# Heatmaps for Economic Analysis

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(DRAFT)

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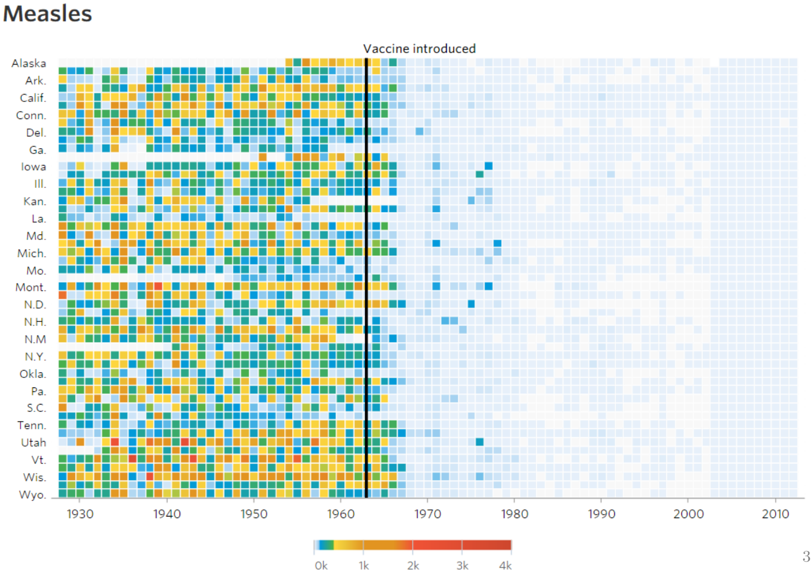
# What is a heatmap?

- **A two-dimensional visualization of data using colour to represent magnitude**
- Broad definition, which could be divided into
- **Embedded** heatmaps that overlay colour on an actual map or image (not covered here)
- **Matrix** heatmaps that presents a grid of values where colours differ by cell

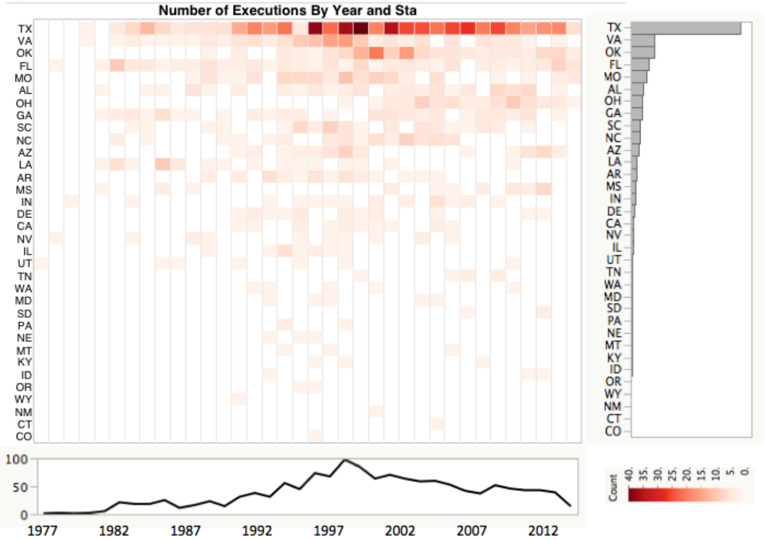
# What is a heatmap?

**Example:** The WSJ vaccine visualization (DeBold, Friedman 2015)



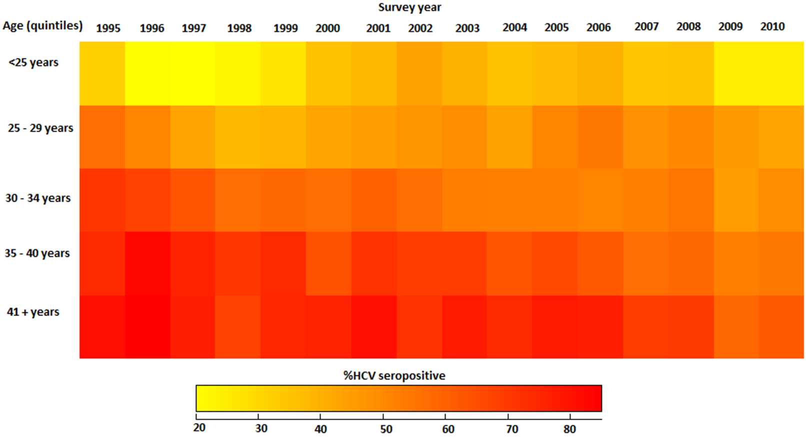
# WHAT IS A HEATMAP?

**Example:** Kaiser Fung's executions data



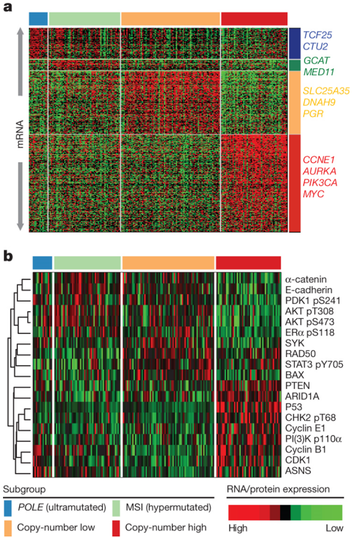
# What is a heatmap?

**Example (Bad):** A "quilt plot" of Hep C prevalence (Wand et al)



# What is a heatmap?

**Example:** Plotting gene expression data over samples (TCGN 2013)



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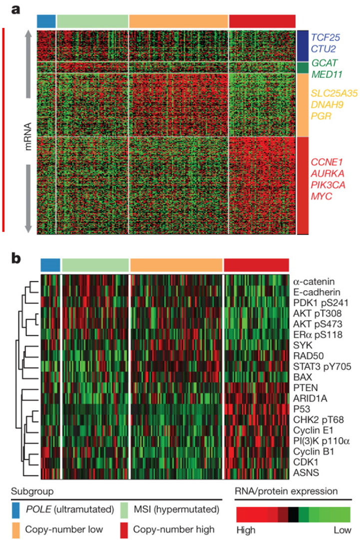
Each row ($\sim$ 1500) is one gene



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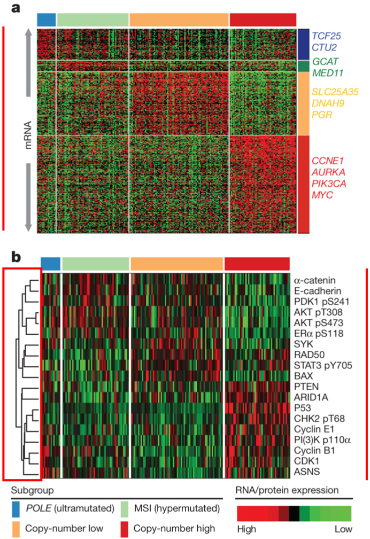
**Dendrogram**




Each row is a protein

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Some takeaways from these examples:

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- Good representation of high-dimensional data
  (4) is an extreme example of this, but common in bioinformatics
- Permuting axis order improves interpretation
  (2) sorts Y by total count over the sampling period, (4) uses cluster analysis (recall dendrogram)

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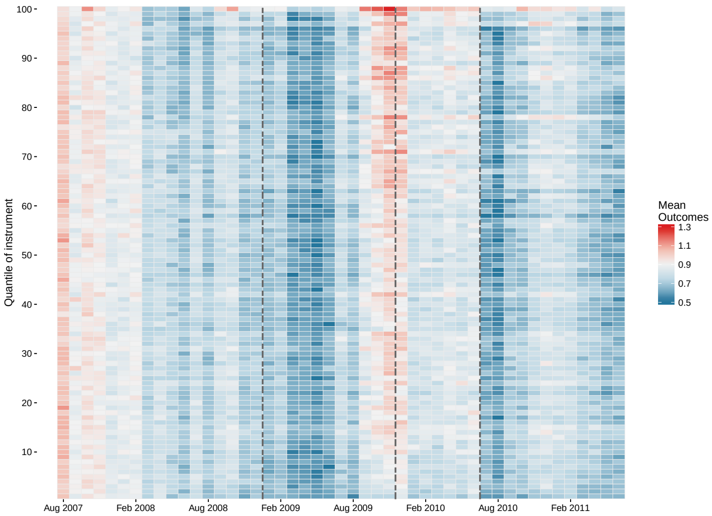
Now consider a heatmap where time is on the X axis (**showing the policy introduction**) and where W, a variable of interest or one related to a latent factor is binned on the Y axis (**showing the support of W**)

# Setting up a heatmap for economics

**Example:** Scaled house sales in a heatmap sorted by FTHB exposure, from Berger, Turner, Zwick (2016)



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  Placing time on X and an instrument of W on Y implies this heatmap is a visualization of nonparametric regression
- Good representation of high-dimensional data
  Around  8600 ZIPs binned into 100 percentiles
- Permuting axis order improves interpretation
  Y axis sorted to be increasing in W's instrument, and figure tells us the effect of W on Y is positive in a linear model

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and so on.

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  - Stata `twoway contour`, `hmap`
  - R base, `gplots`, `ggplot2`, `d3heatmap` ...
  - Matlab and Python `matplotlib`

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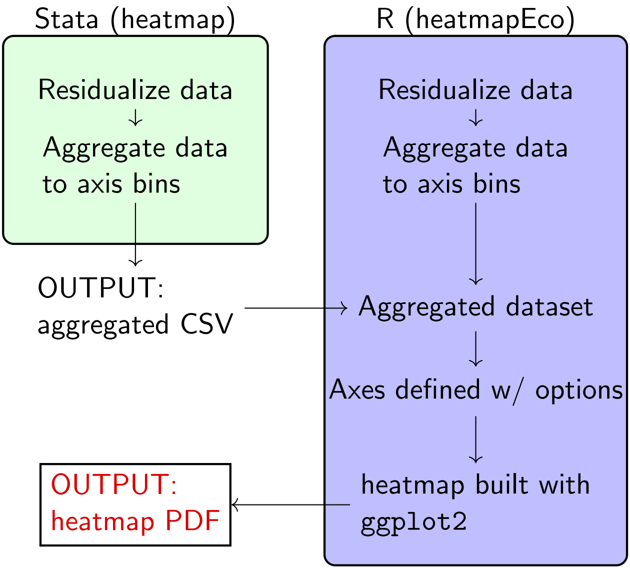
  So why another package?
- `heatmapEco` makes it easy building informative heatmaps by
  - **Focusing on axis setup as a design framework;**
  - **Computing relevant axis permutations;**
  - **Executing prerequisite data cleaning.**

# The heatmapEco package

- Complicated heatmaps like TCGN's are also quite uncomplicated; they are literally a projection of some tabular data
- In other words, the data loaded in is a 373x1500 matrix. The values are then standardized, variables are clustered and given a colour
- But instead data may need to be aggregated, reshaped; axes relabelled; colour palettes adjusted to show significant results
- `heatmapEco` combines R packages to simplify these changes and adds design features of its own

# The heatmapEco package



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- Currently, X axis can be set up as:
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Currently output is in landscape letter format, but ultimately axis placement should be arbitrary and portrait format heatmaps possible

# heatmapEco aggregation

In R the aggregation process is inputted using a pseudo-formula

```
Z ∼ CrS(Y,ID,w):X(t)
```

where

- `Z` is the dependent variable, or the fill variable
- `Y` is the factor independent variable or a continuous instrument to be binned
- `X` is the index or time axis
- `t` allows time varying `Y` to be sorted on its values at a time `t`, (**use caution**)
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In Stata the syntax is
```
heatmap Z Y X [weights], id(varname) [t_sort(string)]
```

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- This means the aggregation function argument `grp.func` can take many forms, so long as a summary function is involved
- E.g. take the median of a quantile-month bin. Or take the log transform of that median
- Or add control flow; if data censored, first remove censored data and output log median of what remains
- Stata's aggregation features are much less rich: every collapse function could be inputted into `grpfunc`

# heatmapEco residualization

Both dependent and independent variables (fill and Y axis) can be first residualized according to a model

$$Y = \beta W + D\theta + F\psi + X\gamma + \varepsilon$$

Where D, F are fixed effects and X are controls.
Stata implementation uses base `areg`. R implementation uses `plm` or `lfe` (TODO)

# Colour palettes

Standard divergent color palette

Semi-sequential palette for count data

- On standard palette, far two shades reserved for outlier detection: binned values above the 1.5 + IQR range are considerably darker
- Standard colors are not equally spaced: distribution below median take longer to get to dark blue hues. This is to emphasize “Ashenfelter dips”
- Count data palette is ColorBrewer YlOrBr, with high outliers and a muted hue to deemphasize data censored by 0 (by default)

# heatmapEco Examples

# WSJ replication

Download data from Project Tycho. The cleaning in R:

```
library(data.table)
obj <- melt(fread("MEASLES_Incidence_1930-2003.csv"),
                  c("YEAR", "WEEK"))
obj[, value := as.numeric(value)]
```

Calling heatmapEco:

```
nasum <- function(...)
         if (all(is.na(...))) NA else sum(..., na.rm=TRUE)
heatmapEco(value ~ CrS(variable,variable):YEAR, obj,
t.fmt="\%Y", t.per="year", pol.break=c("Jan 1963"),
grp.func=nasum, count=T, factor.ax=T, outliers=T, split.x=10,
zlab="Measles Incidence (p100,000)", save="measlesRep.pdf")
```

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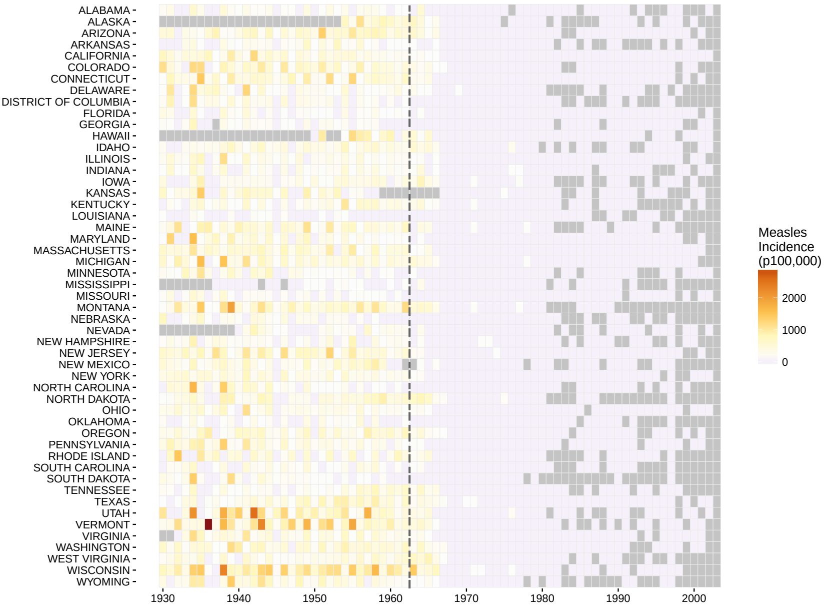

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Overall: **9 lines of code w/ data.table**

- **9 lines fewer** than base w/ heatmap.2
- **25 lines fewer** than pure ggplot2

# The Berger, Turner, Zwick heatmap

Let's call the program from Stata this time

```
heatmap y3_trim fthomebuyers_filingunits_2000 mdate ///
        [aw=totalhsales_base], n(100) id(zip) tperiod(yearmon) ///
        ylabel(10) polbreak(Jan 2009, Dec 2009, Jul 2010) ///
        save(BTZRep.pdf)
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- Default group function is mean, but the quantiles are weighted

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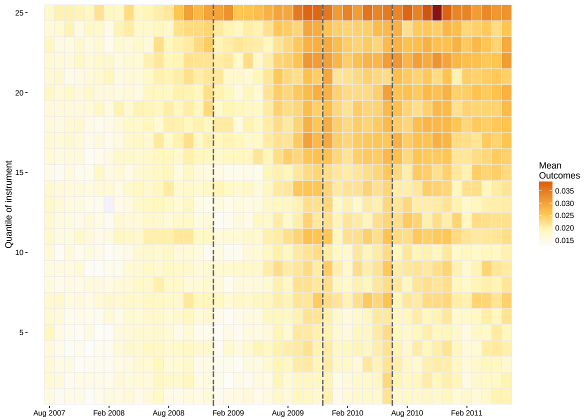
- `ylabel(n)` divides y-axis labels into n even intervals

# The Berger, Turner, Zwick heatmap

Another perspective: check the standard errors on the mean estimates over a coarser partition

```
heatmap y3_trim fthomebuyers_filingunits_2000 mdate ///
       [aw=totalhsales_base], n(25) id(zip) tperiod(yearmon) ///
        grpfunc(sem) ylabel(5) count out ///
        polbreak(Jan 2009, Dec 2009, Jul 2010) save(BTZRep_se.pdf)
```



# Conclusions

# When not to use heatmaps

- Heatmaps are not a panacea: there is a tradeoff between
  - Higher density of effectively presented data;
  - Information lost in using colours, instead of geometric shapes, to represent change
- It is also unclear how heatmaps can display uncertainty of statistics plotted in each bin, e.g. confidence intervals
- A good argument for a package that simplifies heatmap creation — the less time spent making a visualization, the less likely one gets overattached to one when a better solution exists

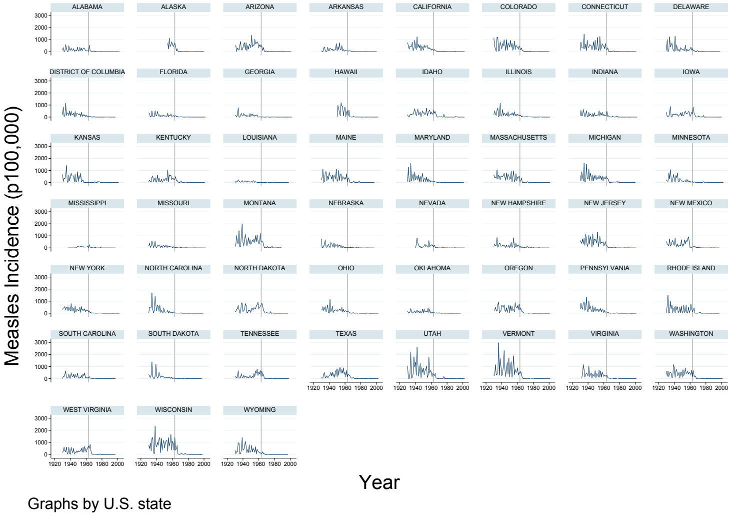
# When not to use heatmaps

A good heuristic (define Z as the variable plotted with colour):

- Plotting quantiles on the Y axis: How much clarity is gained relative to overlapping line graphs split by Y? What information is lost?
- Plotting a factor variable on the Y axis: How much clarity is gained relative to a small multiple plot split by Y? What information is lost?

# When not to use heatmaps

**Example**: Measles vaccine revisited



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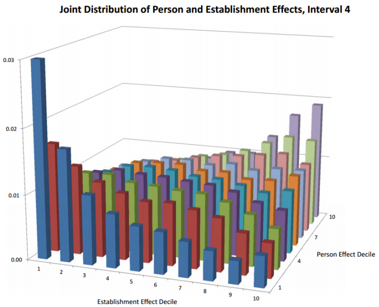
**Example**: visualizing positive assortative matching



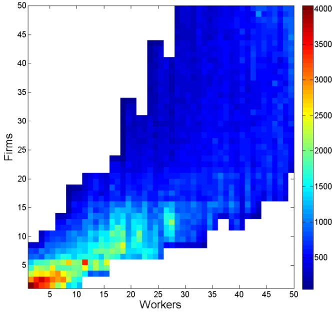




Figure 6: Estimated Match Density.

(L: Card, Heining & Kline (2012); R: Hagedorn, Law & Manovskii (2016)) 2016 How would the interpretation change if the visualization was instead overlaying many marginals over each other? Small multiples of marginals?

# Future updates

- Easy addition of side plots to the heatmap (a histogram on both axes, time series, bar plot of differences over two periods. . . )
- Syntax revisions
- Let either axis support variables belonging in one of four types (time, factor, quantile, index)
- Variable dimensions for heatmap cells (for uneven discretizations of a continuous variable)
- ???

# References I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# Thanks!