Difference-in-Differences Estimators

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Outline

1. Difference-in-difference approach
2. Gasoline distributor joint venture
3. Minimum wage laws

General principles

Sometimes, we don't have an obvious experiment that we can exploit.

But, whenever we do causal inference, we need to find a treatment group and a control group. We want to consider the difference between these groups.

Additionally, it is very beneficial to observe both groups before and after treatment is applied. We can look at how each group changed at the time of treatment.

Main idea

The *difference-in-difference* strategy looks at how the difference between treatment and control group outcomes changes before and after treatment:

$$\left(y^T_{\text{post}} - y^C_{\text{post}}\right) - \left(y^T_{\text{pre}} - y^C_{\text{pre}}\right).$$

We assume that the difference between the treatment and control group should be the same before treatment and after treatment. If they are not the same, we ascribe the difference to treatment.

Gasoline distributor joint venture

We want to analyze the impact of a joint venture between two major Midwestern gasoline distributors, Marathon and Ashland.

Others in the 1990s: Shell-Texaco, BP-ARCO, Exxon-Mobil, Chevron-Texaco, Phillips-Conoco.

FTC worried that mergers increase concentration in a market, reducing competition, driving up prices.

Firms respond that they can exploit efficiencies and economies of scale to lower prices.

Question: Did gasoline prices increase in markets where Marathon and Ashland were separately active before the merger and had a strong presence afterward?

Reference

Taylor, Christopher T. and Daniel S. Hosken. 2004. "The Economic Effects of the Marathon-Ashland Joint Venture: The Importance of Industry Supply Shocks and Vertical Market Structure." FTC working paper.

Factors impacting price

The DID approach leans heavily on modeling; we need a model of gas prices.

What does the price of a good depend upon?

- Cost of producing the good,
- Demand for the good, and
- Competition for supplying the good.

Model for treatment

Consider the model for the treatment group T at time t:

$$p_t^T = \alpha_0^T + \alpha_1^T f_t + \alpha_2^T s_t^T + \alpha_3^T d_t^T + \alpha_4^T m_t + \alpha_5^T v_t + \epsilon_t^T;$$

with price p a function of the future price of oil (measures supply of oil), a shock to the costs of refining and distributing oil s, a shock to the demand for gasoline d, dummies for each month of the year (reflecting changes in both supply and demand) m (though represented by 1 predictor, there are 11 dummies there), and a dummy indicating that the joint venture occurred v. Prices are pre-tax.

Interpreting α_0^T

$$p_t^T = \alpha_0^T + \alpha_1^T f_t + \alpha_2^T s_t^T + \alpha_3^T d_t^T + \alpha_4^T m_t + \alpha_5^T v_t + \epsilon_t^T;$$

$\alpha_0^T = \mathbb{E}\left[p_t^T \mid f_t = 0, s_t^T = 0, d_t^T = 0, m_t = 0, v_t = 0\right];$
this is the price in the treatment group when there are no surprise demand or supply shocks in the base month before the joint venture when the future price of oil is \$0. This is kind of the baseline mark-up over the cost of oil.

Differencing

Consider the model for the control group:

$$p_t^C = \alpha_0^C + \alpha_1^C f_t + \alpha_2^C s_t^C + \alpha_3^C d_t^C + \alpha_4^C m_t + \alpha_5^C v_t + \epsilon_t^C.$$

Take the difference:

$$\begin{aligned}\left(p_t^T - p_t^C\right) = {} & \left(\alpha_0^T - \alpha_t^C\right) + \left(\alpha_1^T - \alpha_1^C\right) f_t \\ & + \left(\alpha_2^T s_t^T - \alpha_2^C s_t^T\right) + \left(\alpha_3^T d_t^T - \alpha_2^C d_t^C\right) \\ & + \left(\alpha_4^T - \alpha_4^C\right) m_t + \left(\alpha_5^T - \alpha_5^C\right) v_t \\ & + \left(\epsilon_t^T - \epsilon_t^C\right)\end{aligned}$$

Assumptions

Problem: The supply and demand shocks are unobservable, so these terms must go away.

We need to make two assumptions:

- The shocks to demand and supply are the same for both the treatment and the control group: $s_t^T = s_t^C$ and $d_t^T = d_t^C$ and
- The response of price to the shocks is the same: $\alpha_2^T = \alpha_2^C$ and $\alpha_3^T = \alpha_3^C$.

Additionally, we choose a control market that is isolated from the merger, so there should be no price response to it; *i.e.*, $\alpha_5^C = 0$.

The challenge

Challenge: We need to find a control group that is similar enough to the treatment group that the supply and demand shocks are the same, but different enough so that it's not affected by the venture.

Another challenge: Think of an experiment that

- Could answer the original question or
- Underlies what this approach is trying to accomplish

(they may not be the same).

The model

With these assumptions, our model becomes

$$\begin{aligned}\left(p_t^T - p_t^C\right) &= \left(\alpha_0^T - \alpha_t^C\right) + \left(\alpha_1^T - \alpha_1^C\right) f_t \\ &\quad + \left(\alpha_4^T - \alpha_4^C\right) m_t + \alpha_5^T v_t + \left(\epsilon_t^T - \epsilon_t^C\right) \\ &= \beta_0 + \beta_1 f_t + \beta_4 m_t + \beta_5 v_t + \tilde{\epsilon}_t;\end{aligned}$$

we want to know whether $\beta_5 > 0$, so we test the null that $\beta_5 \leq 0$.

Comparison cities

Treatment city: Louisville, KY
Only state where Marathon and Ashland were both among top four suppliers pre-treatment; Louisville is largest city (best data available).

Control city: Chicago, IL
Similar fuel type as Louisville; Marathon and Ashland hardly present pre- or post-venture; both cities get supply from the Gulf and are equally distant from the supplies; weather, supply, and demand shocks should be similar.

Other alternatives: Houston, TX and Northern Virginia.

Note: Joint venture began on January 1st, 1998.

	Coefficient	Standard Error
1998 Indicator	0.73	1.40
1999 Indicator	0.10	1.47
January	-0.66	1.24
February	1.42	1.45
March	2.14	1.53
April	3.36	1.58
May	2.66	1.61
June	3.27	1.62
July	1.45	1.58
August	0.83	1.55
September	-0.69	1.47
October	-0.45	1.32
November	0.13	1.04
Futures Price	0.64	0.15
Constant	-22.28	3.49
rho	0.78	

Results

Coefficients on 1998 and 1999 dummies are not different from 0 (even jointly); no evidence that the venture raised retail prices.

Only highly significant coefficient is the constant term. This reflects the fact that Chicago had higher prices than Louisville all through the period.

The month dummies are jointly significant. Chicago and Louisville markets have different seasonal supply and demand patterns.

Serial correlation

We need to worry about serial correlation here; a positive shock to prices today probably means a positive shock to prices tomorrow. The authors use the *Prais-Whinston* procedure to incorporate this and rho is a parameter from that model (we'll cover this after the second preliminary exam).

Minimum wage laws

Economic theory predicts that the minimum wage causes a surplus of workers; *i.e.*, there will be unemployment. It does not say how big of a problem this is.

Question: What is the causal effect of increasing the minimum wage on employment?

Data

On April 1st, 1992, New Jersey changed the minimum wage from \$4.25 to \$5.05. Pennsylvania kept its minimum wage at \$4.25.

BLS data on employment at fast food chains in New Jersey and seven Pennsylvania counties in February and November 1992.

Card, David and Alan B. Krueger. 2000. "Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania: Reply." *American Economic Review*. 90(5) 1397–1420.

The model

Suppose that employment at restaurant i in state s at time t can be written

$$y_{it} = \alpha_0^s + \alpha_1 t + \alpha_2^s r_i + \alpha_3^s c_{it} + \alpha_4 d_{it} + \alpha_5 m_{it} + \epsilon_i;$$

r is a set of restaurant chain dummies, c is a cost/supply shock, d is a demand shock, and m is whether the firm was subject to an increased minimum wage.

Differencing

Let's take the difference for store i from time 0 to time 1:

$$\Delta y_i = \alpha_1 + \alpha_3^s (c_{i1} - c_{i0}) + \alpha_4^s (d_{i1} - d_{i0}) + \alpha_5 m_{i1} + (\epsilon_{i1} - \epsilon_{i0})$$

Since the supply and demand shocks are unobservable, they become part of a new error term:

$$\Delta y_i = \beta_0 + \beta_1 m_i + \tilde{\epsilon}_i$$

Assumptions

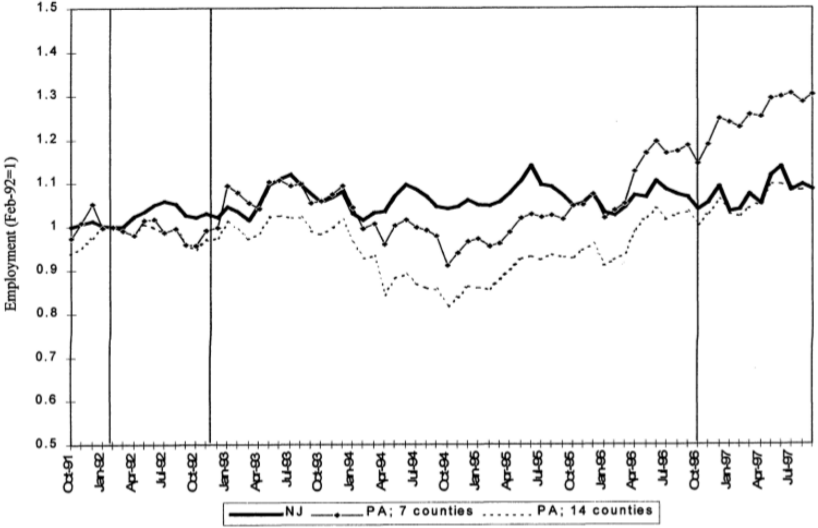
We need to assume that the changes in the supply and demand shocks are uncorrelated with being in New Jersey or not.

For example, New Jersey's economy can't be improving relative to Pennsylvania or vice versa.

Any changes to supply, demand, or unobservable factors must be uncorrelated with the state.

TABLE 2—BASIC REGRESSION RESULTS; BLS ES-202 FAST-FOOD DATA AND CARD-KRUEGER SURVEY DATA

	Dependent variable:			
	Change in levels		Proportionate change	
Explanatory variables	(1)	(2)	(3)	(4)
A. *All of New Jersey and 7 Pennsylvania Counties, BLS Data*				
New Jersey indicator	0.536	0.225	0.007	0.009
	(1.017)	(1.029)	(0.029)	(0.029)
Chain dummies and subunit dummy variable	No	Yes	No	Yes
Standard error of regression	10.09	9.99	0.286	0.281
R^2	0.001	0.029	0.000	0.046



1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
Employment (Feb-92=1)
Oct-91
Jan-92
Apr-92
Jul-92
Oct-92
Jan-93
Apr-93
Jul-93
Oct-93
Jan-94
Apr-94
Jul-94
Oct-94
Jan-95
Apr-95
Jul-95
Oct-95
Jan-96
Apr-96
Jul-96
Oct-96
Jan-97
Apr-97
Jul-97
NJ
PA; 7 counties
PA; 14 counties

Results

There seems to be no impact of the minimum wage on employment; if anything, the estimated effect is *positive*.

But, PA seems to be weakening relative to NJ. How would this bias our results?
If the NJ dummy is correlated with positive economic shocks, which are correlated with higher employment, then our estimates are too big.

This shows the importance of choosing a good control group.