Reproducible Research: Weaving with Stata

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Outline I

Goals

- Learn about reproducible research, or in its snobby name “literate programming”
- Show how this can be done using StatWeave
    - web address goes here

Concept

- Any analysis should be completely reproducible
- Reproduction of an analysis should be accessible

Typical Implementation in Stata

- In Stata, it is possible to have reproducible research by having
  - A series of do-files which reproduce the steps in the analysis
  - A document which somehow includes pieces of the log files produced by the do-files
  - The document could also include output as generated by ado-files
    - Inclusion is simple in something like LaTeX, but is not very easy in typical word-processors
- This is only a partial solution, because this allows only listings and graphics, but not the direct use of computed quantities

Weaving

- Another approach is that of *weaving*, where the text and the analysis code are in the same document
  - It is analogous to writing computer programs which contain both the code (the analysis) and the documentation (the writeup)
  - Such documents *weave* together documentation and code
- Weaving has the advantage that there can be no separation between the statistics and the writeup
- Weaving has also been called *literate programming*
  - This was Knuth's original name for the idea of mixing code and documentation

Other Reasons for Weaving

- Clearly useful for documentation
- Weaving is fantastically useful when teaching using software
  - Can remake documentation as the software is updated, making sure that all commands and output are up-to-date
  - Can make homework and test questions quite easily

Other Implementations

- Knuth wrote WEB for weaving C or C++ code
  - He also wrote TEX, of course
- docstrip is another utility which can combine code and documentation
  - Really hard to use
- Sweave has been around for quite a while for S-plus and R

Today's Topic: StatWeave

- StatWeave is written by Russ Lenth at the University of Iowa
  - `http://www.stat.uiowa.edu/~rlenth/StatWeave`
- It is relatively new, but is quite useful
- Written in Java, so it is cross-platform
- It can support many different programming languages—we'll focus on Stata, of course

What Document Types are Allowed?

- StatWeave allows working with and creating LaTeX and OpenOffice documents
  - Both have nice open formats which allow
- The architecture of StatWeave allows other document types to be added

Building Blocks

- Write a document
- Include code in special blocks
  - Block definitions are specific to the type of document
- Add options which allow reuse or redisplaying of code or output

Creating the Document

- Run the document through StatWeave
  - Currently implemented as a command-line application
- Open up the resulting document
- Smile and nod knowingly

Conceptual Model

- Each block of code is called a *code chunk*
- StatWeave looks through the document and pulls out each code chunk, keeping track of its position and optional label
- The language(s) (here: Stata) run their blocks of code as though they were sequential commands in one session unless specifically overridden
- We can reuse code or output by specifiying options for the code chunks

Input and Output—Basic form

- Each block's input is gathered together
- Each block's output is gathered together
- The output is all displayed after the input
- This is a bit of a shock when using Stata (or most other packages other than SAS)

Taking a Look at Some Examples

- We'll look at examples from both OpenOffice and LaTeX.
- They'll be similar, so that you can see how they work
- Using OpenOffice will be the easiest way to see how the fine-tuning works, also

Working with OpenOffice

- This is most easily done by showing a document which already marked up, and by adding some code chunks
  - The final document will be available from the course website
- Controlling what is being done by StatWeave is done by styles
- The `SWStyles.ott` file contains the styles needed to add code to a document
- The allowable options follow...

Options for Fine Control

- Options are split by their scope
  - Whole document/following chunks
  - Entire code chunks
  - Input, and output
  - There are also special options which pertain to graphics
- Most options are boolean
  - *option* is the same as *option* = `true`
  - `!`*option* is the same as *option* = `false`

Whole Document Options

- These are formatting options which are put into non-code blocks
  - In OpenOffice, these are the SWopts style
  - In LaTeX, these are `\weaveOpts{}` commands
- They pertain to all the following blocks, so they truly are from-here-on options
- These can also be made language-specific by including the language name
  - In OpenOffice, using `Stata:` in the options block
  - In LaTeX, using `\StataweaveOpts{}`

Code Chunk Options

- `label` is string, and defaults to *"lastchunk"*
    - Used for labeling the chunk for later reuse—often worthwhile
- `eval` is boolean, and defaults to *true*
    - If false, the code is displayed but not evaluated
- `restart` is boolean, and defaults to *false*
    - If true, a new session is started, so the previous state is of the package is discarded

Common Input Options

- `echo` is boolean, and defaults to *true*
  - If false, the code is not displayed
- `savecode` is boolean and defaults to *false*
  - If true, the code is saved but is not displayed, sadly enough
  - Main conceptual use is for default setups for following code
- `codestyle` is string
  - For the document as a whole, it defaults to `Winput`
  - It can be a style in OpenOffice, or a FancyVerbatim environment in LaTeX

Less Common Input Options

- `prompt`, `prom` and `ompt` are alll string, and control the look of the prompt
  - None work for Stata
- `showref` is boolean and defaults to *false*
  - If there is recalled code in a block and this is true, the recalled code is displayed
- `codefmt` is LaTeX only, and requires some knowledge of the `fancyvrb` package
- `beforecode` and `aftercode` are also LaTeX only, and cause LaTeX code to be placed before and after every code block

Common Output Options

- `hide` is boolean and defaults to *false*
  - If true, the output is not displayed
- `saveout` is boolean and defaults to *false*
  - It true, the output is saved, but not displayed
- `outstyle` is string, and is similar to `codestyle`
  - For the document as a whole, it defaults to `Woutput`
  - It can be a style in OpenOffice, or a FancyVerbatim environment in LaTeX

Less Common Output Options

- `results` is string, and is used for using a package to insert document-type specific code
- `loose` and `tight` change how series of blank lines are displayed (not too useful in Stata)
- `outfmt` is LaTeX only and is similar to `codefmt`
- `beforeout` and `afterout` are just like their counterparts for code

Common Graphics Options

- `fig` is boolean and defaults to *false*
  - It *must* be specified if a figure is produced by the codeblock
  - There can be only one figure per code block
- `figfmt` is string and specifies the type of output
  - `eps` is a common type, though StatWeave seems to like `png`, which is good for visual materials only
- `scale` is numeric and defaults to 1.0
- `disph` and `dispw` are both numeric control the displayed height and width
  - These can be given in cm, in, pt, etc.
  - Scale overrides `disph` and `dispw`

Less Common Graphics Options

- There are also `height` and `width` options, but they do not preserve the aspect ratio
  - These would make for smaller bitmap files, such as `png`
- `savefig` holds the figure for later display
- `beforefig` and `afterfig` are LaTeX only

Referring to Code

- Besides code chunks, there are other tags
- `coderef` will reuse code by its label
  - The code is executed once again
- `recall`*thing* will recall saved chunks using the chunk's label
  - The *thing* can be `code`, `out`, or `fig`

Special Tricks

- StatWeave understands code substitution for numbered arguments
  - This can be used for defining code chunk templates which get reused
- This provides a very primitive programming interface

Working with Expressions

- StatWeave claims it can evaluate Stata expressions
    - This is badly overstated, but should be easily fixed
- As it stands now, all it understands for expressions are egen functions(!)

Simple Stuff

- Since this is not interactive, it will be simple with a little explanation
- Rest assured that all output displayed below is a part of this LaTeX document
    - I will include the outline of the document on the conference website—it will reproduce the output, but not the formatting
        - It takes some work to integrate this so that it displays nicely on both the slides and the handouts
        - I also have many customizations for putting together blocks of lectures

Building Blocks

- Stata code is enclosed in blocks:

  ```
  \begin{Statacode}
      some code here
  \end{Statacode}
  ```

- There are options for including and hiding code

A First Example

- Opening the ubiquitous `auto` dataset and running a regression:

```
. sysuse auto
. regress mpg weight displacement headroom

(1978 Automobile Data)

      Source |       SS       df       MS              Number of obs =      74
-------------+------------------------------           F(  3,    70) =   44.08
       Model |  1597.77483     3  532.59161            Prob > F      =  0.0000
    Residual |  845.684629    70  12.081209            R-squared     =  0.6539
-------------+------------------------------           Adj R-squared =  0.6391
       Total |  2443.45946    73  33.4720474           Root MSE      =  3.4758

------------------------------------------------------------------------------
         mpg |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      weight |  -.0064885   .0011863    -5.47   0.000    -.0088545   -.0041225
displacement |    .005754   .0099834     0.58   0.566    -.0141573    .0256652
    headroom |  -.2444638   .5525116    -0.44   0.660    -1.346413    .8574858
       _cons |   40.48554   2.224643    18.20   0.000     36.04863    44.92245
------------------------------------------------------------------------------
```

Code for the First Example

- The code for the above block is just:

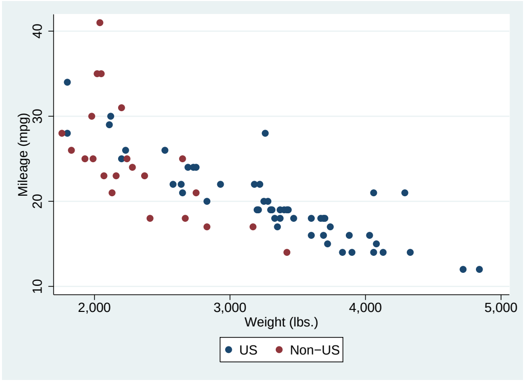
```
\begin{Statacode}
sysuse auto
regress mpg weight displacement headroom
\end{Statacode}
```

- For short blocks, all is quite simple

A Graph

- Here is an example of a graph:

```
. twoway (scatter mpg weight if !foreign) ///
.    (scatter mpg weight if foreign), ///
.    legend(order(1 "US" 2 "Non-US"))
```



Code for the Graph

- Ideally, the code for the graph is also simple:

```
\begin{Statacode}[fig]
twoway (scatter mpg weight if !foreign) ///
  (scatter mpg weight if foreign), ///
  legend(order(1 "US" 2 "Non-US"))
\end{Statacode}
```

- In reality, life is not so simple when working with pdftex
  - We'll see a workaround in a bit

A Little Bit of Mata

- Here is an example from the Mata manual

```
. mata
. X = (76, 53, 48 \ 53, 88, 46 \ 48, 46, 63 )
. Xi = invsym(X)
. Xi
.

[symmetric]
                  1               2               3
    +-----------------------------------------------+
  1 |    .0298458083                                |
  2 |   -.0098470272     .0216268926                |
  3 |   -.0155497706    -.0082885675     .0337724301  |
    +-----------------------------------------------+
```

Continuing with Mata

- This continues the last computation and quits Mata

```
. Xi*X
. end

                1              2              3
    +--------------------------------------------+
  1 |           1   -1.11022e-16   -1.11022e-16  |
  2 | -1.11022e-16             1              0  |
  3 |           0              0              1  |
    +--------------------------------------------+
```

Note on the Last Two Slides

- Even though we were working in Mata, the input was split across the two slides
- This illustrates that each block starts where the previous block stopped
- So... no worry about losing track of where you are

Working with Graphs and pdftex

- Statweave is a bit heavy-handed when trying to make pdf documents—it will not allow making an eps file
    - pdftex doesn't understand eps files, but there is a built-in epstopdf converter with all modern LaTeX distributions
- The trick is to make an eps file, and then use Stata to use internal tools to convert it

Input and Output

- As mentioned above, the behavior of StatWeave is much more SAS-like than Stata-like, because it gathers all output from a code chunk together
- The workaround is simple, though unfriendly: simply enclose each line in its own Statacode environment
    - Not nice, but workable

Input and Output Example, Part I

- All together

```
. sum mpg
. tab foreign, sum(mpg)
```

```
    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
         mpg |        74     21.2973    5.785503         12         41

            |      Summary of Mileage (mpg)
   Car type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Domestic |   19.826923   4.7432972          52
    Foreign |   24.772727   6.6111869          22
------------+------------------------------------
      Total |   21.297297   5.7855032          74
```

Input and Output Example, Part II

- Splitting the lines into separate chunks

```
. sum mpg

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
         mpg |        74     21.2973    5.785503         12         41

. tab foreign, sum(mpg)

            |      Summary of Mileage (mpg)
   Car type |        Mean   Std. Dev.       Freq.
------------+------------------------------------
   Domestic |   19.826923   4.7432972          52
    Foreign |   24.772727   6.6111869          22
------------+------------------------------------
      Total |   21.297297   5.7855032          74
```

What We’ve Seen

- Embedding code in documents
- Being able to rerender output quite simply
- A few rough edges—but these are fixable