ENDOGENEITY ISSUE: INSTRUMENTAL VARIABLES MODELS

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INSTRUMENTS FOR WHAT?

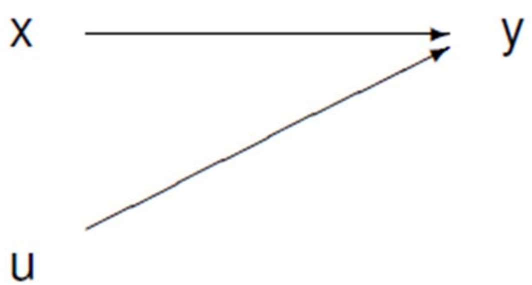
- What are instrumental variables (IV) methods? Such methods are most widely known as a solution to **endogenous independent variables**. In case of variables correlated with the error term, IV methods provide a way to nonetheless obtain consistent parameter estimates.
- The violation of $E(x_i`\varepsilon_i) = 0$ caused by endogenous x's can also arise for common causes: **measurement error** in x's (errors-in-variables), **omitted-variable bias** (a variable known to be relevant for the data generating process is not measurable, and no good proxies can be found) and **reverse causality** (x causes y AND y causes x).

ENDOGENEITY

- Let us consider the simple regression equation:

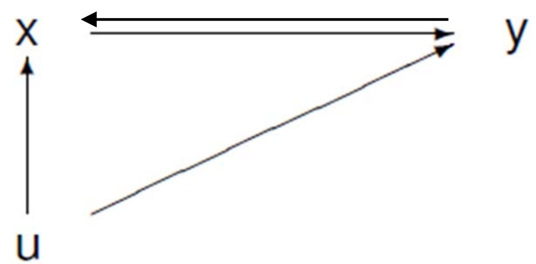
$$y = \beta_0 + \beta_1 \, x + u.$$

OLS consistently estimates if:



- In case of no association between x and u.

OLS fails if:



- The correlation between x and u ($E(x_i`\varepsilon_i) \neq 0$) can be caused by any of several factors.

ENDOGENEITY: SUPPLY-DEMAND

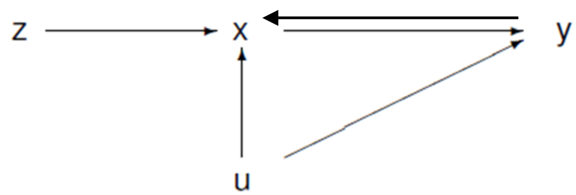
- Endogeneity: the notion that two or more variables are jointly determined in the behavioural model. This arises naturally in the context of a simultaneous equations model such as a supply-demand system in economics, in which price and quantity are jointly determined in the market for that good or service.
- A shock or disturbance to either supply or demand will affect both the equilibrium price and quantity in the market, so that by construction both variables are correlated with any shock to the system. OLS methods will yield inconsistent estimates of any regression including both price and quantity, however specified.

CONDITIONS FOR A VALID INSTRUMENT

- Let us consider:

$$Y_i = \beta_0 + \beta_1 X_i + u_i$$

- For an instrumental variable (an "*instrument*") *Z* to be valid, it must satisfy two conditions:
    1. ***Instrument relevance***: corr(*Zi*,*Xi*) ≠ 0
    2. ***Instrument exogeneity***: corr(*Zi*,*ui*) = 0



- In general, we may have many variables in x, and more than one x correlated with u. In that case, we shall need at least that many variables in z.

HOW TO FIND *Z*? (SUPPLY-DEMAND)

- It may be difficult to find variables that can serve as valid instruments.
- Many variables that have an effect on included endogenous variables also have a direct effect on the dependent variable.
- To deal with the problem of endogeneity in a supply-demand system, a candidate z will affect (e.g.) the quantity supplied of the good, but not directly impact the demand for the good.

- An example for an agricultural commodity might be temperature or rainfall: clearly exogenous to the market, but likely to be important in the production process.

IV APPROACH: LIMITS

- Beyond “practical” difficulties in finding variables that can serve as valid instruments, we need to highlight that:

1. IV estimators are biased in finite samples, and their finite-sample properties are often problematic. Thus, most of the justification for the use of IV is asymptotic, and performance in small samples may be poor.

2. The precision of IV estimates is lower than that of OLS estimates.

IV METHOD: TSLS (1/2)

- We displays the model in the simplest possible case, with one independent variable and one instrument.

$$y_i = \beta_0 + \beta_1\, x_i + u_i$$

- The "Two-Stage-Least-Square" Method (TSLS) has two stages and two regressions.
- At the first stage, we estimate by OLS the relation between the variable to be instrumented (x) and the instrument (z):

$$x_i = \pi_0 + \pi_1\, z_i + v_i,$$

- We estimate $\hat{\pi}_0\ and\ \hat{\pi}_1$, then we compute the predicted values of x_i, $\hat{x}_i = \hat{\pi}_0 + \hat{\pi}_1 z_i$

IV METHOD: TSLS (2/2)

- At the second stage, we simply replace x_i by $\hat{x}_i$ in the basic regression, running an OLS model:

$$y_i = \beta_0 + \beta_1 \hat{x}_i + u_i,$$

that allows us to estimate the coefficient of interest.

- NOTICE THAT:
  - Because $\hat{x}_i$ is uncorrelated with u_i(if n is large), the first least squares assumption holds (if n is large).
  - $\hat{\pi}_0$ and $\hat{\pi}_1$ converge to their true values in large samples.
  - The resulting estimator is called the *Two Stage Least Squares (TSLS)* estimator $\hat{\beta}_1^{TSLS}$.
  - Usually, the IV method is implemented in one single regression (`ivreg` in Stata)

IV METHOD: ALGEBRAIC DERIVATION

- It is possible to derive the TSLS estimator through algebra. Starting from:

$$Y_i = \beta_0 + \beta_1 X_i + u_i$$

- We derive:
$$\begin{aligned} \operatorname{cov}(Y_i, Z_i) &= \operatorname{cov}(\beta_0 + \beta_1 X_i + u_i, Z_i) \\ &= \operatorname{cov}(\beta_0, Z_i) + \operatorname{cov}(\beta_1 X_i, Z_i) + \operatorname{cov}(u_i, Z_i) \\ &= 0 + \operatorname{cov}(\beta_1 X_i, Z_i) + 0 \\ &= \beta_1 \operatorname{cov}(X_i, Z_i) \end{aligned}$$

- Therefore: $\beta_1 = \dfrac{\operatorname{cov}(Y_i, Z_i)}{\operatorname{cov}(X_i, Z_i)}$

IV METHOD: CONSISTENCY

- The IV estimator replaces these population covariances with sample covariances: $\hat{\beta}_1^{TSLS} = \frac{s_{YZ}}{s_{XZ}}$

- The sample covariances are consistent, therefore:

$$\hat{\beta}_1^{TSLS} = \frac{s_{YZ}}{s_{XZ}} \xrightarrow{p} \frac{\operatorname{cov}(Y,Z)}{\operatorname{cov}(X,Z)} = \beta_1$$

  - NOTICE THAT The instrument relevance condition, cov(X,Z) ≠ 0, ensures that you don’t divide by zero.

EXAMPLE ON SUPPLY/DEMAND

[from: Stock and Watson, Introduction to Econometrics, chapter 12]

- IV regression was originally developed to estimate demand elasticity for agricultural goods, for example milk:

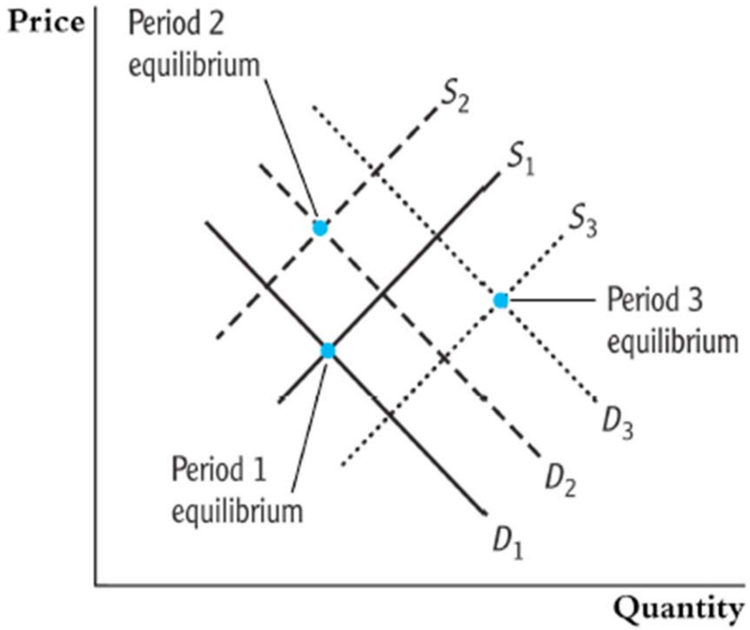
$$\ln(Q_i^{butter}) = \beta_0 + \beta_1 \ln(P_i^{butter}) + u_i$$

- Where:
  - β_1 = price elasticity of butter = % change in quantity for a 1% change in price
  - Data: observations on price and quantity of butter for different years
  - The OLS regression of $\ln(Q_i^{butter})$ on $\ln(P_i^{butter})$ suffers from simultaneous causality bias.

EXAMPLE ON SUPPLY/DEMAND

[from: Stock and Watson, Introduction to Econometrics, chapter 12]

- Simultaneous causality bias in the OLS regression of quantities on prices arises because price and quantity are determined by the interaction of demand and supply!

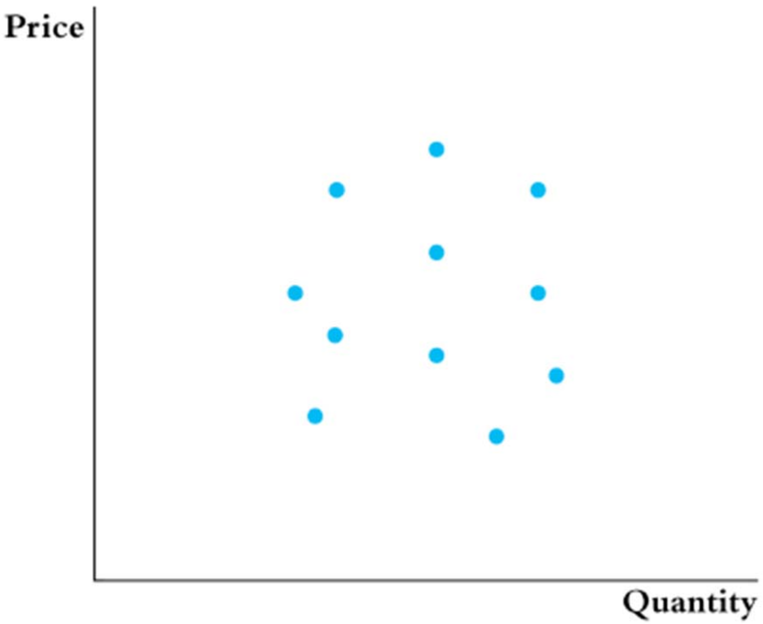


(a) Demand and supply in three time periods

EXAMPLE ON SUPPLY/DEMAND

[from: Stock and Watson, Introduction to Econometrics, chapter 12]

- The interaction between demand and supply could reasonably produce something not useful for our purposes!

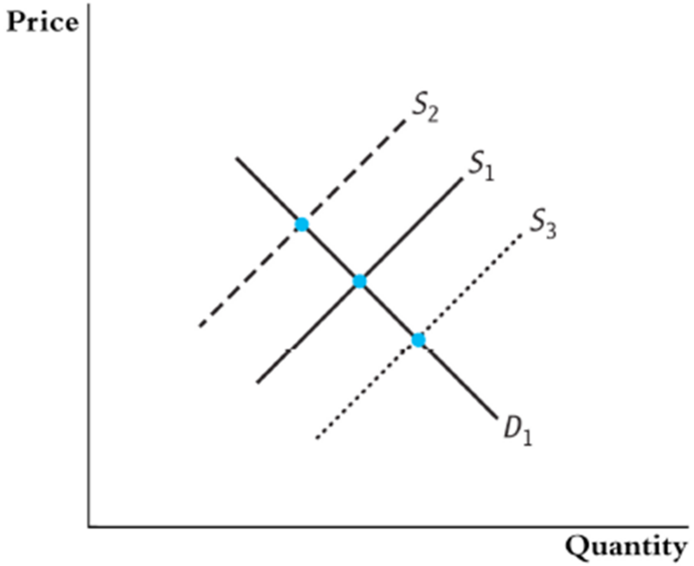


(b) Equilibrium price and quantity for 11 time periods

EXAMPLE ON SUPPLY/DEMAND

[from: Stock and Watson, Introduction to Econometrics, chapter 12]

- But, what if only supply shifts?



(c) Equilibrium price and quantity when only the supply curve shifts

- TSLS estimates the demand curve by isolating shifts in price and quantity that arise from shifts in supply; *Z* is a variable that shifts supply but not demand.

EXAMPLE ON SUPPLY/DEMAND

[from: Stock and Watson, Introduction to Econometrics, chapter 12]

- Let's search for an instrumental variable for the original model: $\ln(Q_i^{butter}) = \beta_0 + \beta_1 \ln(P_i^{butter}) + u_i$
- Let a (possible) instrumental variable for the model to be:

  Z = rainfall in dairy-producing regions:
- We need to check if *Z* is:
  1. $\mathrm{corr}(rain_i, u_i) = 0$ (exogeneity condition): we can *reasonably* assume that rainfall in dairy-producing regions does not affect demand for milk.
  2. $\mathrm{corr}(rain_i, \ln(P_i^{butter})) \neq 0$ (relevance condition): we can *reasonably* assume that insufficient rainfall lowers food available to cows and milk production as a consequence.

EXAMPLE ON SUPPLY/DEMAND

[from: Stock and Watson, Introduction to Econometrics, chapter 12]

- Hence *Z* = rainfall in dairy-producing regions is a good candidate.

- Applying the TSLS method we:
  1. Regress (OLS) milk price on rainfall, thus obtaining the milk price that isolates changes in price itself due to the supply side of the economy (partially, at least).
  2. Regress (OLS) milk quantity on the estimation of milk price; that is, the regression counterpart of using shifts in the supply curve to highlight the demand curve.

$$\ln(Q_i^{butter}) = \beta_0 + \widehat{\beta_1}\ln(P_i^{butter}) + u_i$$

TRADE ANALYSIS (TOPALOVA and KHANDELWAL, TK)

- "Trade Liberalization and Firm Productivity: the Case of India" is a relevant paper to explore how to address the issue of endogeneity in an empirical trade model.
- The paper examines the effects of Indian trade reform on firm-level productivity.
- Endogeneity concerns for the productivity effect of trade policy:
  1. Governments may reduce tariffs only after domestic firms have improved productivity which would result in a spurious relationship between trade and productivity
  2. Selective protection of industries (tariffs may be adjusted in response to industry productivity levels)
  - If policy decisions on tariff changes across industries were indeed based on expected future productivity or on industry lobbying, isolating the impact of the tariff changes would be difficult. Simply comparing productivity in liberalized industries to productivity in non liberalized industries would possibly give a spurious correlation between total factor productivity (TFP) growth and trade policies.

TRADE ANALYSIS (TK)

- Since 1991, over a short period of time, India drastically reduced tariffs and narrowed the dispersion in tariffs across sectors. Since the reform was rapid, comprehensive, and externally imposed (IMF), it is reasonable to assume that the changes in the level of protectionism were unrelated to firm- and industry-level productivity.
- However, at the time the government announced the export-import policy in the Ninth Plan (1997-2002), the sweeping reforms outlined in the previous plan had been undertaken and pressure for further reforms from external sources had abated.
  - More difficult to isolate the causal impact of the tariff changes.

TRADE ANALYSIS (TK)

- The authors address the concern of possible endogeneity of trade policy in 3 ways:

1. Examining the extent to which tariffs moved together.

- Tariff movements were uniform until 1997 and less uniform afterwards, indicating a more pronounced problem of endogenous trade protection in the second period.

2. Testing whether protection correlates with industry characteristics (employment, output, average wage, concentration etc.).

- No statistical correlation (indication of exogeneity)

TRADE ANALYSIS (TK)

- The authors address the concern of possible endogeneity of trade policy in 3 ways:

3. Investigating whether policymakers adjusted tariffs in response to industry's productivity levels.

- The correlation between future trade protection and current productivity is indistinguishable from zero for the 1989-96 period.
- The pattern, however, is quite different for the 1997-2001 period. Here, the coefficient on current productivity is negative and significant, suggesting that trade policy may have been adjusted to reflect industries‘ relative performance.

TRADE ANALYSIS (TK)

- These tests lead to conclude that trade policy was not endogenously determined during the first period.
- The 1991 liberalization episode in India is good to examine the causal effects of trade reform on firm-level productivity.

- The main result: 10% reduction in tariffs will lead to about 0.5% increase in firm TFP. Decreasing trade protection in the form of lower tariffs raises productivity at the firm level.

TRADE ANALYSIS (TK)

- There are two forces driving this finding.

i. Increases in competition resulting from lower output tariffs caused firms to increase their efficiency.

ii. The trade reform lowered the tariffs on inputs which lead to an increase in the number and volume of imported inputs from abroad

- The larger impact appears to have come from increased access to foreign inputs. Thus, India's break from import substitution policies not only exposed these firms to competitive pressures, but more importantly, relaxed the technological constraint on production.

TRADE ANALYSIS (TK)

- Melitz (2003) has shown that trade liberalization may result in a reallocation from low- to high-productivity firms which would increase average productivity because of selection.
- Re-estimating the equation only for the set of companies in operation in 1996, the positive impact of tariff reductions on productivity levels is virtually unchanged.
- This constitutes some mild evidence against the selection channel.
- While the exit of less efficient companies might contribute to productivity improvements, it does not drive the results within this sample.