# Ratio of Changes:

https://dx.doi.org/10.2139/ssrn.3599280

https://www.ivo-welch.info/research/presentations/nber2021.pdf

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October 31, 2021

# What To Remember

1. common panel-regression specification:

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

2. roughly the same as:

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

3. interest is $\Delta x \leftrightarrow \Delta y$, but $\beta$ is also influenced by $\Delta D$.

4. reduce $\Delta D$ noise, focus on x and y, avoid spurious correlation:

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

5. "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

1. 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 $\Delta D$ on $\beta$ depends on many aspects, such as how $\Delta x$ and $\Delta y$ line up with $\Delta D$. (smaller firms are different.)
2. specification is canonical and rarely raises an eyebrow
3. ...but it can bite, as it does in chaney, sraer, thesmar (2012).

(apologies, david.)

# 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).

# Time Falsification?

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

➔ (PS: I love time-falsification placebos when viewed as shocks.)

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

➔ Shock (in title) is not empirically founded.

➔ Presumably, managers did not invest in anticipation of real-estate gains four years into the future.

➔ Shock (in title) is only theoretically founded.

# ? Positive Coefficient Interpretation ?

- ➔ Elaborate on first summary slide now
- ➔ More Real-Estate Collateral $\Rightarrow$ More Investment ?

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

- ➔ Or aligned variation in ppe ?
  - ➔ Here, denoms in X and Y have 100% correlation.
  - ➔ But could be merely correlated, say, 1/ppe for Y and 1/assets for X.
- ➔ Not shown: high variation in 1/ppe, relative to numerators.
- ➔ Q: Does coefficient reflect primarily numerator associations?

# 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?

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

➔ 1. In Paper: Reasonable specifications under the null (of no association) still estimate similar coefficients in Monte-Carlo.

➔ 2. Regression still contains uncontrolled denominator effects:

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

$$+0.15 \times \log\left[\frac{1.0}{\mathsf{ppe}(i,t-1)}\right] + \ldots$$

# Specification

➔ 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.

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## There is a Better Alternative

➔ Remove time-variation in denominator;

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

# Translate Fixed Effects to Changes

➔ Familiar Tranformation (see 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 $\Delta$(v/ppe) with RoC ($\Delta$ v)/ppe is low,
  - ➔ even the sign of CoR $\Delta$(v/ppe) vs RoC ($\Delta$ 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 × 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 <u>mechanical</u>, but <u>empirical</u>.

➔ 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
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- ➔ 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 not 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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➔ CST are top-notch empiricists,

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

➔ I am guessing that CST just used the canonical "standard" specification in the literature, without giving it a second thought.

- ➔ I do not know whether they would still run their AER regressions the way they did in hindsight. Ask David. I obviously wouldn't.

# More 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.