Example: Demand for Cigarettes

- How much will a hypothetical cigarette tax reduce cigarette consumption? To answer this, we need the elasticity of demand for cigarettes

Panel data:

- Annual cigarette consumption and average prices paid (including tax)
- 48 continental US states, 1985-1995

$$\ln(Q_{it}^{cigarettes}) = \alpha_i + \beta_1 \ln(P_{it}^{cigarettes}) + u_{it}$$

- Why is the OLS estimator of β_1 likely to be biased?
- Proposed instrumental variable:

  Z_i = general sales tax per pack in the state = $SalesTax_i$
- Do you think this instrument is plausibly valid?
- Relevant? corr($SalesTax_i$, $\ln(P_{it}^{cigarettes})$) $\neq 0$?
- Exogenous? corr($SalesTax_i$, u_{it}) = 0?
- For now, use data from 1995 only.

STATA ***Example***: **Cigarette demand, First stage**

Instrument = Z = *rtaxso* = general sales tax (real $/pack)

```
          X         Z
. reg lravgprs rtaxso if year==1995, r;

Regression with robust standard errors                 Number of obs =      48
                                                       F(  1,    46) =   40.39
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.4710
                                                       Root MSE      =  .09394

------------------------------------------------------------------------------
             |               Robust
    lravgprs |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      rtaxso |   .0307289   .0048354     6.35   0.000     .0209956    .0404621
       _cons |   4.616546   .0289177   159.64   0.000     4.558338    4.674755
------------------------------------------------------------------------------

                X-hat
. predict lravphat;       Now we have the predicted values from the 1st stage
```

Second stage

```
          Y        X-hat
. reg lpackpc lravphat if year==1995, r;

Regression with robust standard errors                 Number of obs =      48
                                                       F(  1,    46) =   10.54
                                                       Prob > F      =  0.0022
                                                       R-squared     =  0.1525
                                                       Root MSE      =  .22645

------------------------------------------------------------------------------
             |               Robust
     lpackpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lravphat |  -1.083586   .3336949    -3.25   0.002    -1.755279   -.4118932
       _cons |   9.719875   1.597119     6.09   0.000     6.505042    12.93471
------------------------------------------------------------------------------
```

- These coefficients are the TSLS estimates
- The standard errors are wrong because they ignore the fact that the first stage was estimated

Combined into a single command:

```
                    Y           X          Z
. ivregress 2sls lpackpc (lravgprs = rtaxso) if year==1995, vce(robust);

Instrumental variables (2SLS) regression                Number of obs =      48
                                                        Wald chi2(1)  =   12.05
                                                        Prob > chi2   =  0.0005
                                                        R-squared     =  0.4011
                                                        Root MSE      =  .18635

------------------------------------------------------------------------------
             |               Robust
     lpackpc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    lravgprs |  -1.083587   .3122035    -3.47   0.001    -1.695494    -.471679
       _cons |   9.719876   1.496143     6.50   0.000      6.78749    12.65226
------------------------------------------------------------------------------
Instrumented:  lravgprs          This is the endogenous regressor
Instruments:   rtaxso            This is the instrumental varible
------------------------------------------------------------------------------
```

Panel data set

- Annual cigarette consumption, average prices paid by end consumer (including tax), personal income
- 48 continental US states, 1985-1995

Estimation strategy

- Having panel data allows us to control for unobserved state-level characteristics that enter the demand for cigarettes, as long as they don't vary over time
- But we still need to use IV estimation methods to handle the simultaneous causality bias that arises from the interaction of supply and demand.

Fixed-effects model of cigarette demand

$$\ln(Q_{it}^{cigarettes}) = \alpha_i + \beta_1 \ln(P_{it}^{cigarettes}) + \beta_2 \ln(Income_{it}) + u_{it}$$

- $i = 1,\ldots,48$, $t = 1985, 1986,\ldots,1995$
- α_i reflects unobserved omitted factors that vary across states but not over time, e.g. attitude towards smoking
- Still, $\text{corr}(\ln(P_{it}^{cigarettes}), u_{it})$ is plausibly nonzero because of supply/demand interactions
- Estimation strategy:
  - Use panel data regression methods to eliminate α_i
  - Use TSLS to handle simultaneous causality bias

The "changes" method (when T=2)

- One way to model long-term effects is to consider 10-year changes, between 1985 and 1995
- Rewrite the regression in "changes" form:

$$
\begin{aligned}
&\ln(Q_{i1995}^{cigarettes}) - \ln(Q_{i1985}^{cigarettes}) \\
&\quad = \beta_1[\ln(P_{i1995}^{cigarettes}) - \ln(P_{i1985}^{cigarettes})] \\
&\quad\quad + \beta_2[\ln(Income_{i1995}) - \ln(Income_{i1985})] \\
&\quad\quad + (u_{i1995} - u_{i1985})
\end{aligned}
$$

- Must create "10-year change" variables, for example:

  10-year change in log price = $\ln(P_{i1995}) - \ln(P_{i1985})$
- Then estimate the demand elasticity by TSLS using 10-year changes in the instrumental variables

We'll take this approach

Use TSLS to estimate the demand elasticity by using the "10-year changes" specification

```
                    Y         W         X           Z
. ivregress 2sls dlpackpc dlperinc (dlavgprs = drtaxso) , r;

IV (2SLS) regression with robust standard errors       Number of obs =      48
                                                       F(  2,    45) =   12.31
                                                       Prob > F      =  0.0001
                                                       R-squared     =  0.5499
                                                       Root MSE      =  .09092

------------------------------------------------------------------------------
             |               Robust
    dlpackpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    dlavgprs |  -.9380143   .2075022    -4.52   0.000    -1.355945   -.5200834
    dlperinc |   .5259693   .3394942     1.55   0.128    -.1578071    1.209746
       _cons |   .2085492   .1302294     1.60   0.116    -.0537463    .4708446
------------------------------------------------------------------------------
Instrumented:  dlavgprs
Instruments:   dlperinc drtaxso
------------------------------------------------------------------------------
```

NOTE:

- *All the variables – Y, X, W, and Z's – are in 10-year changes*
- *Estimated elasticity = –.94 (SE = .21) – surprisingly elastic!*
- *Income elasticity small, not statistically different from zero*
- *Must check whether the instrument is relevant…*

Check instrument relevance: compute first-stage *F*

```
.  reg dlavgprs drtaxso dlperinc , r;

Regression with robust standard errors                 Number of obs =      48
                                                       F(  2,    45) =   16.84
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.5146
                                                       Root MSE      =  .06334

------------------------------------------------------------------------------
             |               Robust
    dlavgprs |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     drtaxso |   .0254611   .0043876     5.80   0.000      .016624    .0342982
    dlperinc |  -.2241037   .2188815    -1.02   0.311    -.6649536    .2167463
       _cons |   .5321948   .0295315    18.02   0.000     .4727153    .5916742
------------------------------------------------------------------------------

.  test drtaxso;

 ( 1)  drtaxso = 0

       F(  1,    45) =   33.67
           Prob > F =    0.0000
```

We didn't need to run "test" here because with m=1 instrument, the F-statistic is the square of the t-statistic, that is, 5.80*5.80 = 33.67

First stage F = 33.7 > 10 so instrument is not weak

Can we check instrument exogeneity? *No…m = k*

What about two instruments (cig-only tax, sales tax)?

```
                      Y          W          X          Z1     Z2
. ivregress 2sls dlpackpc dlperinc (dlavgprs = drtaxso drtax) , vce(r);

Instrumental variables (2SLS) regression               Number of obs =      48
                                                       Wald chi2(2)  =   45.44
                                                       Prob > chi2   =  0.0000
                                                       R-squared     =  0.5466
                                                       Root MSE      =  .08836

------------------------------------------------------------------------------
             |               Robust
    dlpackpc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    dlavgprs |  -1.202403   .1906896    -6.31   0.000    -1.576148   -.8286588
    dlperinc |   .4620299   .2995177     1.54   0.123    -.1250139    1.049074
       _cons |   .3665388   .1180414     3.11   0.002     .1351819    .5978957
------------------------------------------------------------------------------
Instrumented:  dlavgprs
Instruments:   dlperinc drtaxso drtax
------------------------------------------------------------------------------
      drtaxso = general sales tax only
      drtax = cigarette-specific tax only
      Estimated elasticity is -1.2, even more elastic than using general
      sales tax only
```

With $m>k$, we can test the overidentifying restrictions

Test the overidentifying restrictions

```
.  predict e, resid;        Computes predicted values for most recently
                            estimated regression (the previous TSLS regression)
.  reg e drtaxso drtax dlperinc;     Regress e on Z's and W's

      Source |       SS       df       MS              Number of obs =      48
-------------+------------------------------           F(  3,    44) =    1.64
       Model |  .037769176     3  .012589725           Prob > F      =  0.1929
    Residual |  .336952289    44  .007658007           R-squared     =  0.1008
-------------+------------------------------           Adj R-squared =  0.0395
       Total |  .374721465    47  .007972797           Root MSE      =  .08751

------------------------------------------------------------------------------
           e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     drtaxso |   .0127669   .0061587     2.07   0.044      .000355    .0251789
       drtax |  -.0038077   .0021179    -1.80   0.079     -.008076    .0004607
    dlperinc |  -.0934062   .2978459    -0.31   0.755    -.6936752    .5068627
       _cons |    .002939   .0446131     0.07   0.948    -.0869728    .0928509
------------------------------------------------------------------------------
.  test drtaxso drtax;

 ( 1)  drtaxso = 0                  Compute J-statistic, which is m*F,
 ( 2)  drtax = 0                        where F tests whether coefficients on
                                        the instruments are zero
       F(  2,    44) =    2.47              so J = 2 * 2.47 = 4.93
            Prob > F =    0.0966        ** WARNING – this uses the wrong d.f. **
```

The correct degrees of freedom for the *J*-statistic is *m*–*k*:

- $J = mF$, where F = the F-statistic testing the coefficients on $Z_{1i},\ldots,Z_{mi}$ in a regression of the TSLS residuals against $Z_{1i},\ldots,Z_{mi}$, $W_{1i},\ldots,W_{mi}$.
- Under the null hypothesis that all the instruments are exogeneous, J has a chi-squared distribution with $m–k$ degrees of freedom
- Here, J = 4.93, distributed chi-squared with d.f. = 1; the 5% critical value is 3.84, so reject at 5% sig. level.
- In STATA:

```
.  dis "J-stat = " r(df)*r(F) "  p-value = "  chiprob(r(df)-1,r(df)*r(F));
J-stat = 4.9319853  p-value = .02636401
```

Check instrument relevance: compute first-stage *F*

```
         X       Z1       Z2        W
.  reg dlavgprs drtaxso drtax dlperinc , r;

Regression with robust standard errors                 Number of obs =      48
                                                       F(  3,    44) =   66.68
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.7779
                                                       Root MSE      =  .04333

------------------------------------------------------------------------------
             |               Robust
    dlavgprs |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     drtaxso |    .013457   .0031405     4.28   0.000     .0071277    .0197863
       drtax |   .0075734   .0008859     8.55   0.000     .0057879    .0093588
    dlperinc |  -.0289943   .1242309    -0.23   0.817    -.2793654    .2213767
       _cons |   .4919733   .0183233    26.85   0.000     .4550451    .5289015
------------------------------------------------------------------------------

.  test drtaxso drtax;

 ( 1)  drtaxso = 0
 ( 2)  drtax = 0

       F(  2,    44) =   88.62           88.62 > 10 so instruments aren't weak
            Prob > F =    0.0000
```

Tabular summary of these results:

TABLE 10.1 Two Stage Least Squares Estimates of the Demand for Cigarettes Using Panel Data for 48 U.S. States

Dependent variable: $\ln(Q_{i,1995}^{cigarettes}) - \ln(Q_{i,1985}^{cigarettes})$

Regressor	(1)	(2)	(3)
$\ln(P_{i,1995}^{cigarettes}) - \ln(P_{i,1985}^{cigarettes})$	−0.94** (0.21)	−1.34** (0.23)	−1.20** (0.20)
$\ln(Inc_{i,1995}) - \ln(Inc_{i,1985})$	0.53 (0.34)	0.43 (0.30)	0.46 (0.31)
Intercept	0.21 (0.13)	0.45** (0.14)	0.37** (0.12)
Instrumental variable(s)	Sales tax	Cigarette-specific tax	Both sales tax and cigarette-specific tax
First-stage *F*-statistic	33.70	107.20	88.60
Overidentifying restrictions *J*-test and *p*-value	-	-	4.93 (0.026)

These regressions were estimated using data for 48 U.S. states (48 observations on the ten-year differences). The data are described in Appendix 10.1. The *J*-test of overidentifying restrictions is described in Key Concept 10.6 (its *p*-value is given in parentheses), and the first-stage *F*-statistic is described in Key Concept 10.5. Individual coefficients are statistically significant at the *5% level or **1% significance level.

How should we interpret the J-test rejection?

- J-test rejects the null hypothesis that both the instruments are exogenous
- This means that either rtaxso is endogenous, or rtax is endogenous, or both!
- The J-test doesn't tell us which! You must exercise judgment…
- Why might rtax (cig-only tax) be endogenous?
  - Political forces: history of smoking or lots of smokers (political pressure for low cigarette taxes)
  - If so, cig-only tax is endogenous
- This reasoning doesn't apply to general sales tax
- → use just one instrument, the general sales tax

The Demand for Cigarettes: Summary of Empirical Results

- Use the estimated elasticity based on TSLS with the general sales tax as the only instrument:
  Elasticity = -.94, *SE* = .21
- This elasticity is surprisingly large (not inelastic) – a 1% increase in prices reduces cigarette sales by nearly 1%. This is much more elastic than conventional wisdom in the health economics literature.
- This is a long-run (ten-year change) elasticity. *What would you expect a short-run (one-year change) elasticity to be – more or less elastic?*