Lecture 17:
Micro Mismeasurement and Macro

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ECON 416-1

Micro mismeasurement

- So far, we have focused on how to use micro data for macro models.
  - Measuring causal effects (e.g., shift-share).
  - Measuring the "missing intercept" for aggregation.
- Another area of research is how *mismeasurement* in micro data affects macro.
- Macro conclusions and macro behavior often based on micro data.
- Mismeasurement / misinterpretations can be very meaningful!

A simple example: Taylor rules with real-time data (Orphanides 2002)

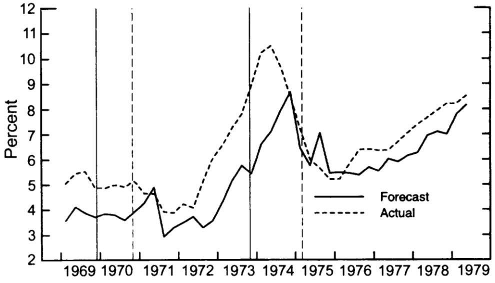

FIGURE 1. INFLATION FORECASTS AND OUTCOMES

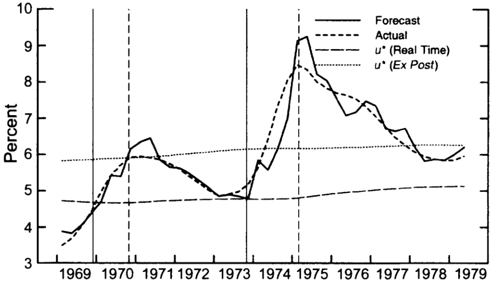

FIGURE 2. UNEMPLOYMENT FORECASTS AND OUTCOMES

- *"Judging from the dismal outcomes of the [1970s...], it is hard to deny that policy was in some way flawed."*
- Greenbook shows biased inflation forecasts. Also: *"Key policymakers suggested that 4 percent was a reasonable estimate of u^* at the end of the 1960s."*

A simple example: Taylor rules with real-time data (Orphanides 2002)

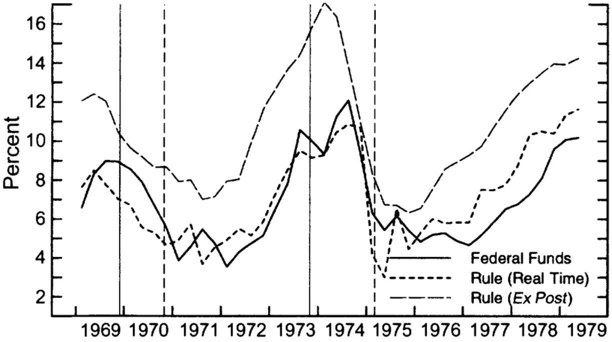

FIGURE 3. REAL-TIME AND *EX POST* TAYLOR RULES

- “Knowing the history of the 1970’s, [...] it is tempting to conclude that the Great Inflation might have been avoided if only policy had followed this retrospective rendition of the policy rule.”

- “Had this policy rule been followed during the 1970’s, economic outcomes would likely have been similar to the actual history.”

Roadmap

- One consequential source of mismeasurement for aggregate statistics is in prices.
- Biases from new varieties and product replacements.
- Implications for inflation, real GDP & productivity growth, terms of trade.
- One way to address mismeasurement is (what I'll call) the "Engel curve" approach.
- Applications to measuring inflation / GDP growth, but also to consumption inequality.

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Real GDP and inflation

- In Lecture 2, we talked about how real GDP is defined and measured.
- Real GDP defined as

$$d\log Y = \sum_i b_i d\log c_i, \qquad \text{where} \qquad b_i = p_i c_i / \sum_j p_j c_j.$$

- In practice, quantities hard to measure, so define changes in GDP deflator by

$$d\log P = \sum_i b_i d\log p_i.$$

  Since $d\log PY = d\log P + d\log Y$, we can construct change in real GDP as

$$d\log Y = d\log PY - d\log P.$$

- Errors in measuring $d\log P$ will affect $d\log Y$, $d\log A$, etc...

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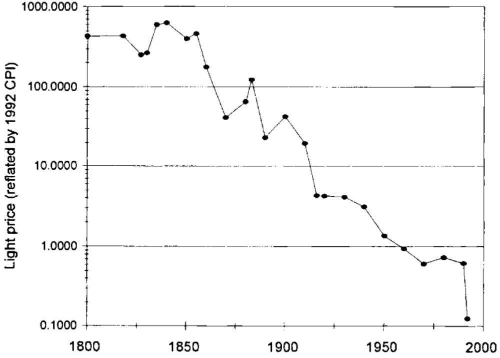
An illuminating example from Nordhaus (1996)

Table 1.3 **Efficiency of Different Lighting Technologies**

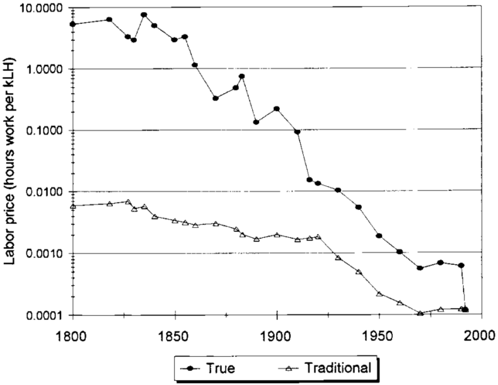
Device	Stage of Technology	Approximate Date	Lighting Efficiency (lumens per watt)	Lighting Efficiency (lumen-hours per 1,000 Btu)
Open fire[a]	Wood	From earliest time	0.00235	0.69
Neolithic lamp[b]	Animal or vegetable fat	38,000–9000 B.C.	0.0151	4.4
Babylonian lamp[a]	Sesame oil	1750 B.C.	0.0597	17.5
Candle[c]	Tallow	1800	0.0757	22.2
	Sperm	1800	0.1009	29.6
	Tallow	1830	0.0757	22.2
	Sperm	1830	0.1009	29.6
Lamp	Whale oil[d]	1815–45	0.1346	39.4
	Silliman's experiment: Sperm oil[e]	1855	0.0784	23.0
	Silliman's experiment: Other oils[f]	1855	0.0575	16.9
Town gas	Early lamp[g]	1827	0.1303	38.2
	Silliman's experiment[e]	1855	0.0833	24.4
	Early lamp[e]	1875–85	0.2464	72.2
	Welsbach mantle[e]	1885–95	0.5914	173.3
	Welsbach mantle[e]	1916	0.8685	254.5
Kerosene lamp	Silliman's experiment[e]	1855	0.0498	14.6
	19th century[h]	1875–85	0.1590	46.6
	Coleman lantern[i]	1993	0.3651	107.0
Electric lamp				
Edison carbon	Filament lamp[j]	1883	2.6000	762.0
Advanced carbon	Filament lamp[j]	1900	3.7143	1,088.6
	Filament lamp[j]	1910	6.5000	1,905.0
Tungsten	Filament lamp[j]	1920	11.8182	3,463.7
	Filament lamp[j]	1930	11.8432	3,471.0
	Filament lamp[j]	1940	11.9000	3,487.7
	Filament lamp[k]	1950	11.9250	3,495.0
	Filament lamp[k]	1960	11.9500	3,502.3
	Filament lamp[k]	1970	11.9750	3,509.7
	Filament lamp[k]	1980	12.0000	3,517.0
	Filament lamp[l]	1990	14.1667	4,152.0
Compact fluorescent	First generation bulb[m]	1992	68.2778	20,011.1

- Nordhaus (1996): *"Quantitative estimates of the growth of real wages or real output have an oft forgotten Achilles heel. [...] The estimates of real income are only as good as the price indexes are accurate."*
- Key challenge is dealing with new goods.
- Nordhaus (1996) considers how price of "service characteristics" evolve.
- Lighting as a laboratory.

Nordhaus (1996): Traditional vs. characteristics-based price indices



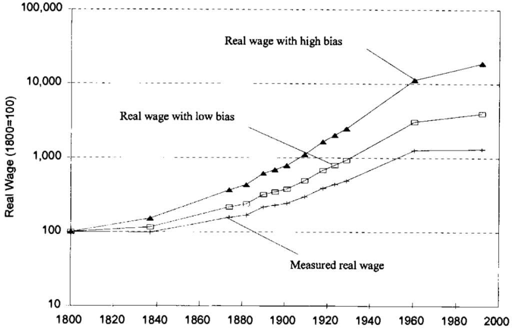
(a) Cents per 1000 lumen-hours (deflated).



(b) Labor price of light.

- Traditional indexes for price of light overstate price rise by 900–1600x.
- Average annual bias is 3.6 percent per year.

Nordhaus (1996): Implications for growth



- Thought experiment: How much is overall measure of consumption growth biased?
  - Lighting: Bias of 3.6 pct / yr.
  - Computers: Estimates of 15 pct / yr.
  - Capital goods: 3–4 pct/ yr (Gordon 1990).
- Split goods into three categories:
  - Run-of-the-mill: E.g., food-at-home. 0 pct.
  - Seismically active: E.g., toys. 0.93 pct / yr.
  - Tectonic: E.g., appliances. 1.85 pct / yr.
- $\Rightarrow$ Real wages grew 40x from 1800–1992, vs. 13x with conventional measures.

Quality change and new product bias: Boskin Commission (1996)

- *"There is no debate regarding the reality of the product cycle, and nobody debates the fact that the CPI introduces many products late, thus missing much of the price decline that typically happens in the first phase of the product cycle. An extreme example involves room air conditioners, which were widely sold in 1951, but not introduced into the CPI until 1964, 13 years later. More recently, the microwave oven was introduced into the CPI in 1978 and the VCR and personal computer in 1987, years after they were first sold in the marketplace. As an even more contemporaneous example, there are currently 36 million cellular phones in use in the United States, but as yet the CPI has no price index for cellular phones."*

- *"A second aspect of new product bias results from a narrow definition of a commodity. When a new product is finally introduced into the CPI, no comparison is made of the price and quality of the new product with the price and quality of an old product that performed the same function. For instance, people flock to rent videos, but the declining price of seeing a movie at home, as compared to going out to a theater, is not taken into account in the CPI."*

Quality change and new product bias: Boskin Commission (1996)

- Is level of quality bias estimated by Nordhaus (1996) reasonable?
- Boskin commission report (1996): *“Another problem is suggested by a ”thought experiment” recently conducted by Nordhaus (1996), who extrapolated backward substantial upward bias in the CPI over a long period of 190 years and arrived at implausibly low estimates of the standard of living of the average U. S. citizen in the year 1800. The implausibility of continuous upward bias in earlier decades at the rate suggested for recent decades in this report implies that in some earlier era the upward bias in the CPI was substantially less. This, of course, is natural. Long ago more was more important than better, e.g., enough to eat was more important than variety. As incomes rises beyond some point it is natural to expect increased demand for quality in many goods and services.”*

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Product replacement bias and exchange rate pass-through

Table 3—Price Changes per Quote Line

Number of price changes	Imports LCP	Imports PCP	Exports LCP	Exports PCP
0	44.3	43.8	16.3	39.2
1 or less	59.3	65.2	27.0	57.6
2 or less	68.7	77.7	30.0	68.2
3 or less	74.8	84.4	32.3	75.6
4 or less	79.2	90.7	34.7	80.8
5 or less	82.1	93.7	35.3	83.8
10 or less	88.4	98.1	77.0	90.1
15 or less	91.6	99.2	84.3	93.0

Notes: The table presents the fraction of products in the BLS microdata on import and export price data with less than or equal to a given number of price changes over the entire time span for which they are in the dataset. These statistics are for market-based products for 1994–2004 and are reported for both local currency priced (LCP) and producer currency priced (PCP) products. The statistics are weighted percentiles, using as weights the cumulative product-level weights over each product's lifetime.

- Official estimates of real exchange rate and terms of trade use micro data on imported and exported goods.
- Two features of these data emphasized by Nakamura and Steinsson (2012):
    1. Substantial price rigidity.
    2. Frequent product substitutions.

Product replacement bias and exchange rate pass-through

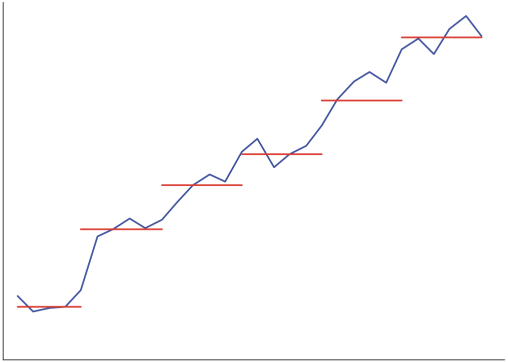


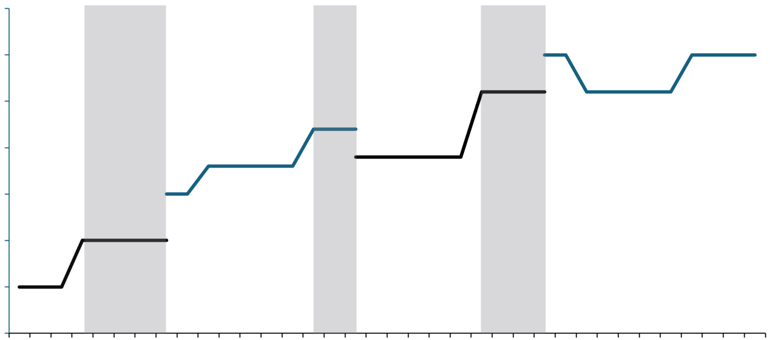
Figure 1. Product Replacement and the Comovement of Prices and Exchange Rates

- Why might this be a problem?
- Suppose prices rigid during product lifetime.
- All adjustment takes place at time of product replacement.
- Statistical agency unable to directly observe quality-adjusted prices.
- Always estimate zero pass-through!

Product replacement bias and exchange rate pass-through

- Why not just use unit prices for aggregated category?
  - Can reflect changes in quality mix (incl. endogenous changes).
  - In practice, unit prices highly volatility; difficult to estimate pass-through.
- In micro data with product replacements, which exchange rate movements are "accounted for" and which are not?
- Suppose we have sample of product lines, each consisting of sequence of models.
- Let p^*_{it} denote optimal price at time t for product i.
- Given state s, frequency of price change $f_i(s)$ and product replacement hazard $z(s)$.
- Suppose that new models are introduced at optimal price (relaxed in paper).

Product replacement bias and exchange rate pass-through



- Changes in optimal price between model's last price change and new model introduction never accounted for.
- Unaccounted fraction of time periods: $1 - f_i(s)/[f_i(s) + z(s)(1 - f_i(s))]$.

Product replacement bias and exchange rate pass-through

- Estimate pass-through using standard distributed lag regression,

$$\Delta p_{it} = \alpha + \sum_{k=0}^{K} b_{ik} \Delta e_t + \varepsilon_{it}.$$

- Suppose we estimated for both “matched model” data (i.e., ignoring price changes at product replacement) and also true quality-adjusted prices.

- Then, bias in long-run pass-through is simply

$$\sum_{k=0}^{K} b_{ik}^{\text{mm}}(s) = \frac{f_k(s)}{f_i(s) + z(s)(1 - f_i(s))} \sum_{k=0}^{K} b_{ik}^{\text{true}}(s).$$

- Extension: if initial prices of new products are “stale” (not equal to optimum).

Product replacement bias and exchange rate pass-through

- Integrating over i and s, assuming for simplicity that long-run pass-through is the same for all i,

$$\sum_{k=0}^{K} b_k^{\text{mm}} = \left[\int \int \frac{f_i(s)}{f_i(s) + z(s)(1 - f_i(s))} dF_s(i) ds \right] \sum_{k=0}^{K} b_k^{\text{true}},$$

  where F_s is distribution of expenditures across products i in state s.

- Since $\frac{f_i(s)}{f_i(s)+z(s)(1-f_i(s))}$ is concave in $f_i(s)$, heterogeneity in frequency of price adjustment will further bias down pass-through.

Product replacement bias and exchange rate pass-through

TABLE 4—THE DISTRIBUTION OF PRICE CHANGES AND SUBSTITUTIONS

	Imports		Exports	
	LCP	PCP	LCP	PCP
Fraction of imports/exports	0.922	0.078	0.032	0.968
Mean frequency of price change	0.151	0.061	0.572	0.130
Median frequency of price change	0.066	0.033	0.573	0.060
Mean frequency of substitutions				
Forced	0.025	0.016	0.062	0.020
Forced including refusals	0.037	0.026	0.064	0.032
All	0.049	0.046	0.067	0.046
Distribution of the frequency of price change				
a	0.44	0.82	0.36	0.50
	(0.01)	(0.06)	(0.06)	(0.01)
b	3.50	20.72	3.52	4.59
	(0.05)	(1.74)	(0.87)	(0.10)

Notes: The top panel reports summary statistics for the mean and median frequency of price change and product substitution calculated using IPP microdata on import and export prices. The sample period is 1994–2004. Statistics are reported for both local currency priced (LCP) and producer currency priced (PCP) products. The weighted means and medians are calculated using the item-level weights described in the paper. The lower panel reports our estimates of "a" and "b," which are the parameters in the estimated distribution of the frequency of price change, assumed to be Beta(a,b). This distribution is estimated using the BLS microdata on imports and exports.

- Nakamura and Steinsson (2012) measure frequency of substitutions and price changes across imports and exports.
- Beta distribution to capture heterogeneity in frequency of price change.

Product replacement bias and exchange rate pass-through

TABLE 1—COMOVEMENT OF PRICES AND EXCHANGE RATES

	Imports	Exports
Measured:		
Aggregate	0.43	0.85
	(0.05)	(0.05)
VECM	0.41	0.87
	(0.05)	(0.06)
Adjusting for product replacement bias:		
Benchmark	0.64	0.79
Forced substitutions including refusals	0.69	0.76
All substitutions	0.74	0.74

Notes: The top panel presents alternative measures of the long-run relationship between the trade-weighted real exchange rate and aggregate import or export price indexes (standard errors in parentheses). "Aggregate" reports the sum of the coefficients on lagged exchange rate changes with six quarterly lags (equation (1)). "VECM" reports the estimated coefficient on exchange rates in the cointegrating relationship between prices and exchange rates (equation (2)). The bottom panel presents the estimated relationship based on the aggregate pass-through regression adjusted for "product replacement bias" according to the methods discussed in the paper, under alternative assumptions about heterogeneity in pricing behavior across products and the frequency of product replacement.

- Result: Long-run exchange rate pass-through is 50% higher accounting for product replacement bias.
- Product replacement bias biases *up* PCP exports.

Product replacement bias and exchange rate pass-through

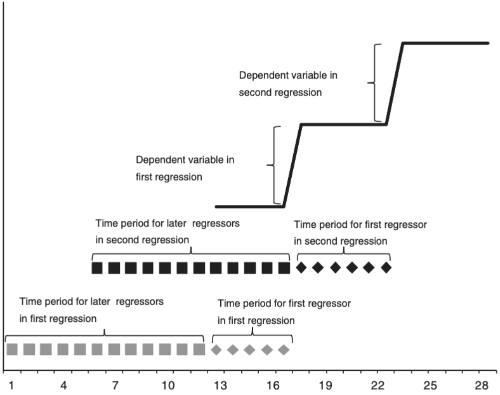


Figure 5. Graphical Depiction of Regressions in Table Five

Table 5—Price Change for First and Second Spell on Exchange Rate

	Imports		Exports	
	First price change	Second price change	First price change	Second price change
Panel A				
Exchange rate change:				
During price spell that is ending	0.23	0.26	0.13	0.11
	(0.03)	(0.03)	(0.03)	(0.03)
First quarter before price spell that is ending	0.19	0.18	0.03	0.14
	(0.05)	(0.04)	(0.07)	(0.06)
Second quarter before price spell that is ending	0.13	0.11	−0.06	−0.02
	(0.04)	(0.04)	(0.06)	(0.06)
Third quarter before price spell that is ending	−0.01	0.05	0.14	0.15
	(0.05)	(0.04)	(0.06)	(0.05)
Fourth quarter before price spell that is ending	0.07	0.09	−0.09	0.09
	(0.04)	(0.04)	(0.05)	(0.05)
Fifth quarter before price spell that is ending	0.05	0.04	0.19	0.08
	(0.04)	(0.04)	(0.06)	(0.06)
Sixth quarter before price spell that is ending	0.14	0.06	0.06	−0.01
	(0.05)	(0.04)	(0.07)	(0.06)
p-value for the null that coefficients for price spell and second quarter before price spell are equal	0.052	0.002	0.008	0.059

- What if new product prices are “stale” (e.g., drawn from existing price distribution)?
- If so, would expect greater responsiveness for first price change.

Product replacement bias and exchange rate pass-through

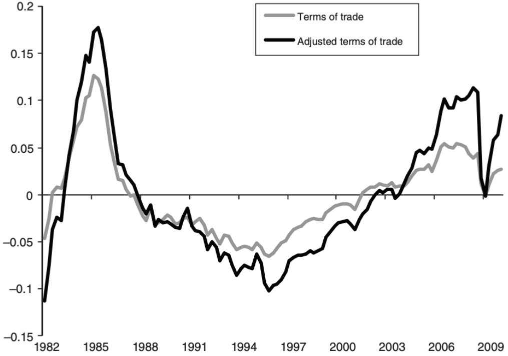


Figure 6. US Terms of Trade Adjusted for Product Replacement Bias

- In two-country RBC model, ToT more volatile than real exchange rates.
    - Productivity shocks move ToT.
    - Nontradables in RER dampen volatility.
- Sticky-price NK models can match the volatility of RER.
- But matching RER yields ToT volatility $>$ official series.
- Adjusting for product replacement bias raises volatility to roughly match NK models.

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The Engel curve approach

- One way to estimate degree of quality mismeasurement is “Engel curve approach.”
- Basic idea: Suppose cross-sectional and time series relationships between consumer characteristic (e.g., income) and outcome (e.g., expenditure share) are stable.
  - We can measure relationship in cross-section.
  - We can use this relationship to infer change we should have seen in time series.
  - Gap between predicted and actual change isolates mismeasurement.
- Same approach has also been used to answer other questions:
  - Has the growth in income inequality been mirrored in consumption inequality?
  - Do China’s official statistics overstate true growth?

The Engel curve approach: Framework

- Suppose outcome for good i for household h at time t is:

$$y_{iht} = \phi_i^x x_{ht} + z_{it} + \varepsilon_{iht},$$

  where

  - x_{ht} is characteristic of household h at time t (e.g., income).
  - z_{it} is characteristic of good i at time t (e.g., quality-adjusted price).

- Key assumption: ϕ_i^x is stable across time (though it can differ across goods i).

- Aggregate outcome in year t is Y_t,

$$Y_{it} = \phi_{ix}\bar{x}_t + z_{it},$$

  where $\bar{x}_t$ is average across households.

The Engel curve approach: Framework

- What is the change in aggregate outcome across two periods t and $t+1$?

$$\Delta Y_{it} = Y_{it+1} - Y_{it} = \phi_{ix} \underbrace{(\bar{x}_{t+1} - \bar{x}_t)}_{\Delta \bar{x}_t} + \underbrace{(z_{it+1} - z_{it})}_{\Delta z_{it}}.$$

- $\Delta \bar{x}_t$ shared across goods, but goods have different exposures ϕ_{ix} which can be measured in cross-section.

- For example, predicted difference across two goods i and j:

$$\Delta Y_{it} - \Delta Y_{jt} = (\phi_{ix} - \phi_{jx}) \Delta \bar{x}_t + (\Delta z_{it} - \Delta z_{jt}).$$

- How can we use this?
  - We can use ϕ_{ix} as instrument for ΔY_{it} (Bils and Klenow 2001).
  - If we observe ΔY_{it}, we can use ϕ_{ix} to estimate $\Delta \bar{x}_t$.
    (Aguiar & Bils 2015; Nakamura, Steinsson, and Liu, 2016).

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Quality growth (Bils and Klenow 2001)

- Bils and Klenow (2001): How much does the BLS truly net out quality changes?
- As pointed out by Nordhaus (1996), we need to measure changes in quality-adjusted prices (e.g., price of service characteristic).
  - BLS undertakes some hedonic adjustments for cars, houses, computers.
  - If BLS does not fully net out quality changes, CPI inflation biased up and real GDP growth biased down.
  - Nordhaus (1996) on 1800–1992 growth impact w/ quality growth between 0–1.85 pct / yr.
  - Boskin Commission (1996) estimated unmeasured quality changes bias of 0.6 pct / year.
  - Yet, detailed empirical evidence still scant.

Quality growth (Bils and Klenow 2001): Model

- Suppose household h's utility from nondurables (c_{ht}) and N durable goods:

$$u_{ht} = \frac{c_{ht}^{1-1/\sigma} - 1}{1 - 1/\sigma} + \sum_{i=1}^{N} \frac{q_{iht}^{1-1/\sigma_i}}{1 - 1/\sigma_i}.$$

- For durables, consumption of quality q_{iht}. Let p_{iht} be unit price paid, where

$$p_{iht} = z_{it} q_{iht},$$

where z_{it} is quality-adjusted price.

- Result:

$$\log q_{iht} = \frac{\sigma_i}{\sigma} \log c_{ht} - \sigma_i \log z_{it}.$$

$$\Delta \log p_{iht} = \Delta \log z_{it} + \Delta \log q_{iht} = \frac{\sigma_i}{\sigma} \Delta \log c_{ht} + (1 - \sigma_i) \Delta \log z_{it}.$$

Quality growth (Bils and Klenow 2001): Model

- BLS aims to capture inflation rates holding quality constant, i.e. Δz_{it}.

- However, suppose they still capture fraction μ of quality-induced changes in unit price.

$$\Delta \log p_{it}^{\text{BLS}} = \Delta \log z_{it} + \mu \Delta \log \bar{q}_{it},$$

where $\bar{q}_{it}$ is average over q_{iht}.

- Since $\Delta \log \bar{p}_{it} = \Delta \log z_{it} + \Delta \log \bar{q}_{it}$,

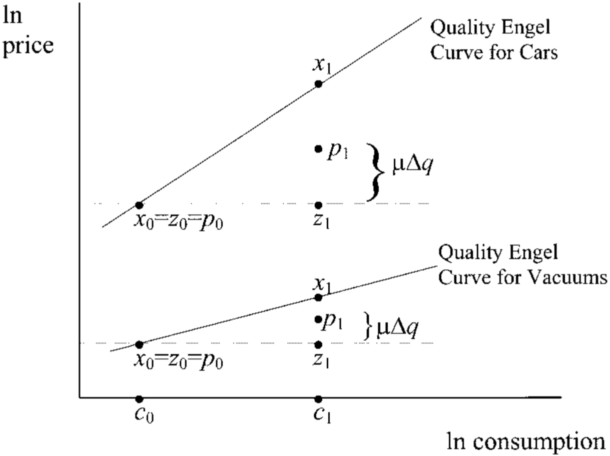
$$\Delta \log p_{it}^{\text{BLS}} = \mu \Delta \log \bar{p}_{it} + (1 - \mu) \Delta \log z_{it}.$$

Since

$$\Delta \log \bar{p}_{it} = \frac{\sigma_i}{\sigma} \Delta \log \bar{c}_t + (1 - \sigma_i) \Delta \log z_{it},$$

we can use σ_i as an instrument for $\Delta \log \bar{p}_{it}$ and recover μ if $Cov(\sigma_i, \Delta \log z_{it}) = 0$.

Quality growth (Bils and Klenow 2001): Model



- Intuition: When c_t rises, households will pay for higher quality.
- If quality changes not fully netted out, BLS's prices for goods with steeper Engel curves will have greater increase in price.

Quality growth (Bils and Klenow 2001): Data

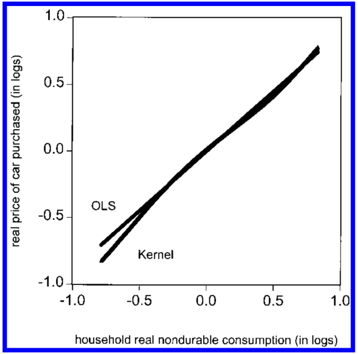


FIGURE 3. QUALITY ENGEL CURVE FOR CARS

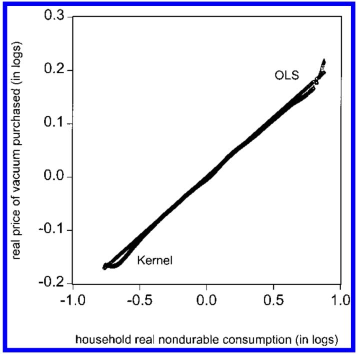


FIGURE 4. QUALITY ENGEL CURVE FOR VACUUMS

- Systematic differences in Quality Engel curves ($\theta_i = \sigma_i / \sigma$).
- Steepest Engel curves: jewelry, window coverings, rugs, and cars.
- Flattest Engel curves: Microwaves, sewing machines, vacuums, and lawn equipment.

Quality growth (Bils and Klenow 2001): Data

TABLE 5—PREDICTING CHANGES IN UNIT PRICES

Weighted least-squares regressions	Coefficient on θ_i (percent)	Adjusted R^2	Number of observations
Full sample of goods	4.24 (0.72) $t = 5.8$	0.93	66
Minus 2 + SD Δx_i extremes (excludes microwave ovens and trucks)	4.13 (0.34) $t = 12.1$	0.98	64
Minus 2 + SD θ_i extremes (excludes jewelry, rugs, and window coverings)	4.25 (0.75) $t = 5.7$	0.93	63
Minus CPI weight extremes (excludes cars and trucks)	3.21 (0.62) $t = 5.2$	0.31	64
Minus apparel (excludes the 16 clothes and shoes categories)	3.66 (1.06) $t = 3.4$	0.93	50

Notes: The weighted least squares weights are equal to December 1997 CPI shares. The dependent variable is Δx_i (percent unit price growth for good i) averaged over 1980–1996. The regressor is θ_i, the quality slope for good i. According to equation (9) in the text, the coefficient on θ_i should equal $\Delta c - \sigma \Delta z$. This regression is the first-stage regression for the instrumental variables estimation that follows in Table 6.

- First stage: Quality Engel curve elasticity $\theta_i = \sigma_i / \sigma$ predicts growth in unit prices.

Quality growth (Bils and Klenow 2001): Data

TABLE 6—ESTIMATES OF μ, QUALITY GROWTH, AND INFLATION BIAS

Instrument set ↓	μ	Average quality growth (percent per year)	Upward inflation bias (percent per year)	Adjusted R^2
θ_i	0.618 (0.125) $t = 4.9$	3.8	2.4	0.56
θ_i, $(\theta_i - \theta)\Delta z_i$	0.601 (0.119) $t = 5.0$	3.7	2.2	0.57

Notes: The number of observations = 66. μ = the fraction of quality growth that shows up as inflation in the BLS price deflators. θ_i = the quality slope for good i. Δz_i = the growth rate of the quality-adjusted relative price of good i (relative to the price of nondurable consumption). Estimation: The estimating equation is $\Delta p_i = \mu \cdot \Delta x_i + (1 - \mu) \cdot \Delta z_i$. This is equation (7) in the text. Here μ is estimated by GMM using the instruments listed above. That is, μ is estimated by exploiting the orthogonality of Δz_i to the instruments given. Average quality growth: The difference between the unit price inflation rates Δx_i and the BLS inflation rates Δp_i is an estimate of the BLS's quality adjustments. Across our 66 goods, these quality adjustments averaged 1.46 percent per year (when the goods are weighted by their 1997 CPI share). Thus if the BLS adjustments are capturing only $(1 - \mu)$ of total quality growth, total quality growth must be $1.46/(1 - \mu)$. This is equation (13) in the text. Upward inflation bias: The BLS misses the fraction μ of total quality growth, which equals $1.46 \cdot \mu/(1 - \mu)$. This is equation (14) in the text.

- Result: 60% of price changes due to quality growth not netted out!
- $Cov(\sigma_i, \Delta \log z_{it}) = 0$? Quantity Engel curves not predictive of unit price changes; industries with steep quality Engel curves have more rapid TFP growth.

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Consumption inequality (Aguiar and Bils 2015): Motivation

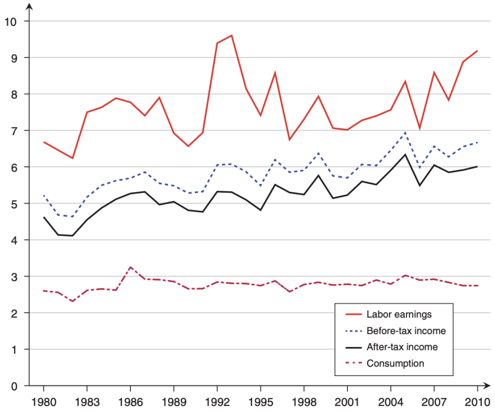

Figure 1. Trends in Inequality

Notes: This figure depicts the ratio of high-income to low-income respondents' reported labor earnings, before-tax income, after-tax income, and consumption expenditures. High income refers to respondents who report before-tax household income in the eightieth through ninety-fifth percentiles. Low income refers to respondents in the fifth through twentieth percentiles. Definitions of each series and sample construction are given in the data section.

- Aguiar and Bils (2015) use this Engel curve approach to study change in consumption inequality.
- Consumer Expenditure Survey suggests that consumption inequality has not kept pace with income inequality (Krueger and Perri, 2006).

Consumption inequality (Aguiar and Bils 2015): Motivation

TABLE 1—TRENDS IN INEQUALITY: RATIO OF HIGH-INCOME TO LOW-INCOME RESPONDENTS

	1980–1982	1991–1993	2005–2007	2008–2010	log change 1980–1982/ 2005–2007	log change 2005–2007/ 2008–2010
Labor earnings	6.41	8.47	7.88	8.59	0.21	0.09
Before-tax income	4.75	5.80	6.40	6.50	0.30	0.02
After-tax income	4.21	5.12	5.87	5.92	0.33	0.01
Consumption expenditures	2.47	2.77	2.93	2.77	0.17	−0.06
Non-durable expenditures	2.31	2.58	2.76	2.62	0.18	−0.05

Notes: High income refers to respondents who report before-tax household income in the eightieth through ninety-fifth percentiles. Low income refers to respondents in the fifth through twentieth percentiles. The elements of the first three columns are the ratio of the average of high-income respondents to the average for low-income respondents, where the averages are taken over the pooled years indicated at the head of the respective column. The last two columns are the log difference of the first and third columns and the third and fourth columns, respectively. All variables are converted into constant dollars before averaging. Definitions of each series and sample construction are given in the data section.

Consumption inequality (Aguiar and Bils 2015): Motivation

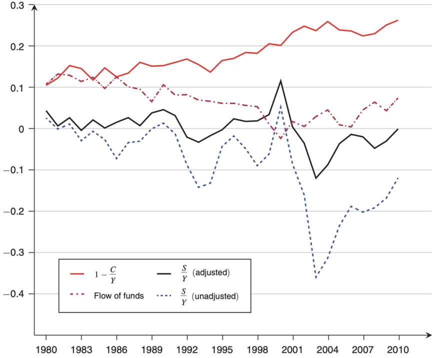

FIGURE 2. AGGREGATE SAVING RATES

Notes: This figure depicts the aggregate savings rates. The line labeled $1 - C/Y$ refers to implied savings computed as after-tax income minus reported consumption expenditures. The line labeled "Flow of funds" is the flow of funds aggregate private savings rate out of disposable income. The lines labeled S/Y refer to CE average reported savings divided by average reported after-tax income. Adjusted and unadjusted refer to whether we adjust reported new mortgages, as described in the data section of the text. Definitions of each series and sample construction are given in the data section of the text.

- Closer look suggests something is off.
- Personal saving rate reported in Flow of Funds steadily decreases over time.
- But implied savings rate constructed using CEX consumption is increasing over time.
- Even savings rate reported in CEX is decreasing over time (but noisy due to new mortgages).
- Assuming proportional underreporting across all groups would imply extreme decline in savings rate for lowest income.

Consumption inequality (Aguiar and Bils 2015): Model

- Suppose true expenditure on good *i* by household *h* follows

$$\log x^*_{iht} = \alpha_{it} + \beta_i \log X^*_{ht} + \Gamma_i Z_h + \varepsilon_{iht}.$$

- Suppose observed expenditure is

$$\log x_{iht} = \log x^*_{iht} + \psi_{it} + \phi_{\text{inc}(h),t} + \nu_{iht},$$

where ψ_{it} is good-specific misreporting and $\phi_{\text{inc}(h),t}$ is income group misreporting.

- In cross-section, ψ_{it} is constant, and we can estimate β_i and Γ_i. Then, we have:

$$\log x_{iht} - \log \bar{x}_{it} - \Gamma_i Z_h = \alpha_{it} + \beta_i \log X^*_{ht} + \phi_{\text{inc}(h),t} + \varepsilon_{iht} + \nu_{iht}.$$

Consumption inequality (Aguiar and Bils 2015): Model

$$\log x_{iht} - \log \bar{x}_{it} - \Gamma_i Z_h = \alpha_{it} + \beta_i \log X^*_{ht} + \phi_{\text{inc}(h),t} + \varepsilon_{iht} + \nu_{iht}.$$

- Comparing expenditures x_{iht} to $\bar{x}_{it}$ purges out good-specific misreporting ψ_{it}.
- Estimates of β_i from cross-section tell us how much consumption grew.
  - Use estimated $\hat{\Gamma}_i$ and $\hat{\beta}_i$ from first stage.
  - $\phi_{\text{inc}(h),t}$ estimated with income group-time dummies.
  - $\log X^*_{ht}$ estimated with income group-time dummies interacted with $\hat{\beta}_j$.
- Identification threat: Good $\times$ household misreporting ν_{iht} correlated with $\beta_i \times 1_{\text{inc}(h),t}$.
  - Some econometric subtleties with generated regressors $\hat{\beta}_i$.

Consumption inequality (Aguiar and Bils 2015): Data

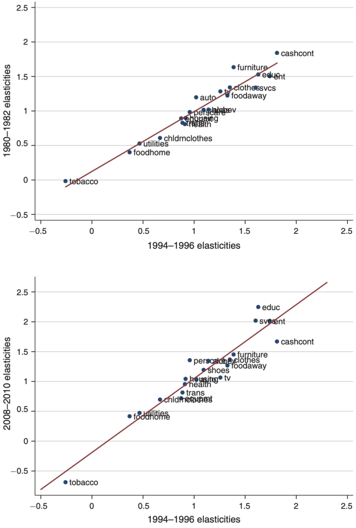

Figure 5. Stability of Expenditure Elasticities over Time

- Substantial differences in Engel curves across goods.
- Necessities: Food-at-home, utilities, children's clothes.
- Luxuries: Services, education, cash contributions, entertainment.
- Income elasticities relatively stable over time.

Consumption inequality (Aguiar and Bils 2015): Data

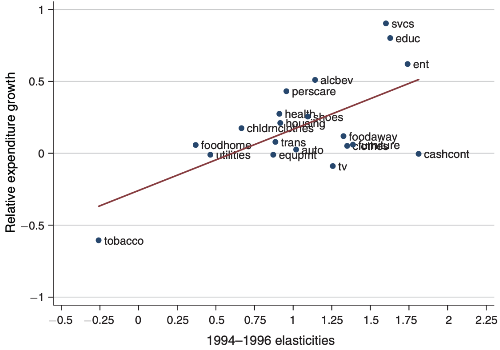

Figure 4. Relative Expenditure Growth for 20 Goods

Notes: This figure is a scatter plot of relative (high- versus low-income) expenditure growth over the sample period for each good versus expenditure elasticity. The vertical axis depicts the difference across high-income and low-income households in the log growth in expenditure for each good between 1980/1982 and 2008/2010. The horizontal axis is each good's estimated expenditure elasticity from Table 2, column I. The slope of the scatter plot's regression line is 0.425.

- Expenditures of high- vs. low-income on goods from 1980/2 to 2008/10.
- Slope identifies true expenditure growth $\Delta \log X^*_{ht}$.
- Slope in this example is 0.425!

Consumption inequality (Aguiar and Bils 2015): Data

TABLE 3—TRENDS IN CONSUMPTION INEQUALITY BASED ON RELATIVE EXPENDITURE PATTERNS

	(1)	(2)	(3)	(4)	(5)
log inequality, 1980–1982	0.85	0.90	0.82	0.71	0.91
	(0.07)	(0.06)	(0.08)	(0.05)	(0.06)
log change, 1980–1982/1991–1993	0.27	0.17	0.20	0.27	0.15
	(0.08)	(0.06)	(0.07)	(0.06)	(0.07)
log change, 1980–1982/2005–2007	0.48	0.35	0.43	0.46	0.30
	(0.08)	(0.07)	(0.08)	(0.06)	(0.07)
log change, 2005–2007/2008–2010	−0.06	−0.04	−0.05	−0.05	−0.04
	(0.08)	(0.06)	(0.08)	(0.06)	(0.06)
Categories included	All	All	All	Without durables	Without tobacco
Specification	OLS	WLS	WLS	WLS	WLS
First-stage instrument	Income	Income	Lagged expenditure	Income	Income

Notes: This table reports the estimated change in consumption inequality for top versus bottom income quintiles obtained from the second-stage regressions. Column 3 uses the first-stage estimated expenditure elasticities reported in column II of Table 2, while all other specifications use the column I estimates. The estimated parameters in the first row represent log inequality between the high-income and low-income households in 1980–1982. The next three rows represent the relative growth in total expenditure for high-income households relative to low-income households for the period specified. See the specification in the text for full details. The first column implements the second stage by OLS while the remaining columns implement weighted least squares, using the average NIPA shares for 1980–2010 as weights. For column 4, the weights are adjusted by multiplying the NIPA shares by the average share of each category's expenditure that is nondurable in our CE sample. The standard errors are calculated using a bootstrap with 100 replications.

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China's official statistics (Nakamura et al. 2016)

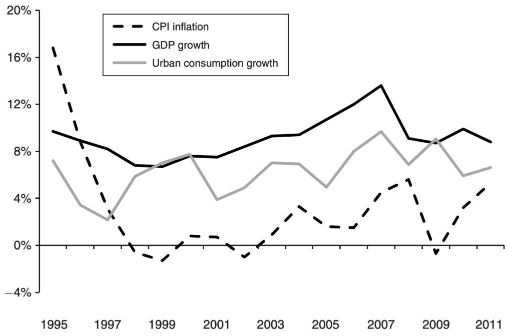
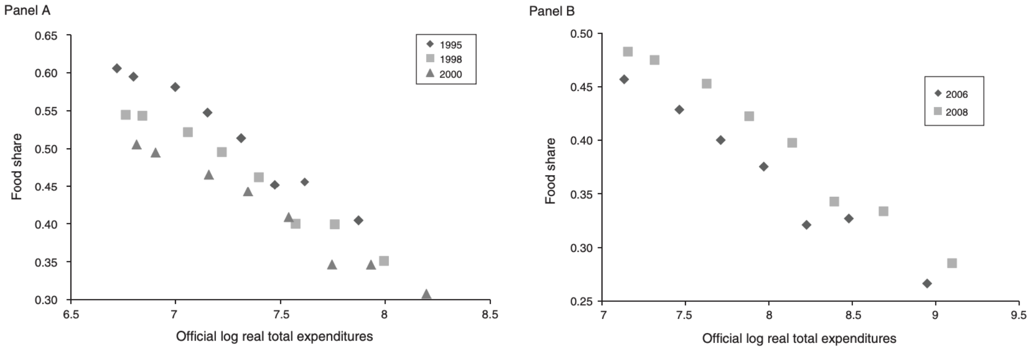


Figure 1. Official Growth and Inflation in China

- Rapid GDP growth in China from 1995–2011, with low, stable inflation after 1997. (Avg. nonfood inflation of -0.1 pct, standard deviation 1 pct.)
- Nakamura, Steinsson, and Liu ask whether the official statistics appear too smooth.

China's official statistics (Nakamura et al. 2016)



- Conditional on real expenditures, consumption of food shifted down from 1995–2000 and shifted up from 2006–2008.
- Consistent w/ CPI growth overstated from 1995–2000, understated from 2006–08.

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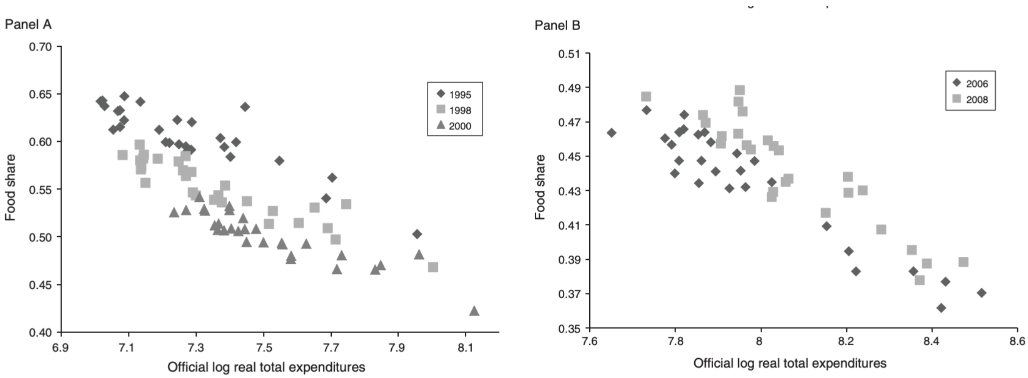

- Similar patterns looking across regions.
- Similar patterns for food subcategories (e.g., grain) or other goods categories.

China's official statistics (Nakamura et al. 2016)

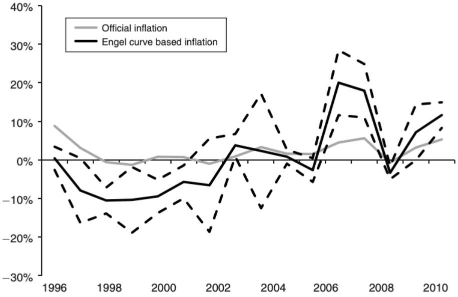

FIGURE 5. OFFICIAL AND ENGEL CURVE BASED INFLATION

Notes: Official inflation is the Chinese CPI. Adjusted inflation is from a pooled specification using the Engel curve for food expenditures as a fraction of total expenditures and Engel curves for the expenditures on 14 major subcategories of food (e.g., grain, mean, or eating out) as a fraction of food expenditures. Dashed lines are two standard error bands. Standard errors are clustered by commodity.

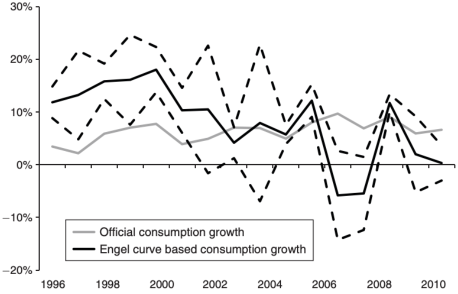

FIGURE 6. OFFICIAL AND ENGEL CURVE BASED URBAN CONSUMPTION GROWTH

Notes: Adjusted urban consumption growth is from a pooled specification using the Engel curve for food expenditures as a fraction of total expenditures and Engel curves for the expenditures on 14 major subcategories of food (e.g., grain, mean, or eating out) as a fraction of food expenditures. Official consumption growth is for urban consumption from the National Accounts. Dashed lines are two standard error bands. Standard errors are clustered by commodity.

- Suggests CPI growth overstated and consumption growth understated from 2006–08.
- Two interpretations: official statistics smoothed for political motivations, or difficulties in measuring true inflation. Latter appears more likely.

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Disaggregation: Theoretical and empirical tools

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- Micro data allows us to unpack black box of "macro shocks."
  - Models of disaggregated supply-side offers sufficient statistics.

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  - Direct measurement of GE forces, aggregation when theory is ambiguous.
  - Measurement can also tells us where *measurement* needs to improve!

Advice on research process

- Second and third years of PhD are hardest.
- Draw a lot from your distribution of ideas, see what sticks.
  - One way to vet idea quality is to collect reactions from faculty.
  - Another way is to come up with “minimum viable paper.”
  - Sprint toward proving or disproving that there is something there.

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  - Sprint toward proving or disproving that there is something there.
- Treat advisors as both coaches and referees.
  - Transparency.
  - If they have a conceptual question or concern, you should address it!

Advice on research process

- There are some types of papers in macro I would love to see more of.

1. Use specific industries or settings as a laboratory for big ideas.
   - E.g., “Waves in ship prices and investment” (Greenwood and Hanson, 2015).
2. Prove out phenomenon by showing that it appears across a wide array of contexts.
   - E.g., “Prices rise faster than they fall” (Peltzman, 2000).
3. Bring back old (correct) ideas about how things work.
   - E.g., “Why don’t old firms do new things?” (Crouzet, He, Lyonnet & Ma, 2025).

Empirical macro

- “The master-[macro]economist must possess a rare combination of gifts .... He must be mathematician, historian, statesman, philosopher—in some degree. He must understand symbols and speak in words. He must contemplate the particular, in terms of the general, and touch abstract and concrete in the same flight of thought. He must study the present in the light of the past for the purposes of the future. No part of man’s nature or his institutions must be entirely outside his regard. He must be purposeful and disinterested in a simultaneous mood, as aloof and incorruptible as an artist, yet sometimes as near to earth as a politician.”

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- Thanks for being a great class, and looking forward to your presentations!