Measuring Business Value and Productivity

Ellen McGrattan
University of Minnesota

Lectures in Honor of Zvi Griliches, Abidjan 2024
Outline for Lectures

• Prologue: Remembering Zvi Griliches

• Lecture 1: The 1990s Technological Revolution

• Lecture 2: Updating Theory and Measurement

• Lecture 3: Measuring the Unmeasurable

• Epilogue: Open Questions
Prologue: Remembering Zvi Griliches
Our measurement and observation tools are becoming increasingly inadequate in the context of our changing economy.

— Zvi Griliches

Productivity, R&D, and the Data Constraint

American Economic Review, 1994
What Bothered Griliches?

- Large unexplained Solow’s residual
- Large unexplained changes in this residual
- Constraints of data
The Solow Residual

- Aggregate production function: $Y = F(K, H; t)$
  - Conventional inputs $(K, H)$: capital and hours
  - "Technical change" $(t)$: any kind of shift

- Solow’s main findings about technical change:
  - Was roughly neutral, e.g., $Y = A(t)f(K, H)$
  - $\dot{A}/A$ accounts for 88% of observed growth

$\Rightarrow$ Viewed by Griliches as “an embarrassment”
Large Contribution of $\dot{A}/A$

- Answering:
  - Is it truly due to improved efficiency?
  - Is it instead a measure of our ignorance?
- Has inspired generations to track the sources of $\dot{A}/A$
Sources of Technical Change

- Decades of research highlighted
  - Improvements in input qualities
  - Contributions of science (eg, R&D)

- But productivity slowdown in 1970s left Griliches doubting
US Productivity Slowdown in 1970s

- Led to pessimistic forecasts:
  - Inadequate measurement tools clouding reality
  - Diminished returns to inventive activity
- What observations triggered this pessimism?
Observations Triggering Pessimism

• During 1970s productivity slowdown
  ◦ Share of “measurable” sectors declining
  ◦ TFP growth not rising with R&D spending
  ◦ Patents per dollar/scientist declining

• Let’s review data from Griliches (1994)
Share of “Measurable” Sectors Declining

- “Measurable” (eg, primarily goods-producing)
  - Agriculture
  - Mining
  - Utilities
  - Manufacturing
  - Transportation
  - Communications

- “Unmeasurable” (eg, primarily service-producing)
  - Construction
  - Trade
  - Finance
  - Other services
  - Government
“Unmeasurable” Impacting Overall Productivity
TFP and R&D Spending in Manufacturing

- Total factor productivity (TFP) growth:
  \[ \frac{\dot{Y}}{Y} - \sum_{j} \omega_j \frac{\dot{X}_j}{X_j}, \omega_j = \text{input shares} \]
  - With 5 factors of production \((X_j)\):
    1. Capital
    2. Production worker hours
    3. Non-production worker hours
    4. Non-energy materials
    5. Energy

  - Aggregated at 3-digit industry level

- R&D spending from National Science Foundation
TFP and R&D Spending in Manufacturing
TFP and R&D Spending in Manufacturing

Only see R&D impact in one industry
Fewer Patents Per $/Scientist
Glass Half-Empty/Half-Full

- Positive signs for Griliches:
  - Productivity and investment in computer industry
  - Patent applications rose sharply at the end of 1980s
  - Rise in automation (eg, bank ATMs) noticeable

- Meanwhile, a technological revolution was in fact beginning...
Lecture 1: The 1990s Technological Revolution
...they, like everyone else, are somewhat embarrassed by the fact that what everyone feels to have been a technological revolution, a drastic change in our productive lives, has been accompanied everywhere by a slowing down of productivity growth, not by a step up. You can see the computer age everywhere but in the productivity statistics.

— Robert Solow

We’d Better Watch Out

Puzzling Macro Observations

- Stock market valuations were starting to soar
- Employment and hours indices were booming
- Aggregate labor productivity and TFP measures were not

⇒ Minneapolis Fed President asked: what should the Fed do?
An Academic Answer

- Set up a laboratory
  - Pull our basic model off the shelf
  - Estimate model parameters
  - Simulate data from the model
  - Compare model and actual US data

- Ask:
  - Is anything off?
  - Should the Fed be doing anything?
Our Simple Laboratory

- Households
- Firms
- Financial intermediaries
- Government
- Equilibria
Problem Solved by Households

- Choose at each date $t$:
  - Consumption $c_t$
  - Hours of leisure $\ell_t$ and work $h_t = 1 - \ell_t$
  - Saving $a_{t+1} - a_t$ (eg, change in assets)

- Maximize:
  - Utility $U(c_t, \ell_t)$

- Subject to a budget with prices $r_t, w_t$:

$$c_t + a_{t+1} - a_t = r_t a_t + w_t h_t - \text{taxes} + \text{transfers}$$
Problem Solved by Firms

- Choose:
  - Factors of production: capital $K_t$ and hours $H_t$
  - Output $Y_t = F(K_t, H_t; A_t)$ given productivity $A_t$
  - Gross investment $X_t = K_{t+1} - K_t - \delta K_t$
  - Distributions $D_t = Y_t - w_t H_t - X_t - \text{taxes}$

- Maximize (with discount factors $p_t$):
  - Value for owners $V_0 = \mathbb{E} \sum_{t=0}^{\infty} p_t D_t$
Financial Intermediation

• Each household $i$
  
  ◦ Deposits $a_{i,t+1} - a_{i,t}$
  
  ◦ Receives return $r_t$ on deposits

• Intermediaries
  
  ◦ Invest $K_{t+1} - K_t$ in new capital in firms
  
  ◦ Receive distributions $D_t$
Government

- Fiscal policy:
  - Taxes on consumption
  - Taxes on labor earnings
  - Taxes on profits
  - Taxes on firm distributions
  - Transfers

- Monetary policy: absent in simplest model†

† An assumption Fed President Stern questioned
Equilibrium and Prediction

1. Find:
   - Allocations: \( Y_t, C_t, H_t, X_t, K_t, D_t, V_t \)
   - Prices: \( r_t, w_t, p_t \)

   that clear goods, labor, and asset markets

2. Simulate GDP and hours predictions after feeding in:
   - \( A_t \): Solow residual based on US aggregate data
   - \( \tau_{ct} \): retail sales tax rate
   - \( \tau_{ht} \): labor income tax rate

   with other taxes set at average levels over 1990-2003
How Did We Do?†

† Unmeasured Investment and the Puzzling US Boom in the 1990s
AEJ Macroeconomics, 2010 (with E.C. Prescott)
How Did We Do?†

• Not good!

• Theory was grossly at odds with observations

† Unmeasured Investment and the Puzzling US Boom in the 1990s
AEJ Macroeconomics, 2010 (with E.C. Prescott)
How Did We Do?†

- Not good!
- Theory was grossly at odds with observations
- Economic theories predicted a depressed economy
  - But the US economy boomed
  - Especially hours worked

† Unmeasured Investment and the Puzzling US Boom in the 1990s
  
  *AEJ Macroeconomics*, 2010 (with E.C. Prescott)
Hours: Simple Theory and Data

US Hours Per Capita
(1990=100)

Model Prediction
GDP: Simple Theory and Data

US Real GDP Per Capita
(divided by 1.02^t, 1990=100)

Model Prediction
Lecture 2: Updating Theory and Measurement
Some Clues About Missing Factors

- Clues in the aggregate data:
  - Hours rose while wages fell
  - GDP rose while profits fell
  - Corporate price-dividend ratios were soaring

- Clues in the micro data
  - Industry R&D rose significantly
  - IPO gross proceeds boomed
  - Average hours boomed in select occupations
Hours Rose While Wages Fell

US Hours Per Capita
(1990=100)

US Compensation Per Hour
(divided by 1.02, 1990=100)
Hours Rose While Wages Fell

US Hours Per Capita
(1990=100)

“Sweat equity” expensed?

US Compensation Per Hour
(divided by 1.02', 1990=100)
GDP Rose While Profits Fell

US Real Corporate Profits Per Capita
(divided by 1.02', 1990=100, right scale)

US Real GDP Per Capita
(divided by 1.02', 1990=100, left scale)
GDP Rose While Profits Fell

US Real Corporate Profits Per Capita
(divided by 1.02', 1990=100, right scale)

US Real GDP Per Capita
(divided by 1.02', 1990=100, left scale)

R&D expensed?
Total Industry R&D Boomed

- Between 1994 and 2000, nominal
  - Spending for industry R&D increased 68 percent
  - GDP increased 39 percent
- R&D is expensed by corporations, lowering profits
Share of R&D by Tech Firms

Percent

S&P Price-Dividend Soared in 1990s
IPO Gross Proceeds Boomed

- Gross proceeds of IPOS averaged
  - $8.2 billion over 1980–1989
  - $30.9 billion over 1990–1999

- Some forgo compensation and get paid later with IPO
Average Hours Boomed Selectively

<table>
<thead>
<tr>
<th></th>
<th>Total (1992=100)</th>
<th>The Educated in Select Occupations†</th>
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<tr>
<td>1992</td>
<td>100.0</td>
<td>10.3</td>
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<td>2000</td>
<td>106.5</td>
<td>13.3</td>
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<tr>
<td>% Chg.</td>
<td>6.5</td>
<td>30.0</td>
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† Managerial, computational, and financial occupations
Share of Employment by Tech Firms

[Graph showing the share of employment by tech firms from 1990 to 2002, with a peak around 2000 and a decline thereafter.]
Extending Theory
Two Key Factors Absent in Simple Theory

- Introducing:
  - Intangible investment that is expensed
  - Nonneutral technical change in its production

⇒ An hours boom without a boom in measured TFP
Updating the Model

- Capital inputs
  - Tangible $K_T$
  - Intangible $K_I$

- Technologies to produce
  - Goods and services: $Y_b = A^1 F(K^1_T, K_I, H^1)$
  - New intangible capital: $X_I = A^2 G(K^2_T, K_I, H^2)$

- Total output at $t$: $Y_t = Y_{bt} + q_t X_{It}$
Key Features of Technology

- Intangible capital is
  - Nonrival: used in production of $Y_b$ and $X_I$
  - Excludable: no spillovers assumed here
  - Expensed: can be used to lower taxable profits or wages

$\Rightarrow$ Relatively minor extension of simple theory
Hypothesis for 1990s Boom

- Technological change was nonneutral: \( \frac{A_t^2}{A_t} \uparrow \)

\[ \Rightarrow \] More hours to intangible sector \( \frac{H_t^2}{H_t} \uparrow \)

\[ \Rightarrow \] Measured labor productivity was stagnant \( \frac{Y_{bt}}{H_t} \rightarrow \)

While true labor productivity was rising \( \frac{Y_t}{H_t} \uparrow \)
How to Identify Changes in TFPs

1. Start with observations on $Y_{bt}, C_t, H_t, K_{Tt}$

2. Use intratemporal conditions to infer
   - Split of hours into $H_t^1, H_t^2$
   - Output from intangible sector $q_t X_{It}$

3. Use intertemporal conditions infer relative price $q_t$ and $K_{It}$

4. Finally, use production technologies to back out $A_t^1, A_t^2$
Implied TFPs

- Intangible capital sector TFP
- Final goods and services sector TFP
- US business sector TFP

Index

Implied Intangible Share of Output

Percent

Revisiting Predictions for Hours and GDP

- Predictions in simple model were grossly at odds with data
- What are the new predictions?
Hours: Extended Theory and Data

US Hours Per Capita
(1990=100)

Model Prediction

Index

GDP: Simple Theory and Data

US Real GDP Per Capita
(divided by 1.02, 1990=100)

Index

Was Success Guaranteed?

- Did additional “residuals” \((A_t^2, X_{It})\) ensure good fit?

- Consider alternative economy and “free” parameters:
  - Neutral technology change \(A_t\) in both sectors
  - Labor wedge ensuring intratemporal condition holds

  \(\Rightarrow\) Predictions grossly at odds with data

- In other words: success is not guaranteed
Reevaluating Productivity in 1990s

Real Business Productivity Predictions
(divided by 1.02, 1990=100)

Includes intangible investment

Excludes intangible investment
Reevaluating Investment in 1990s

Real Per Capita Investment Predictions
(divided by 1.02^t, 1990=100)

Index

Includes intangible investment

Excludes intangible investment
Reevaluating Policy

Clearly, sustained low inflation implies less uncertainty about the future, and lower risk premiums imply higher prices of stocks and other earning assets...But how do we know when irrational exuberance has unduly escalated asset values...and how do we factor that assessment into monetary policy?

— Alan Greenspan, Chairman of the Federal Reserve

The Challenge of Central Banking in a Democratic Society

Speech at the American Enterprise Institute, December 1996
Our Answer

- The Fed should
  - Continue pursuing low inflation
  - Not intervene in financial markets
Two Decades After Griliches (1994):
A Major Update to National Accounting
• New category of investment introduced in 2013

• Now included in IPP are expenditures on:
  ○ R&D
  ○ Software and databases
  ○ Entertainment and artistic originals

• Currently in progress:
  ○ Advertising and marketing
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GDI: Gross Domestic Income  
GDP: Gross Domestic Product
IPP Share of Investment

- IPP share now larger than equipment or structures
- Mostly done in sectors Griliches calls "unmeasurable"
IPP Shares by Sector

![Graph showing IPP shares by sector over time. The x-axis represents years from 1950 to 2020, and the y-axis represents percent share. Three lines are plotted:
- Blue line: Measurable sectors
- Red line: Unmeasurable private sectors
- Green line: Unmeasurable public sector
The graph illustrates the trends in IPP shares across different sectors over the years.]
Griliches’ Measured Shares Never Recovered

![Graph showing the trend of Griliches’ measured shares over time. The graph displays two lines, one representing 'Value added' and the other 'Hours.' The x-axis represents years from 1950 to 2020, while the y-axis represents percent values. The lines indicate a decline in measured shares over the years.]
GDP Per Hour Continued to Diverge

Thousands of 2012 US Dollars

- Blue: Measurable sectors
- Red: Unmeasurable sectors
- Green: Total economy

Years: 1950 to 2020
Recap

- Since 1994,
  - Economies have become more “unmeasurable”
  - Old empirical tools are no longer able to detect gains
- Next, we consider how to use theory as a new lens
Lecture 3: Measuring the Unmeasurable
(and Implications for Business Value, Productivity, and Policy)
Measuring the Unmeasurable

- BEA is including more investment in IPP category

- But have no measures for prices, depreciation, stocks
  - Publicly-traded firms: observe only enterprise value
  - Private firms: observe assets if sold (and taxed!)

⇒ Lots of capital/value can never be measured

⇒ Old-style growth accounting is not appropriate
What to Do?

- Use theory incorporating latent factors
- Use all micro and macro data available
  - National accounts
  - Census surveys
  - Tax data
- Construct same measures/moments in data and model
Key Observations

• Tangible capital stocks (structures, equipment)

• Business profits and values if known

⇒ Used to infer unmeasured assets

• Next: apply idea to data from publicly-traded corporations
Market Value

\[ V \equiv \sum_{t=0}^{\infty} \sum_{s^t} p(s^t) D(s^t) \]

- Where,
  - \( p(s^t) \): consumption price in state \( s^t \) relative to \( s^0 \)
  - \( D(s^t) \): dividends in state \( s^t \)
Market Value

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Hard to compute, but can use fixed assets ...
Estimating Market Value

\[ V = (1 - \tau_{dist})qK \]

- Why?
  - Without tax, \( V \) is value of productive fixed assets
  - With tax, value adjusted by tax on distributions
The Value with Intangible Capital

\[ V = (1 - \tau_{\text{dist}}) \left( q_T K_T + (1 - \tau_{\text{prof}}) q_I K_I \right) \]

- Why?
  - Tangible \((T)\) investment is capitalized
  - Intangible \((I)\) investment is expensed
Inference About Intangible Capital

- Applying basic principles:
  - Investments in intangibles lead to future profits
  - Optimality implies returns to different capitals equated

- Using accounting relation:

\[
\Pi_{\text{profits}} = (1 - \tau_{\text{prof}}) \left( r_T K_T + r_I K_I - \delta_T K_T - X_I \right)
\]

- profits
- rents to capital
- tangible depreciation
- intangible investment
Inference About Intangible Capital

• Applying basic principles:
  ◦ Investments in intangibles lead to future profits
  ◦ Optimality implies returns to different capitals equated

• Using accounting relation on BGP \( X_I = (g + \delta_I)K_I \):

\[
\Pi = (1 - \tau_{prof}) \left( r_T K_T + r_I K_I - \delta_T K_T - (g + \delta_I)K_I \right)
\]

- Profits
- Rents to capital
- Tangible depreciation
- Intangible investment
Inference About Intangible Capital

• Applying basic principles:
  ◦ Investments in intangibles lead to future profits
  ◦ Optimality implies returns to different capitals equated

• Using accounting relation with returns equated ($i$):

\[
\Pi = iK_T + (1 - \tau_{\text{prof}})iK_I - (1 - \tau_{\text{prof}})gK_I
\]

- $\Pi$: profits
- $iK_T$: income to capital
- $(1 - \tau_{\text{prof}})iK_I$: growth in intangibles
Inference About Intangible Capital

- Applying basic principles:
  - Investments in intangibles lead to future profits
  - Optimality implies returns to different capitals equated

- Using accounting relation with $\Pi$, $\tau_{\text{prof}}$, $K_T$, $i$, $g$:

\[
\Pi = iK_T + (1 - \tau_{\text{prof}})iK_I - (1 - \tau_{\text{prof}})gK_I
\]
An Application:
The Stock Market Crash of 1929
(and the fate of Irving Fisher)
Irving Fisher

- Lost his fortune in 1929

- Prior to the market crash, Fisher reasoned†
  
  - Stocks were still undervalued
  
  - Price-earnings ratios would go higher
    - More productive capital implies higher value
    - More expensing implies lower earnings

† *Stock Market Crash—And After*, 1930
Applying the Formula

- Using US data (1925–1929):
  - $\Pi = 8.3\% = \text{ratio of corporate profits to GDP}$
  - $K_T = 1.4 = \text{ratio of tangible capital to GDP}$
  - $i = 4.73\% = \text{after-tax return to noncorporate capital}$
  - $g = 2.6\% = \text{trend growth}$
  - $\tau_{\text{prof}} = 14.6\% = \text{average corporate tax rate}$

- Applying the formula:

$$K_I = \frac{[\Pi/K_T - i]}{(1 - \tau_{\text{prof}})(i - g)} K_T = 0.61K_T$$
Implications for Corporate Value

• If:
  
  ◦ $K_I = 0.61K_T$
  
  ◦ Adjustment costs of capital small ($q_T = q_I \approx 1$)

• Then:

$$\hat{V} = (1 - \tau_{\text{dist}})(K_T + (1 - \tau_{\text{prof}})K_I)$$

$$= (1 - 0.103)(1 + (1 - 0.146) \times 0.61)1.4$$

$$= 1.9 \times \text{GDP} > \text{actual value of 1.7}$$
Implications for Corporate Value†

• If:
  
  - $K_I = .61K_T$
  - Adjustment costs of capital small ($q_T = q_I \approx 1$)

• Then:

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\[
= (1 - .103))(1 + (1 - .146) \times .61)1.4
\]
\[
= 1.9 \times \text{GDP} > \text{actual value of 1.7}
\]

⇒ Fisher was right!

† The 1929 Stock Market: Irving Fisher was Right
But, Not Completely Right

- Fisher and many others:
  - Had leveraged investments
  - Would have been rich if held long-term

- Anyone challenging Fisher’s reasoning needs to:
  - Develop new theory
  - Solve the volatility puzzle \( \text{var}(V) \gg \text{var}(K_T) \)
Implications for Productivity

• Observing only tangible capital $K_T$

$\Rightarrow$ Solow’s technical change picks up changes in $K_I$
An Application:
The Stock Market Boom of the 1990s
(and the testimony of Campbell and Shiller)
Campbell and Shiller (CS)

- Testified before Fed Board on 12/3/96
  - Price-dividend ratios historically high
  - Reversion to mean likely

- What were they seeing?
Meanwhile

- Greenspan publicly worried about irrational exuberance

- Prescott privately worried he invested too much in stocks!
Fast Forward to 2001

- Campbell and Shiller updated their analysis
  - Price-dividend ratios were even higher
  - Reversion to mean very likely

- What were they seeing?
S&P Price-Dividend Ratio, 1871:01–2000:12
Fast Forward to Today...
(with the P/D ratio well above the 1870–1990 average)
S&P Price-Dividend Ratio, 1871:01–2023:03
Including All Publicly-Traded Firms

- CS focused on price-dividend ratio for narrow set of firms
- But significant rise also observed in aggregate value-to-GDP
Value of Publicly Traded Firms, 1960–2023
Value of Publicly Traded Firms, 1960–2023

More than doubled since 1960
More than quadrupled since 1980
Role of Taxes

• Income tax rates are critical for investors

• US rates were high right after WWII
  ○ Top rate above 90% on individual income
  ○ Top rate above 50% on corporate income

• US rates have fallen dramatically since
Taxes Most Relevant for Corporate Values

- Effective tax rate on firm distributions, $\tau_{\text{dist}}$
  - Statutory rates lowered, especially in 1980s
  - Regulations changed allowing tax deferrals on pensions

- Effective tax rate on firm profits, $\tau_{\text{prof}}$
  - Statutory rates lowered, especially recently
Effective Tax Rate on Distributions

Percent

Estimating Intangible Contributions, 2000–2019

• As before, use data on $i$, $g$, $K_T$:
  ○ Real interest rate of 4.1%
  ○ Real GDP growth of 3%
  ○ Average tangible capital of 1.22 times GDP

• What are the implied intangible contributions to $\Pi, V$?
# Estimated Intangible Contributions

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<th>Shares</th>
<th>Corporate Income Tax Rate (%)</th>
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<td>32</td>
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<tr>
<td><strong>In profits</strong></td>
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<tr>
<td>Intangible capital</td>
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<tr>
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<td>88</td>
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<td><strong>In market values</strong></td>
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<tr>
<td>In market values</td>
<td></td>
</tr>
<tr>
<td>Intangible value</td>
<td>33</td>
</tr>
<tr>
<td>Tangible value</td>
<td>67</td>
</tr>
</tbody>
</table>

What does this imply for the bottom line?
Bottom Line: A Visual Summary
Corporate Total Value to GDP

<table>
<thead>
<tr>
<th>$\tau_{\text{prof}}$</th>
<th>$V_f$/GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>.32</td>
<td>.54</td>
</tr>
<tr>
<td>.25</td>
<td>1.02</td>
</tr>
<tr>
<td>.21</td>
<td>1.29</td>
</tr>
</tbody>
</table>

Estimates of $V$/GDP:
- A = McGrattan-Prescott (2005)
- B = McGrattan (2023)
Was the Stock Market Overvalued in 2000-2019?

• Reasons for answering no:
  ○ Investments were steady through 2001-02 & 2008-09
  ○ Distributions were steady through 2001-02 & 2008-09
  ○ Taxes on distributions were low
  ○ Outward FDI continued rising

⇒ Mostly undervalued relative to theory
Is the Stock Market Overvalued in 2023?

- Reasons for answering no:
  - Large decline in corporate tax rate, $\tau_{\text{corp}}$
  - Multinationals have had time to figure out TCJA
  - Taxes on distributions have remained low
  - Outward FDI still rising

⇒ Revising current estimate upward based on theory
Implications for Productivity

• At $\tau_{prof} = 21\%$, intangible capital $K_I$
  
  o Contributes 54% of corporate value
  
  o Contributes to *endogenous* technical change

⇒ Significantly different result than model with only $K_T$
Measuring the Unmeasurable Abroad
Measuring the Unmeasurable Abroad

- Multinationals invest in
  - R&D
  - Brands
  - Organizational capital

- That generate returns to foreign direct investment (FDI)
  - Profits abroad for already developed technologies
  - Higher TFP and welfare for host countries

- But are booked as operating expenses, not investments
Expensing vs Capitalizing

- Matters for accounting rates of return (RoR):

\[
\text{RoR} = \begin{cases} 
  \frac{(r_T K_T + r_I K_I - \delta_T K_T - X_I)}{K_T} & \text{if expensed} \\
  \frac{(r_T K_T + r_I K_I - \delta_T K_T - \delta_I K_I)}{(K_T + K_I)} & \text{if capitalized}
\end{cases}
\]

- Expensing distorts RoR if
  - Net intangible investment large \((X_I - \delta_I K_I)\)
  - Intangible capital large \((K_I)\)
With Open Capital Markets

- Accounting rates of return depend on whether
  - Expensing done at home or abroad
  - Capital is rival or nonrival

- Let’s consider two extreme cases....
With Open Capital Markets

- Suppose economic return same for all assets

- Can have:
  - High RoR of FDI with little or no investment
  - Low RoR of FDI with new investment

- Depends on expensing and rivalry of intangible investments
With Open Capital Markets

• High RoR of FDI is possible with little or no investment

• How?
  ○ Invest in R&D and brands at home
  ○ Use them abroad

... In fact, RoR of FDI could in theory be infinite
With Open Capital Markets

- Low RoR of FDI is possible with new investment

- How?
  - New subsidiary established by multinational
  - Start up costs include expensed intangible investments

... In fact, returns to FDI could in theory be negative
To Interpret the Data

• Need to consider nature of intangibles
  ◦ Rival versus nonrival
  ◦ Expensed at home versus abroad

• Want theory that incorporates these
A Useful Example

- US drug company Medicate™ with employees:
  - Bob: develops a new drug in North Carolina
  - 50 drug representatives (reps) at 50 US locations
  - 2 drug reps at 2 Belgian locations

- Measuring impact of intangibles, need to keep in mind
  - Some capital is nonrival, some rival
  - Production opportunities vary with country size
  - Profits depend on timing of investments and rents
Modeling Medicate’s Production

- Add two types of intangible capital
  1. Rival that is plant-specific ($K_I$)
  2. Nonrival that is firm-specific ($M$)
- Add locations since technology capital nonrival ($N$)
- To otherwise standard model
Output of Multinationals from Country $j$ in $i$

$$Y^j_i = A_i \left( K_{T,i}^j \right)^{\alpha_T} \left( L_i^j \right)^{1-\alpha_T}$$

- $A_i$ : country $i$’s TFP
- Tangibles

$K_{T,i}^j$ and $L_i^j$ represent the $j$th country's tangible capital and labor in country $i$ respectively.
Output of Multinationals from Country \( j \) in \( i \)

\[
Y^j_i = A_i \left[ (K^j_{T,i})^{\alpha_T} (L^j_i)^{1-\alpha_T} - \alpha_I (K^j_{I,i})^{\alpha_I} \right]^{1-\alpha_I}
\]

- **Tangibles**
- Add \( K_I \)

\( A_i \) : country \( i \)'s TFP
Output of Multinationals from Country $j$ in $i$

$$Y_i^j = A_i \left( (K_{T,i}^j)^{\alpha_T} (L_i^j)^{1-\alpha_T - \alpha_I} (K_{I,i}^j)^{\alpha_I} \right)^{1-\phi} (N_i M^j)^{\phi}$$

- Tangibles
- Add $K_I$
- Add $M$

$A_i$: country $i$’s TFP

$N_i$: country $i$’s measure of production locations
Output of Multinationals from Country $j$ in $i$

\[ Y_{i}^{j} = A_{i} ((K_{T,i}^{j})^{\alpha_{T}} (L_{i}^{j})^{1-\alpha_{T} - \alpha_{I}} (K_{I,i}^{j})^{\alpha_{I}})^{1-\phi} (N_{i} M^{j})^{\phi} \]

Tangibles \quad \text{Add } K_{I} \quad \text{Add } M

(drug reps) \quad (Bob)

$A_{i}$: country $i$’s TFP

$N_{i}$: country $i$’s measure of production locations
Output of Multinationals from Country $j$ in $i$

\[ Y^j_i = A_i \left( (K^j_{T,i})^{\alpha_T} (L^j_i)^{1-\alpha_T} - \alpha_I (K^j_{I,i})^{\alpha_I} \right)^{1-\phi} \sigma_i (N_i M^j)\]

- $A_i$: country $i$’s TFP
- $N_i$: country $i$’s measure of production locations
- $\sigma_i$: country $i$’s degree of openness to FDI
Output of Multinational from Country \(j\) in \(i\)

\[
Y^j_i = A_i \left( (K^j_{T,i})^{\alpha_T} (L^j_i)^{1-\alpha_T} - \alpha_I (K^j_{I,i})^{\alpha_I} \right)^{1-\phi} \sigma_i (N_i M^j) \phi
\]

Tangibles  Add \(K_I\)  Add \(M\)

\[
\hat{A}^j_i = Y^j_i / \left( (K^j_{T,i})^{\alpha_T} (L^j_i)^{1-\alpha_T} \right)
\]

\[
= A_i \sigma_i (K^j_{I,i} / L^j_i)^{\alpha_I (1-\phi)} (N_i M^j) \phi
\]

\(A_i\) : country \(i\)’s TFP

\(N_i\) : country \(i\)’s measure of production locations

\(\sigma_i\) : country \(i\)’s degree of openness to FDI

\(\hat{A}^j_i\) : multinational \(j\)’s measured TFP in \(i\)
Output of Multinationals from Country $j$ in $i$

\[ Y_i^j = A_i \left( (K_{T,i}^j)^{\alpha_T} (L_i^j)^{1-\alpha_T} - \alpha_I (K_{I,i}^j)^{\alpha_I} \right)^{1-\phi} \sigma_i (N_i M_j^j)^{\phi} \equiv Z_i^j \]

\[ \hat{A}_i^j = \frac{Y_i^j}{((K_{T,i}^j)^{\alpha_T} (L_i^j)^{1-\alpha_T})} \]

\[ = A_i \sigma_i (K_{I,i}^j/L_i^j)^{\alpha_I (1-\phi)} (N_i M_j^j)^{\phi} \]

$A_i$ : country $i$’s TFP

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Output of Multinationals from Country $j$ in $i$

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Y^j_i = A_i \left( (K^j_{T,i})^{\alpha_T} (L^j_i)^{1-\alpha_T} - \alpha_I (K^j_{I,i})^{\alpha_I} \right)^{1-\phi} \sigma_i (N_i M^j)^{\phi} \\
\equiv Z^j_i
\]

\[
\hat{A}^j_i = \frac{Y^j_i}{(K^j_{T,i})^{\alpha_T} (L^j_i)^{1-\alpha_T}}
= A_i \sigma_i (K^j_{I,i} / L^j_i)^{\alpha_I (1-\phi)} (N_i M^j)^{\phi}
\]

Next, aggregate over output of all multinationals $j$
New Aggregate Production Function

\[ Y_{it} = A_{it} N_{it}^\phi (M_i^t + \sigma_{it} \sum_{j \neq i} M_j^t)^\phi Z_{it}^{1-\phi} \]

- Key results:
  - Output per effective person increasing in size
  - Greater openness (\(\sigma_{it}\)) yields intangible gains

Note: Size \(\equiv A_i^{\frac{1}{1-(\alpha_T+\alpha_I)(1-\phi)}} N_i\)
Implications for Policy

• Policymakers warned of global “imbalances” in 2008

• Model generates current account deficits with
  
  ○ Perfectly efficient goods and asset markets
  
  ○ Time series consistent with global capital flows

⇒ No need for policy intervention
Measuring the Unmeasurable in Private Firms
Measuring the Unmeasurable in Private Firms

• Major shift in US legal forms of organization
  ○ From C corporations that pay corporate income tax
  ○ To *pass-through* entities taxed at individual level
    – Sole proprietors
    – Partners
    – S-corporation owners

⇒ Major shift to smaller, private firms
Shares of Business Net Income, 1980–2017

Source: US Internal Revenue Service
• Tax data include *reported* incomes

• National accountants add estimates of misreporting:
  
  ◦ Pass-throughs reported 1.3 $Trillion on taxes
  ◦ IRS estimates true income of 2 $Trillion

⇒ 700 $Billion untaxed and thus unmeasured
Tax Gap: A Measure of Taxes Owed

- Tax gap = random audits + “DCE” adjustments

- Random audits:
  - Taxpayer compliance measurement program, 1962–88
  - National research program, 2000–present

- *Detection controlled estimation* (DCE) adjustments:
  - Scale up recommendations of all examiners
  - Use data from examiners with largest adjustments
# How Big is the Tax Gap?

<table>
<thead>
<tr>
<th>Gross tax gap</th>
<th>2001</th>
<th>2011</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>billions of 2023$</td>
<td>567</td>
<td>575</td>
<td>763</td>
</tr>
<tr>
<td>% of GDP</td>
<td>3.3</td>
<td>2.7</td>
<td>2.9</td>
</tr>
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</table>
### What is the Main Source of the Gap?

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</tr>
<tr>
<td>Source share:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underreporting</td>
<td>83</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Underpayment</td>
<td>10</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Nonfiling</td>
<td>7</td>
<td>8</td>
<td>11</td>
</tr>
</tbody>
</table>
What is the Main Source of Underreporting?

<table>
<thead>
<tr>
<th>Source share</th>
<th>2001</th>
<th>2011</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business</td>
<td>62</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Wages &amp; salaries</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>34</td>
<td>42</td>
<td>43</td>
</tr>
</tbody>
</table>
How Widespread is Cheating?

- Evidence from 2 NRP random-audit studies (no DCE)
  - All owners—ranked by reported incomes
  - Sole proprietors—ranked by understated tax
- Reveal same patterns
  - Cheating is widespread
  - Few owners account for most cheating
Pass-Through Sectors Not Fully Measurable

- Corporations:
  - More oversight implies less underreporting income
  - Valuation of company observed daily for many

- Pass-throughs:
  - No oversight implies more underreporting income
  - Valuations not observed until businesses are sold
  - When sold
    - Do observe transferable assets (customer bases etc)
    - Never observe intangibles specific to owner
Key Factors Absent in Simpler Theory

- Introducing:
  - Occupational choice of working or running a business
  - Owners invest in sweat capital (eg, customer bases)
  - Policies related to tax compliance

⇒ A policy trade-off between taxation and enforcement
Occupational Choice

• Choose business $b$ or work $w$

\[ V(s) = \max \{ V^b(s), V^w(s) \} \]

\[ V^i(s) = \max_x \{ U(c, \ell) + \beta \sum_{z', \epsilon'} \pi(z', \epsilon'|z, \epsilon) V(s') \} \]

where $s = (a, \kappa, d, z, \epsilon)$ and

- $a$: financial assets
- $\kappa$: sweat capital, eg, reputation, brands, etc
- $d$: back taxes, eg, accumulated unpaid taxes
- $z$: productivity in self-employment
- $\epsilon$: productivity in paid-employment
- $x$: consumption, labor, investment choices
Continuation Value

\[ V(a', \kappa', d', z', \epsilon') \]

\[ = (1 - \Pi(d'))V(a', \kappa', d', z', \epsilon') \]

no audit

\[ + \Pi(d')V(a' - f_a(d'), f_r(\kappa'), 0, z', \epsilon') \]

audit

\[ \uparrow \]

Probability of audit
\[ V(a', \kappa', d', z', \epsilon') = (1 - \Pi(d'))V(a', \kappa', d', z', \epsilon') \]

no audit

\[ + \Pi(d')V(a' - f_a(d'), f_r(\kappa'), 0, z', \epsilon') \]

Audits result in fines and reputational loss
Business Owner’s Technologies

- Goods and services: \( y_p = zf_p(\kappa, k_p, h_p) \)
  - \( z \) = productivity in self-employment
  - \( \kappa \) = sweat capital
  - \( k_p \) = rented physical capital
  - \( h_p \) = owner time in production

- Sweat investment: \( x_\kappa = f_\kappa(h_\kappa, e) \)
  - \( h_\kappa \) = owner time in brand building
  - \( e \) = owner expenses
Implications for Productivity

- Productivity depends on
  - Owners’ ability to run a business ($z$)
  - Owners’ investments in transferable assets ($\kappa$)

- If audits are *infrequent* and cheating possible
  - More people choose business
  - Business productivity lower due to selection
Implications for Investment

- Productivity depends on
  - Owners’ ability to run a business \( (z) \)
  - Owners’ investments in transferable assets \( (\kappa) \)

- If audits are frequent and cheating costly
  - Fewer people choose business
  - Those that do have higher \( z \) but invest less in \( \kappa \)
Implications for Policy

- Policymakers face trade-off when raising revenues
  - Higher tax rates on everyone
  - Higher enforcement rates aimed at cheaters

⇒ On-going work is trying to quantify impacts
Epilogue: Open Questions
Revisiting Griliches Questions

- 30 years later...
  - Are Griliches’ data woes resolved?
  - Is Solow’s residual still accounting for most change?
  - Is there much we can do about it?
Revisiting Griliches Questions

• 30 years later...

○ Are Griliches’ data woes resolved? No

○ Is Solow’s residual still accounting for most change? Yes

○ Is there much we can do about it? Yes
What Can we Do?

- Continue to ask good questions
- Continue to develop and test our theories
- Continue to use models as policy laboratories
What Can we Do?

- Continue to ask good questions
- Continue to develop and test our theories
- Continue to use models as policy laboratories

*Not everything that can be counted counts and not everything that counts can be counted*

— Albert Einstein
Some Unresolved Issues

- Corporate valuations fluctuate more than theory predicts
  - Decade to decade
  - Year to year
  - Month to month
  - Day to day

- Crises occur but are hard to fully understand
  - Great Depression
  - Technology Bust
  - Great Recession

- True cross-country productivity differentials are unknown