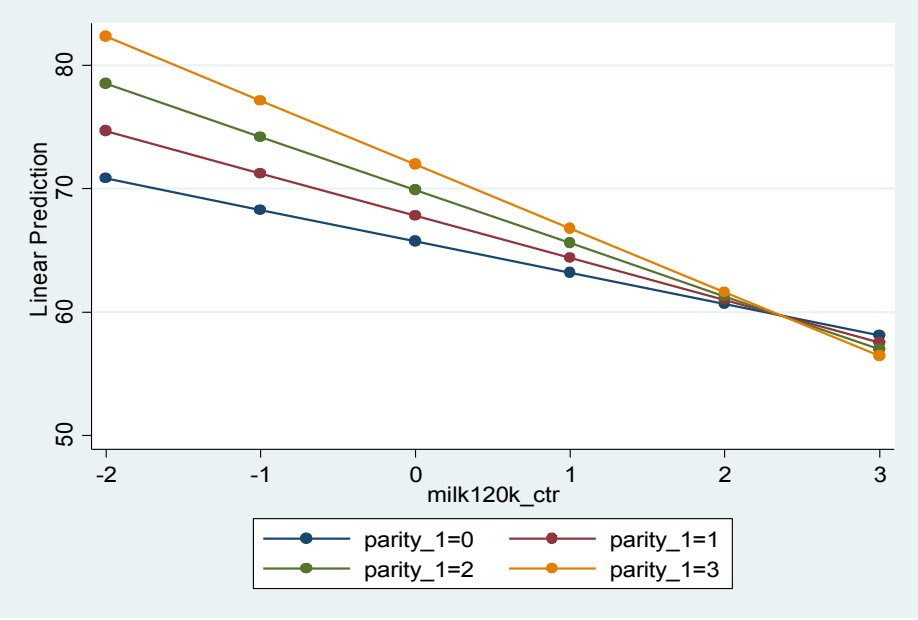
```
      Source |       SS       df       MS              Number of obs =    1536
-------------+------------------------------           F(  3,  1532) =    3.83
       Model |  30572.8752     3  10190.9584           Prob > F      =  0.0095
    Residual |  4073791.78  1532  2659.13302           R-squared     =  0.0074
-------------+------------------------------           Adj R-squared =  0.0055
       Total |  4104364.66  1535   2673.8532           Root MSE      =  51.567

------------------------------------------------------------------------------
                 wpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------------+--------------------------------------------------------------
               dyst |
                yes |    8.20714   5.718528     1.44   0.151     -3.00983    19.42411
       milk120k_ctr |  -3.446531   1.928535    -1.79   0.074    -7.229379    .3363161
dyst#c.milk120k_ctr |
                yes |   29.14238   9.468101     3.08   0.002     10.57057    47.71419
              _cons |   68.75682   1.357147    50.66   0.000     66.09475    71.41888
------------------------------------------------------------------------------
```



Interaction between 2 continuous predictors

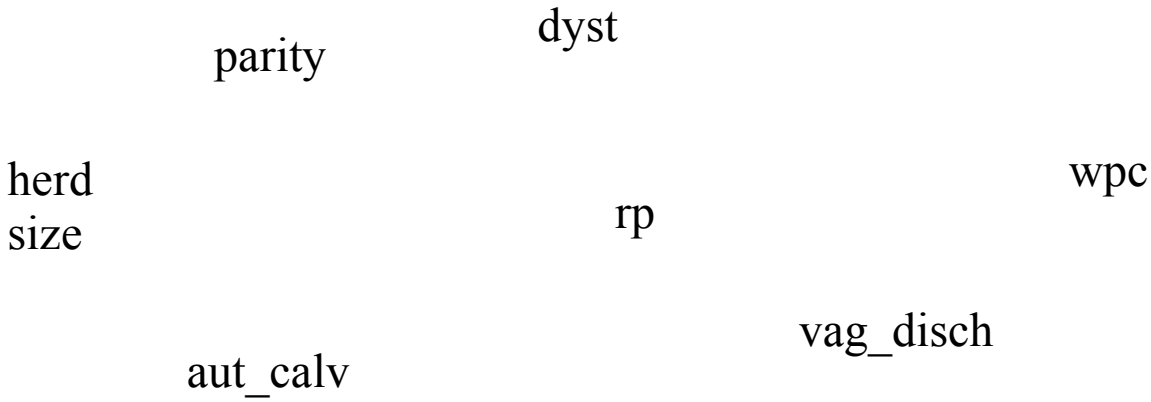
.reg wpc c.parity_1##c.milk120k_ctr

```
      Source |       SS       df       MS              Number of obs =    1536
-------------+------------------------------           F(  3,  1532) =    2.26
       Model |  18084.1899     3  6028.06329           Prob > F      =  0.0797
    Residual |  4086280.47  1532   2667.2849           R-squared     =  0.0044
-------------+------------------------------           Adj R-squared =  0.0025
       Total |  4104364.66  1535   2673.8532           Root MSE      =  51.646

------------------------------------------------------------------------------
         wpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   parity_1 |   2.072164   .9549532     2.17   0.030     .1990103    3.945318
milk120k_ctr |  -2.542834   3.091716    -0.82   0.411    -8.607278    3.521609
             |
c.parity_1#c.milk120k_ctr |  -.8764358   1.363504    -0.64   0.520    -3.550968    1.798096
             |
       _cons |   65.73655   2.207989    29.77   0.000     61.40555    70.06755
------------------------------------------------------------------------------
```



- Two way interactions between continuous predictors are difficult to interpret, and, whenever significant, should be evaluated by fitting a range of possible values for both predictors.

Causal interpretation (VER 14.7)



- graphical assessment confounding
  - identify potential confounder variables in complex causal models
  - steps
    - draw causal diagram
      - nodes-> variables; arrows-> causal relations
      - time on horizontal axis (right most recent)
      - intermediate variables
    - delete all arrows from E->Y
    - identify potential confounders
      - unblocked paths E->Y
    - identify collider variables

```
. reg wpc c.hs100_ctr##c.hs100_ctr parity_1 i.aut_calv i.twin i.dyst rp##vag_disch

      Source |       SS       df       MS              Number of obs =    1574
-------------+------------------------------           F(  9,  1564) =   12.67
       Model |  284624.575     9  31624.9528           Prob > F      =  0.0000
    Residual |  3903465.98  1564  2495.82224           R-squared     =  0.0680
-------------+------------------------------           Adj R-squared =  0.0626
       Total |  4188090.56  1573  2662.48605           Root MSE      =  49.958
------------------------------------------------------------------------------
             wpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----------------+------------------------------------------------------------
        hs100_ctr |   19.95934   2.166523     9.21   0.000     15.70974    24.20894
c.hs100_ctr#c.hs100_ctr |   11.01938   3.115218     3.54   0.000     4.908933    17.12982
         parity_1 |   1.133798   .8603017     1.32   0.188    -.5536683    2.821264
       1.aut_calv |  -6.233634   2.547009    -2.45   0.014    -11.22955   -1.237722
             twin |
             yes  |   20.20742   9.857903     2.05   0.041     .8713237    39.54352
             dyst |
             yes  |   11.97194     5.4714     2.19   0.029     1.239883    22.70399
               rp |
             yes  |   6.069851   4.820726     1.26   0.208    -3.385915    15.52562
       vag_disch |
             yes  |   1.457361   7.171815     0.20   0.839    -12.61002    15.52475
    rp#vag_disch |
          yes#yes |   23.50198   12.53811     1.87   0.061    -1.091296    48.09526
             _cons |   63.83234   2.711612    23.54   0.000     58.51356    69.15112
------------------------------------------------------------------------------
```

- herd_size
- parity
- aut_calv
- twin
- dyst
- rp
- vag_disch