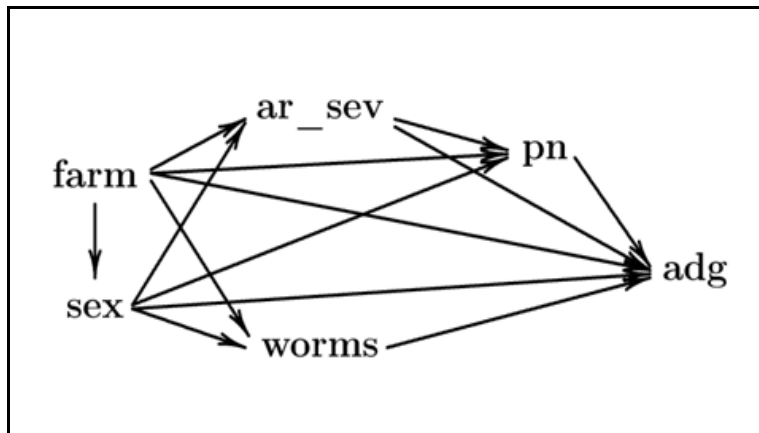


## Model Building Exercise (VER 15) Solution

### 1. Identify the primary outcome of interest and main predictors of interest.

A: The primary outcome of interest is -adg- and the primary predictors of interest are \_worms-, -pn-, and -ar\_sev-.

### 2. Draw the causal diagram for your full causal model.



### 3. Identify which variables are potential confounders.

For the -pn- → -adg- relationship, -ar\_sev-, -farm- and -sex- are potential confounders.

For the -ar\_sev- → -adg- relationship, -farm- and -sex- are potential confounders.

For the -worms- → -adg- relationship, -farm- and -sex- are potential confounders.

Since both -sex- and -farm- likely have very strong relationships with -adg-, we will make the apriori decision to force them into all regression models.

### 4. Identify any intervening (intermediate) variables.

A: -pn- is a (partially) intervening variable for the -ar\_sev- → -adg- relationship.

### 5. Identify any exposure-independent variables.

A: -worms- is an exposure-independent variable for the -pn- and -ar\_sev- effects.

### 6. Go through the exercise of computing descriptive statistics for each variable, evaluate unconditional associations and carry out a pairwise correlation/association analysis among all predictors. If you were looking to eliminate potential predictors at this stage, are there any likely candidates?

## Outcome variable:

```
adg  Average daily weight gain (gms)
-----
      type:  numeric (int)
      range:  [317,707]          units:  1
unique values: 194              missing .: 0/341
      mean:   519.399
      std. dev: 70.9674
      percentiles:  10%    25%    50%    75%    90%
                   427    469    519    568    610
```

There are no missing observations for -adg-. The values are well spread out with some pigs gaining over twice as much as other pigs in the dataset. The mean and the median are very close which indicates that the data are roughly symmetrically distributed. The histogram confirms that they have an approximate normal distribution.

## Main predictors:

```
pn  Pneumonia (lu>0)
-----
      type:  numeric (byte)
      label:  yn
      range:  [0,1]          units:  1
unique values: 2              missing .: 0/341
      tabulation:  Freq.  Numeric  Label
                  155     0     no
                  186     1     yes.
```

The pigs are roughly split between those with and without pneumonia. This will make the analysis of the effects of -pn- reasonably powerful. There are no missing data.

```
ar_sev  (unlabeled)
-----
      type:  numeric (float)
      range:  [0,1]          units:  1
unique values: 2              missing .: 0/341
      tabulation:  Freq.  Value
                  307     0
                  34      1
```

There are only 34 pigs with severe atrophic rhinitis. Consequently, the study will not have much power to detect an effect of this disease (i.e., we will only find an effect if it is relatively large). There are no missing data.

```
worms  Count of nematodes in small intestine at time of slaughter
-----
      type:  numeric (byte)
      range:  [0,72]          units:  1
unique values: 31              missing .: 0/341
      mean:   3.36657
      std. dev: 9.88183
      percentiles:  10%    25%    50%    75%    90%
                   0      0      0      2      8
```

Worm counts range from 0 to 72 but over 50% of pigs have no worms at all (distribution is highly skewed). A few pigs with very large worm burdens will probably have a profound influence on the estimate of the effect of worms (if -worms- is modelled as a continuous variable). There are no missing values.

## Potential confounders:

```
farm  Farm identification number
-----
      type:  numeric (byte)
      range:  [1,15]
unique values: 15
      units:  1
      missing .: 0/341

      mean:   7.77419
      std. dev: 4.36888

percentiles:    10%    25%    50%    75%    90%
                2      4      8      11    14
```

```
. tab farm
```

| Farm  <br>identificat  <br>ion number | Freq. | Percent | Cum.   |
|---------------------------------------|-------|---------|--------|
| 1                                     | 26    | 7.62    | 7.62   |
| 2                                     | 21    | 6.16    | 13.78  |
| 3                                     | 28    | 8.21    | 21.99  |
| 4                                     | 26    | 7.62    | 29.62  |
| 5                                     | 19    | 5.57    | 35.19  |
| 6                                     | 24    | 7.04    | 42.23  |
| 7                                     | 21    | 6.16    | 48.39  |
| 8                                     | 28    | 8.21    | 56.60  |
| 9                                     | 25    | 7.33    | 63.93  |
| 10                                    | 17    | 4.99    | 68.91  |
| 11                                    | 21    | 6.16    | 75.07  |
| 12                                    | 14    | 4.11    | 79.18  |
| 13                                    | 25    | 7.33    | 86.51  |
| 14                                    | 24    | 7.04    | 93.55  |
| 15                                    | 22    | 6.45    | 100.00 |
| Total                                 | 341   | 100.00  |        |

The pigs were relatively evenly distributed across the 15 farms. There were no missing values.

```
sex  Sex of the pig
-----
      type:  numeric (byte)
      label:  sex
      range:  [0,1]
unique values: 2
      units:  1
      missing .: 0/341

      tabulation:  Freq.  Numeric  Label
                  172      0  female
                  169      1  castrate
```

The pigs are roughly equally split between the two sexes. There are no missing values.

## Unconditional associations:

All of the following associations were evaluated by fitting simple (unconditional) linear regression models (data not shown):

- -farm- is very strongly associated with -adg-.
- -sex- is significantly ( $P=0.001$ ) associated with -adg-. Females gained an average of 506 gms/day, while the weight gain was 26.5 gms/day higher for castrated males.
- -pn- (pneumonia) is significantly ( $P=0.001$ ) associated with -adg-, with -pn- positive pigs gaining 24.5 gms/day less per day than -pn- negative pigs (533 gms/day).
- -ar\_sev- (severe atrophic rhinitis) seems to have a profound (and strongly significant) impact on -adg-; on average, affected pigs gained 68 gms/day less than unaffected pigs.
- -worms- (worm burden) seems to be significantly associated with -adg-, but surprisingly, the -adg- goes

up as the worm burden goes up (we would have expected an effect in the opposite direction).

### Correlations:

```
. pwcorr sex adg pn ar_sev worms
```

|        | sex     | adg     | pn      | ar_sev  | worms  |
|--------|---------|---------|---------|---------|--------|
| sex    | 1.0000  |         |         |         |        |
| adg    | 0.1868  | 1.0000  |         |         |        |
| pn     | -0.0021 | -0.1723 | 1.0000  |         |        |
| ar_sev | -0.0166 | -0.2892 | 0.0482  | 1.0000  |        |
| worms  | 0.0066  | 0.2472  | -0.0646 | -0.0074 | 1.0000 |

There are no correlations among predictors that are sufficiently large that I would worry about collinearity problems. (Note: many of the predictors are dichotomous, and correlations are not a good measure of association among dichotomous variables, but the very low correlations observed give us hope that collinearity will not be a serious problem).

### 7. Decide what 2-way interactions you want to examine.

A: Based on knowledge of the two diseases (and to keep this teaching exercise reasonably short), we will apriori decide to look only at the possible interaction between -pn- and -ar\_sev-. The model including this interaction only is shown below.

```
. regress adg pn##ar_sev
```

| Source   | SS         | df  | MS         | Number of obs = 341 |        |  |
|----------|------------|-----|------------|---------------------|--------|--|
| Model    | 197166.325 | 3   | 65722.1084 | F( 3, 337) =        | 14.62  |  |
| Residual | 1515201.43 | 337 | 4496.14669 | Prob > F =          | 0.0000 |  |
| -----    |            |     |            | R-squared =         | 0.1151 |  |
| -----    |            |     |            | Adj R-squared =     | 0.1073 |  |
| Total    | 1712367.76 | 340 | 5036.37576 | Root MSE =          | 67.053 |  |

| adg       | Coef.     | Std. Err. | t     | P> t  | [95% Conf. Interval] |           |
|-----------|-----------|-----------|-------|-------|----------------------|-----------|
| pn        |           |           |       |       |                      |           |
| yes       | -18.89445 | 7.67544   | -2.46 | 0.014 | -33.99226            | -3.796644 |
| 1.ar_sev  | -42.9117  | 19.42989  | -2.21 | 0.028 | -81.13083            | -4.692567 |
| pn#ar_sev |           |           |       |       |                      |           |
| yes#1     | -38.80518 | 24.87714  | -1.56 | 0.120 | -87.73922            | 10.12885  |
| _cons     | 536.3732  | 5.626989  | 95.32 | 0.000 | 525.3048             | 547.4417  |

The interaction is not quite significant, but perhaps strong enough to be included in the model building.

### 8. Use forward selection, backward elimination and stepwise selection procedures to identify potential models for further investigation.

A: All 3 procedures produced exactly the same model. This is unusual and is a function of the fact that we have a small number of predictors and they either have relatively strong associations with the outcome or non at all (ie no borderline significant associations). For the sake of simplicity, only the results for the stepwise backwards elimination procedure are shown.

```
. stepwise, lockterm1 pe(0.05): regress adg (i.farm sex) worms (i.pn##i.ar_sev)
```

```
begin with term 1 model
p = 0.0000 < 0.0500 adding 1.pn 1.ar_sev 1.pn#1.ar_sev
```

| Source   | SS         | df  | MS         | Number of obs | = | 341    |
|----------|------------|-----|------------|---------------|---|--------|
| Model    | 1099087.8  | 18  | 61060.4335 | F(18, 322)    | = | 32.06  |
| Residual | 613279.957 | 322 | 1904.59614 | Prob > F      | = | 0.0000 |
|          |            |     |            | R-squared     | = | 0.6419 |
|          |            |     |            | Adj R-squared | = | 0.6218 |
| Total    | 1712367.76 | 340 | 5036.37576 | Root MSE      | = | 43.642 |

| adg       | Coef.     | Std. Err. | t     | P> t  | [95% Conf. Interval] |
|-----------|-----------|-----------|-------|-------|----------------------|
| farm      |           |           |       |       |                      |
| 2         | 19.81175  | 12.83143  | 1.54  | 0.124 | -5.432275 45.05577   |
| 3         | 23.34785  | 12.44097  | 1.88  | 0.061 | -1.127998 47.82369   |
| 4         | -113.5638 | 12.27253  | -9.25 | 0.000 | -137.7082 -89.4193   |
| 5         | -24.56906 | 13.21677  | -1.86 | 0.064 | -50.57119 1.433069   |
| 6         | -69.86855 | 12.38692  | -5.64 | 0.000 | -94.23807 -45.49903  |
| 7         | -14.67511 | 12.90451  | -1.14 | 0.256 | -40.06291 10.71269   |
| 8         | -57.57176 | 13.10607  | -4.39 | 0.000 | -83.35611 -31.78742  |
| 9         | -62.704   | 12.39326  | -5.06 | 0.000 | -87.08599 -38.32202  |
| 10        | -84.08496 | 13.76267  | -6.11 | 0.000 | -111.1611 -57.00886  |
| 11        | -97.94475 | 12.9311   | -7.57 | 0.000 | -123.3849 -72.50463  |
| 12        | -123.4743 | 14.57479  | -8.47 | 0.000 | -152.1481 -94.80047  |
| 13        | -115.3472 | 12.74396  | -9.05 | 0.000 | -140.4192 -90.27531  |
| 14        | -60.59613 | 12.6888   | -4.78 | 0.000 | -85.55955 -35.63271  |
| 15        | 23.50103  | 13.0893   | 1.80  | 0.074 | -2.250319 49.25238   |
| sex       | 29.16879  | 4.77938   | 6.10  | 0.000 | 19.76604 38.57155    |
| pn        |           |           |       |       |                      |
| yes       | -17.46428 | 5.59491   | -3.12 | 0.002 | -28.47147 -6.45708   |
| 1.ar_sev  | -30.9291  | 13.11464  | -2.36 | 0.019 | -56.7303 -5.127898   |
| pn#ar_sev |           |           |       |       |                      |
| yes#1     | -38.84491 | 16.73416  | -2.32 | 0.021 | -71.76701 -5.922819  |
| _cons     | 568.4791  | 10.17541  | 55.87 | 0.000 | 548.4604 588.4978    |

**9. Evaluate potential confounding effects by forcing all removed predictors that may be confounders, back into the model. Do any of them need to be kept, even though not statistically significant, because they appear to exert a confounding effect?**

A: There really is nothing to do here since, based on our causal diagram, worms can not be a confounder for the effects of either -pn- or -ar\_sev- on -adg-. However, if we do force it back in the model it has virtually no effect on the coefficients for the other disease variables (results not shown, see do-file for details).

**10. Identify the model which best evaluates the effect of -ar\_sev- on -adg-.**

A: This is the model shown above.

**11. Evaluate the reliability of the model. Compute also the PRESS statistic, and explain what it tells you about the fitted model.**

The leave-one-out cross-validation implicit in the PRESS statistic, we will compare the  $R^2=0.64$  of the full model (above) to the predictive  $R^2$  value:

```
. predict resid, res
. predict lev, leverage
. gen eq1=(resid/(1-lev))^2
. summ eq1
```

| Variable    | Obs | Mean     | Std. Dev. | Min      | Max      |
|-------------|-----|----------|-----------|----------|----------|
| -----+----- |     |          |           |          |          |
| eq1         | 341 | 2033.087 | 2998.274  | .0189977 | 17353.27 |

```
. di "PRESS =" r(sum)
PRESS =693282.69
```

```
. di "R2(pred) = "1-(r(sum)/ (`e(mss)' + `e(rss)'))
R2(pred) = .59513213
```

The PRESS value increased to 693,283 (from 613,280 - the residual sum of squares of the full data model), and the corresponding  $R^2$  dropped to 0.595. This shrinkage in predictive ability does however not give rise to serious concern.