Ratio of Changes:

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Presentation
https://www.ivo-welch.info/research/presentations/oklahoma2022.pdf

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What To Remember

- interest in corporate finance interest is $x \leftrightarrow y$ in panels, but
  - variables have trends, so we must work in differences.
  - firms are vastly different in size, so we must normalize.
- canonical common panel-regression specification:

$$\frac{y_{i,t}}{D_{i,t}} = \beta \times \frac{x_{i,t}}{D_{i,t}} + FE_i + controls_{i,t} + e_{i,t}$$

What To Remember

$$\frac{y_{i,t}}{D_{i,t}} = \beta \times \frac{x_{i,t}}{D_{i,t}} + FE_i + e_{i,t}$$

- is roughly the same as:

$$\left(\frac{y_{i,t}}{D_{i,t}} - \frac{y_{i,t-1}}{D_{i,t-1}}\right) = \beta \times \left(\frac{x_{i,t}}{D_{i,t}} - \frac{x_{i,t-1}}{D_{i,t-1}}\right) + e_{i,t}$$

- alternative primitive specification. reduces ΔD noise, focus on x and y, avoid spurious correlation:

$$\left(\frac{y_{i,t} - y_{i,t-1}}{D_{i,t-1}}\right) = \beta \times \left(\frac{x_{i,t} - x_{i,t-1}}{D_{i,t-1}}\right) + e_{i,t}$$

  Not microfounded. Better one soon...(with Jinyong Han)

- "stock-return" like definition is not a bad idea for any corp var. Does x or D matter? (Few theories are so specific on scalar D.)

Problem

- canonical specification is used in many corpfin papers:
  - Fazzari, Hubbard, Petersen (2000)
  - Baker, Wurgler, Stein (2003)
  - Almeida, Campbell, Weisbach (2004)
  - Rauh (2006)
  - and many others.

  influence of ΔD on β depends on many aspects, such as how Δx and Δy line up with ΔD. (smaller firms are different.)
- specification is canonical and rarely raises an eyebrow
- ...but it can bite, as it does in influential chaney, sraer, thesmar (AER 2012), to be explained.

Simplified Chaney, Sraer, Thesmar (AER 2012)

- Does an increase in collateral induce more investment?
- Uses common corporate-finance specification:

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = \beta \times \frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

- capex (capital expenditures),
- real-estate (dollar value, mostly headquarter),
- ppe (property plant and equipment)
  - really just a scale adjustment
  - (titled) interest is about real-estate and capex
- CST add fixed effects (FE) for time and other controls.

! Positive Coefficient Interpretation !

Title: How real-estate shocks affect corporate investment

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.07 \times \frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

➔ CST emphasize coefficient magnitude

➔ too much? a one-time shock on real-estate value stock will have a permanent effect on capex flow. Is the payoff on capex immediate?

➔ CST emphasize shock aspect

➔ despite simul-timing.

➔ T around 20 (3,000 firms, 15 years).

Placebo Tests – Time Shock (Near)

➔ Actual:

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.07 \times \frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

➔

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.08 \times \frac{\text{realestate}(i,t+4)}{\text{ppe}(i,t+3)} + \text{FE}(i) + \ldots + e$$

where $t + \cdot$ is next years, firm held constant.

➔ "Real-estate collateral shocks affect past capital expenditures?!"

➔ Not a shock.

(PS: I always love time-falsification placebos when effect is supposed to be an event or shock.)

Placebo Tests – Similar Firm (Near Size)

➔ Actual:

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.07 \times \frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

➔

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.03 \times \frac{\text{realestate}(j,t)}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

where j is next-5-largest firm at inception, firm held constant.

➔ Real-estate investment affects capital expenditures of similar-sized firms?! (No industry or real-estate or other control.)

➔ Not a firm-specific but a size-related phenomenon.

Placebo Tests – Random Firm Year

➔ Actual:

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.07 \times \frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

➔

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.004 \times \frac{\text{realestate}(j,s)}{\text{ppe}(j,t-1)} + \text{FE}(i) + \ldots + e$$

where j, s is random firm-year.

➔ Better be zero now. The variable on the RHS is nearly completely random here. Denominator could equally compress or expand numerators.

What About The Constant 1.0?

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.07 \times \frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

More 1.0 $\Rightarrow$ More Investment ?

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.13 \times \frac{1.0}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

More Real-Estate Collateral $\Rightarrow$ More 1.0 ?

$$\frac{1.0}{\text{ppe}(i,t-1)} = 0.20 \times \frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

➔ Somehow real-estate and capex each increased (heterogeneously) in non-(FE)-controlled way.

- ➔ Recipe for spurious association
- ➔ PS: Coefs reflect T-stats and magnitudes fairly.

Chaney, Sraer, Thesmar (2020) Response

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.07 \times \frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.13 \times \frac{1.0}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

➔ Let's "split" the difference?

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.05 \times \frac{\text{realestate}}{\text{ppe}(i,t-1)} + 0.12 \times \frac{1.0}{\text{ppe}(i,t-1)} + \ldots$$

- ➔ CST: Problem is now under control: 0.05 coef is still positive.
- ➔ Me: Specification is still bad ("trended"): *see* 0.12 coef on constant.

Is Specification Under Control Now?

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = 0.05 \times \frac{\text{realestate}}{\text{ppe}(i,t-1)} + 0.12 \times \frac{1.0}{\text{ppe}(i,t-1)} + \ldots$$

- ➔ Placebo
  - ➔ t+3 Real Estate: 0.062 on real-estate/ppe (not 0.078)
  - ➔ j+3 Real Estate: 0.018 on real-estate/ppe (not 0.027)
- ➔ Regression still contains uncontrolled denominator effects:

Is Specification Under Control Now?

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➔ Placebo

  ➔ t+3 Real Estate: 0.062 on real-estate/ppe (not 0.078)

  ➔ j+3 Real Estate: 0.018 on real-estate/ppe (not 0.027)

➔ Regression still contains uncontrolled denominator effects:

➔ The specification wrestles (badly) with shared variation in 1/ppe on both X and Y.

➔ The specification is not a good solution for the problem at hand.

➔ Not shown: adding log(1/P) makes RE reverse sign

Specification

There is The Better Alternative

➔ Remove time-variation in denominator;

➔ and thus remove the problem, once and for all.

Translate Fixed Effects to Changes

➔ Familiar Tranformation (see [Angrist-Pischke, etc.] first slide):

From ratios and fixed effects (R + FE):

$$\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} = \beta \times \frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)} + \text{FE}(i) + \ldots + e$$

to changes of ratios (CoR):

$$\Delta_t \left[\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)} \right] = \beta \times \Delta_t \left[\frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)} \right] + \ldots + e$$

➔ Identical in two periods.

➔ Similar in more periods.

Care About Numerator?

➔ Changes of Ratios (CoR, $\Delta(v/z)$):

$$\left[\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)}\right] - \left[\frac{\text{capex}(i,t-1)}{\text{ppe}(i,t-2)}\right]$$

$$= \beta \times \left\{ \left[\frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)}\right] - \left[\frac{\text{realestate}(i,t-1)}{\text{ppe}(i,t-2)}\right] \right\} + \ldots + e$$

➔ vs. Ratios of Changes (RoC, $(\Delta v)/z$):

$$\left[\frac{\text{capex}(i,t)}{\text{ppe}(i,t-1)}\right] - \left[\frac{\text{capex}(i,t-1)}{\text{ppe}(i,t-1)}\right]$$

$$= \beta \times \left\{ \left[\frac{\text{realestate}(i,t)}{\text{ppe}(i,t-1)}\right] - \left[\frac{\text{realestate}(i,t-1)}{\text{ppe}(i,t-1)}\right] \right\} + \ldots + e$$

➔ By RoC, I mean ratio with a change in the numerator, not in the denominator.

➔ What theory about numerators would not allow this?

Ratios of Changes

- RoC:

$$\left[\frac{\Delta_t \text{capex}(i,t)}{\text{ppe}(i,t-1)}\right] = \beta \times \left[\frac{\Delta_t \text{realestate}(i,t)}{\text{ppe}(i,t-1)}\right] + \ldots + e$$

- Denominator now does only what you need it for:
  - scale control across different firms.
- All time-variation in ppe is removed by specification.
  - similar to rescaling the lagged variable by $\text{ppe}(i,t-2)/\text{ppe}(i,t-1)$.
  - Not revolutionary:
    we use "rate of returns": $(P_t - P_{t-1})/P_{t-1}$,
    not "differences in price-appreciations": $P_t/P_{t-1} - P_{t-1}/P_{t-2}$.
  - Some cases where meaning could change; try ppi(t) as denom? discuss both cases? see where results are sensitive. note: doubling still works, because x and y double. D is just heteroscedasticity scalar now.

Ratio of Changes (RoC) Variables

- ➔ This is about variables, not about regressions.
  - ➔ Doesn't need to be in both X and Y.
  - ➔ CoR in either X or in Y can create trouble, too.
- ➔ RoC and Cor variables can be very different:
  - ➔ ...obviously only when the denominator changes greatly.
  - ➔ Example: num=(19.9,20.0); denom=(100,200).
  - ➔ RoC = 0.2 – 0.1 = +0.1; vs.
  - ➔ CoR = –0.1/100 = –0.001
- ➔ CST
  - ➔ correlation of CoR Δ(v/ppe) with RoC (Δ v)/ppe is low,
  - ➔ even the sign of CoR Δ(v/ppe) vs RoC (Δ v)/ppe changes often,
  - ➔ and disproportionately more for growing, volatile (small, non-RE).

Back to CST 2012

- Denominator-neutral RoC Regression:

$$\left[\frac{\Delta_t \text{capex}(i,t)}{\text{ppe}(i,t-1)}\right] = -0.02 \times \left[\frac{\Delta_t \text{realestate}(i,t)}{\text{ppe}(i,t-1)}\right] + \ldots + e$$

  - Not shown: bad CoR reg has positive coef, just like CST F + R

- Not Shown:
  - In CST, one regression specification in which a different independent variable (REisPos $\times$ repi) is not ppe normalized;
  - but with R + FE continuing for the dependent variable (capex/lagppe), the positive CoR coefficient turns negative in the RoC version, too.
  - Here spurious time corr problem is not mechanical, but empirical.
  - Why? The reason are differential trends of small vs large firms.

- Same results when Great (Real-Estate) Recession data is added.

Simple To Remember

- ➔ If you care about the numerator in a ratio, and
- ➔ you use the denominator primarily as a scale adjustment, and
- ➔ firms are different enough to require mean adjustments;

Simple To Remember

- ➔ If you care about the numerator in a ratio, and
- ➔ you use the denominator primarily as a scale adjustment, and
- ➔ firms are different enough to require mean adjustments;

➔ then do <u>not</u> use a fixed-effects level regression!

➔ Use an RoC specification instead!

Fixed-Effect Regressions With Ratio Variables are Dangerous

and there is an easy and safer alternative to CoR, RoC.

So What Went Wrong in CST?

➔ Usually, I do not speculate on motives of authors,

... but

➔ CST are top-notch empiricists,

➔ ... and I believe the answer is quite innocuous.

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➔ ...and they are probably not the only paper whose results come from scale effects, but I do not know this for sure.

Is Critique Unfair?

I believe that the profession needs to routinely independently and skeptically assess (and iterate over) every paper.

- ➔ Most CorpFin papers have never been reexamined (incl my own).
- ➔ It sucks that critiques pick almost randomly on just some papers.
- ➔ It sucks that it had to be me who had to be the bad guy. Not fun.

Take the Critical Finance Review seriously!

Future Critiques

- ➔ Take any number of papers using panel regressions with ratios.
- ➔ Throw in 1/d. What happens?
- ➔ Placebo the timing. What happens?

I am guessing 1 in 5 papers will turn out to be wrong.

Future Critiques

➔ Take any number of papers using panel regressions with ratios.

➔ Throw in 1/d. What happens?

➔ Placebo the timing. What happens?
I am guessing 1 in 5 papers will turn out to be wrong.
Are you guessing 1 in 5 that I am wrong?

AER Response

We don't like what you wanted to write in your letter to CST. Therefore, we will not publish your critique, but stand by our paper.

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Huh? Congratulations?

So, I posted this on SSRN, with correspondence.

Please do not use CST like estimators.

Microfounded Estimator

$$y_{i,t} = \beta \cdot x_{i,t} + \alpha_i \cdot s\left(d_{i,t}\right) + d_{i,t} \cdot \epsilon_{i,t},$$

$$E\left[\epsilon_{i,t} \middle| d_{i,1}, \ldots, d_{i,T}, x_{i,1}, \ldots, x_{i,T}, \alpha_i\right] = 0.$$

$$\frac{y_{i,t}}{d_{i,t}} = \beta \cdot \left(\frac{x_{i,t}}{d_{i,t}}\right) + \alpha_i \cdot \left[\frac{s\left(d_{i,t}\right)}{d_{i,t}}\right] + \epsilon_{i,t} \quad ,$$

$$\left(\frac{y_{i,t}}{d_{i,t}} - \frac{y_{i,t-1}}{d_{i,t-1}}\right) = \beta \cdot \left(\frac{x_{i,t}}{d_{i,t}} - \frac{x_{i,t-1}}{d_{i,t-1}}\right) + \alpha_i \cdot \left[\frac{s\left(d_{i,t}\right)}{d_{i,t}} - \frac{s\left(d_{i,t-1}\right)}{d_{i,t-1}}\right] + \left(\epsilon_{i,t} - \epsilon_{i,t-1}\right).$$

$$s\left(d_{i,t}\right) \quad \equiv \quad \gamma_i + \theta_i \cdot d_{i,t}.$$

We can then rewrite the two differenced specifications as

$$\left(\frac{y_{i,t}}{d_{i,t}} - \frac{y_{i,t-1}}{d_{i,t-1}}\right) \quad = \quad \beta \cdot \left(\frac{x_{i,t}}{d_{i,t}} - \frac{x_{i,t-1}}{d_{i,t-1}}\right) + \alpha_i \gamma_i \cdot \left(\frac{1}{d_{i,t}} - \frac{1}{d_{i,t-1}}\right)$$
$$+\epsilon_{i,t} - \epsilon_{i,t-1} \quad .$$

converges in probability to

$$b_1 \quad \equiv \quad \frac{E\left[\left(\frac{x_{i,t}}{d_{i,t}} - \frac{x_{i,t-1}}{d_{i,t-1}}\right)\left(\frac{y_{i,t}}{d_{i,t}} - \frac{y_{i,t-1}}{d_{i,t-1}}\right)\right]}{E\left[\left(\frac{x_{i,t}}{d_{i,t}} - \frac{x_{i,t-1}}{d_{i,t-1}}\right)^2\right]}$$

$$= \quad \beta + \frac{E\left[\alpha_i \gamma_i \left(\frac{x_{i,t}}{d_{i,t}} - \frac{x_{i,t-1}}{d_{i,t-1}}\right)\left(\frac{1}{d_{i,t}} - \frac{1}{d_{i,t-1}}\right)\right]}{E\left[\left(\frac{x_{i,t}}{d_{i,t}} - \frac{x_{i,t-1}}{d_{i,t-1}}\right)^2\right]},$$

biased as long as $\gamma_i \neq 0$ and associations between ...

Alternative Estimator

$$y_{i,t} = \beta \cdot x_{i,t} + \alpha_i \cdot (\gamma_i + \theta_i \cdot d_{i,t}) + d_{i,t} \cdot \epsilon_{i,t} \ ,$$

and

$$y_{i,t} - y_{i,t-1} = \beta \cdot (x_{i,t} - x_{i,t-1}) + \alpha_i \theta_i \cdot (d_{i,t} - d_{i,t-1}) + d_{i,t} \cdot \epsilon_{i,t} - d_{i,t-1} \cdot \epsilon_{i,t-1} \ ,$$

Divide by $d_{i,t} - d_{i,t-1}$,

$$\frac{y_{i,t} - y_{i,t-1}}{d_{i,t} - d_{i,t-1}} = \beta \cdot \frac{x_{i,t} - x_{i,t-1}}{d_{i,t} - d_{i,t-1}} + \alpha_i \theta_i + \frac{d_{i,t} \cdot \epsilon_{i,t} - d_{i,t-1} \cdot \epsilon_{i,t-1}}{d_{i,t} - d_{i,t-1}} \ ,$$

Now difference again, and we are rid of the intercepts!!

$$\underbrace{\frac{y_{i,t} - y_{i,t-1}}{d_{i,t} - d_{i,t-1}} - \frac{y_{i,t-1} - y_{i,t-2}}{d_{i,t-1} - d_{i,t-2}}}_{\equiv Y_{i,t}} =$$

$$\beta \cdot \overbrace{\left(\frac{x_{i,t} - x_{i,t-1}}{d_{i,t} - d_{i,t-1}} - \frac{x_{i,t-1} - x_{i,t-2}}{d_{i,t-1} - d_{i,t-2}} \right)}^{\equiv X_{i,t}}$$

$$+ \frac{d_{i,t} \cdot \epsilon_{i,t} - d_{i,t-1} \cdot \epsilon_{i,t-1}}{d_{i,t} - d_{i,t-1}} - \frac{d_{i,t-1} \cdot \epsilon_{i,t-1} - d_{i,t-2} \cdot \epsilon_{i,t-2}}{d_{i,t-1} - d_{i,t-2}} \quad .$$

Observations

- Bad residual error correlation, so this needs a White-Hansen type correction.
- Needs T=3, rather than T=2
- Remove observations with $d_{i,t} \approx d_{i,t-1}$, and maybe use in canonical estimator.
    - Econometricians hate data cleaning.
    - Applied economists have no choice but to data clean.
- Other possible estimators, too.

Please wait three months for paper.

What else?

May I beg you to indulge me?

➔ 5th Edition CorpFin Textbook, Free in pdf (iPad). Quiz system. Instructor Notes.

➔ Climate Change – Very fun course to teach; lots of student interest.

➔ Equity Premium Prediction II

Thanks for having allowed me to give this talk.