Can Intangible Investment Explain the UK Productivity Puzzle?

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Click for: short summary of paper: paper. Papers referred to herein intangible spillovers, NESTA innovation index work

Disclaimer: personal views only. Prepared for NIESR review.
The double productivity dip puzzle
(data = $\Delta \ln V/H$, market sector)

2007-9:
- MSGVA fell by 7.4%
- MS Hours fell by 3.5%
$\Rightarrow$ MS LPG fell by 4%

2011-12Q3:
- MSGVA has grown by 0%
- MS Hours grew by 3.4%
$\Rightarrow$ Productivity fell by 3.4%

Note: Measured data includes software, min & cop for intangibles
Quarterly TFP: 2005Q1-12Q4

Notes: own calculations using ONS real MSGVA, ONS MS Hours, estimates of MS K stock (G. Wallis) based on ONS VICS dataset
Labour and Capital shares assumed to be 0.67 and 0.33 respectively
UK TFP after recessions
(indexed to 1 at start of recession)

Source: EUKLEMS, extended to 2010 using ONS estimates of TFP
Towards a partial explanation: intangible investment relatively strong in recession...

Source: ONS GFCF release and BERD “Total Civil Intramural R&D”, Dec 2012
...but it fell from high levels before the recession (shares of intangible adjusted market sector GVA)

Notes: Tangible investment= plant/machinery, vehicles, commercial buildings
Intangible investment = software, R&D, design, market research and branding, training, organisational change.
Source: Goodridge, Haskel, Wallis, 2012
Two possible effects from intangibles

• Effect on current measured output looks like labour hoarding
  – Output of skilled/knowledge workers producing intangibles e.g. R&D aren’t measured in GDP
  – But they are in hours
  – So measured output per hour looks low
• Post-2000 slowdown in intangible investment e.g. R&D, might have slowed TFP growth before the recession if
  – spillovers from intangibles to TFP growth and
  – Spillovers take time
Might be part of many effects accounting for productivity growth slowdown?

- Labour hoarding
  - See below
- GDP mismeasurement/revisions
  - Nominal GDP in line with tax take data
  - Average revisions are downwards in recent years
- Capital/labour substitution with falling real wages
  - See below: TFP growth has fallen
- Capital reallocation issues
  - Between industry-flows (Broadbent), bank crises, entry and exit “zombie firms”
- Unmeasured utilisation affecting TFP
  - See below
- (Reviews of this other work in e.g. Barriel/Oulton, Grice, Pattinson, Hughes/Saleheen, Martin/Rowthorn, IFS Green Budget, Disney, Jin, Miller, 2013)
Common explanation: labour hoarding

• Labour hoarding
  – firms maintaining low skilled/cheap labour for anticipated recovery
  – firms have to retain overhead workers
  – Hoarding explains *initial* productivity dip
  – *Recent* productivity dip because firms are taking on low-paid workers in sectors where they were not hoarded e.g. retail

• Issues with this view
  – Seems important for initial fall. But are workers really hoarding labour 4 years on?
  – Paper sets out (we think new) direct evidence: look at ONS data on quality-adjusted labour input (QALI)
    • Have firms been particularly hoarding unskilled workers over the recession?
    • Have low productivity sectors been hiring unskilled since initial recession?
  – Answer to both questions seems to be: no.
## Labour composition by industry

*(Acheson and Franklin, 2010)*

<table>
<thead>
<tr>
<th>Rowthorn &amp; Martin: Low (L) / High (H) productivity sectors</th>
<th>2001-7: Annual Average Change in labour composition (Δln(L/H))</th>
<th>2008Q1 - 09Q2: Change in labour composition (Δln(L/H))</th>
<th>2009Q3 - 10Q4: Change in labour composition (Δln(L/H))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole economy</td>
<td>0.4</td>
<td>1.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Market sector</td>
<td>0.3</td>
<td>1.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Agriculture &amp; Mining</td>
<td>L</td>
<td>0.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>0.7</td>
<td>1.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Construction</td>
<td>0.0</td>
<td>2.4</td>
<td>-1.3</td>
</tr>
<tr>
<td>Distribution</td>
<td>L</td>
<td>0.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Transport</td>
<td>0.1</td>
<td>-0.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Information &amp; Communication</td>
<td>0.9</td>
<td>4.0</td>
<td>4.4</td>
</tr>
<tr>
<td>Financial Services</td>
<td>1.6</td>
<td>0.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Professional &amp; Administrative Services</td>
<td>L</td>
<td>0.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Public Services</td>
<td>L</td>
<td>0.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Arts &amp; Recreation</td>
<td>L</td>
<td>0.1</td>
<td>4.6</td>
</tr>
<tr>
<td><strong>Average High</strong></td>
<td><strong>0.7</strong></td>
<td><strong>1.6</strong></td>
<td><strong>1.9</strong></td>
</tr>
<tr>
<td><strong>Average Low</strong></td>
<td><strong>0.4</strong></td>
<td><strong>2.5</strong></td>
<td><strong>2.0</strong></td>
</tr>
</tbody>
</table>


**Findings:** upskilling is (a) faster than pre-recession (b) faster in low productivity sectors
Could Intangible Investment look like Labour Hoarding?

• As intangibles aren’t included in final output, the product of “knowledge workers” would not show up in GVA
• Would show up in hours though
• Knowledge production requires high-skilled labour so would also show up in growth in labour composition (which QALI data supports)
Potential for further effects from intangibles?

• Possible pre-recession effects
  – After the intangibles boom in the late 90s, investment declined through much of the 2000s
  – If
    • intangible investments generate spillovers,
    and
    • Spillovers take time
  – then may cause a slowdown in productivity anyway i.e. pre-recession
Investment

Nominal Investment, selected assets (2008=100)

- Recession
- Buildings excl dwellings
- Total P&M
- Software
- R&D

Current Price Investment (Index)

## Recent data

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Δln(V/H)</strong> (without intangibles, market sector)</td>
<td><strong>sL.Δln(L/H)</strong> (contribution of labour composition, whole economy)</td>
<td><strong>sK.Δln(K/H)</strong> (contribution of capital, whole economy)</td>
<td><strong>ΔlnTFP</strong> (without intangibles, market sector)</td>
<td><strong>ΔlnTFP</strong> (with intangibles, market sector)</td>
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<tr>
<td><strong>ONS</strong></td>
<td><strong>ONS</strong></td>
<td><strong>ONS</strong></td>
<td><strong>GHW(2012)</strong></td>
<td><strong>ONS</strong></td>
<td>Conference Board: Total Economy Database</td>
<td><strong>GHW(2012)</strong></td>
<td><strong>ONS</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Utilisation</strong> (hours per worker, market sector (000's))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2001-07</strong></td>
<td>2.7%</td>
<td>0.4%</td>
<td>1.0%</td>
<td>1.3%</td>
<td>0.9%</td>
<td>0.8%</td>
<td>1.1%</td>
<td>1.71</td>
</tr>
<tr>
<td><strong>2008</strong></td>
<td>-1.6%</td>
<td>0.3%</td>
<td>1.0%</td>
<td>-1.9%</td>
<td>-2.3%</td>
<td>-0.8%</td>
<td>-2.0%</td>
<td>1.70</td>
</tr>
<tr>
<td><strong>2009</strong></td>
<td>-2.3%</td>
<td>1.0%</td>
<td>1.6%</td>
<td>-5.0%</td>
<td>-3.6%</td>
<td>-4.4%</td>
<td>-5.1%</td>
<td>1.67</td>
</tr>
<tr>
<td><strong>2010</strong></td>
<td>1.5%</td>
<td>0.9%</td>
<td>0.6%</td>
<td>-</td>
<td>0.4%</td>
<td>0.3%</td>
<td>-</td>
<td>1.68</td>
</tr>
<tr>
<td><strong>2011</strong></td>
<td>0.1%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.4%</td>
<td>-</td>
<td>1.68</td>
</tr>
<tr>
<td><strong>2012</strong></td>
<td>-2.8%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Column 2: shows the impact of “upskilling” since 2009 - hoarding of knowledge workers rather than unskilled
Column 3: sharp fall in 2010, so substituting from K to L has lowered labour prod. But not whole story since TFGP falls too (columns 4 to 7).  
Column 8: Basu/Fernald/Kimball utilisation term falls
Bias to measured growth

\[ Q_t = A_t F (L_t, K_t, R_t) \]
\[ V = C + I \]
\[ Q = C + I + N \]

R=real intangible capital stock; N=real intangible investment
Q= real value added including intangibles

\[ \Delta \ln Q_t = \Delta \ln V_t + s_t^{Q,N} (\Delta \ln N_t - \Delta \ln V_t) \]

If \( \Delta \ln N_t > \Delta \ln V_t \) measured growth is understated
Assuming \( \Delta \ln N_t \) can be proxied using the most recent data for R&D, can estimate this bias
Measured MSGVA growth in 2012: -0.26% pa
Bias ~0.5% in 2012
Correcting for bias: MSGVA growth ~0.31% pa
Note: measured (red line) already includes software, min & cop, green line adjusts for all other intangibles
Spillovers

Lots of evidence for spillovers from R&D
GHW (2012) find evidence for inter- and intra-industry spillovers from R&D and some limited evidence for other intangibles

Slowdown in intang/GVA in 2000s
Pattern of fast growth in ΔlnK in late 90s/early 00s
Followed by slower growth in lead up to recession
If there is a lagged effect on TFP, would show up as TFP slowdown in late 00s
### Spillover contributions

<table>
<thead>
<tr>
<th>Year</th>
<th>Peak/Trough</th>
<th>DlnTFP</th>
<th>DlnK(rd)</th>
<th>DlnK(com equip)</th>
<th>dlnTFP slowdown</th>
<th>0.25*lagged dlnK(rd) slowdown</th>
<th>0.04*lagged dlnK(com equip) slowdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-98</td>
<td>T-P</td>
<td>1.83%</td>
<td>1.60%</td>
<td>1.86%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998-02</td>
<td>P-T</td>
<td>1.26%</td>
<td>3.75%</td>
<td>8.77%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002-07</td>
<td>T-P</td>
<td>1.39%</td>
<td>1.87%</td>
<td>2.28%</td>
<td>0.12%</td>
<td>0.54%</td>
<td>0.28%</td>
</tr>
<tr>
<td>2007-10</td>
<td>P-T</td>
<td>-2.29%</td>
<td>1.20%</td>
<td>-1.94%</td>
<td>-3.68%</td>
<td>-0.47%</td>
<td>-0.26%</td>
</tr>
</tbody>
</table>

ΔlnK(rd) and ΔlnK(telecom) both speed up in late 90s. This is followed by a speed-up in TFP in early 2000s. Slowdown in ΔlnK(rd) and ΔlnK(telecom) in early 2000s followed by a slowdown in TFP in late 2000s.

Final columns estimate the contributions of these changes, with coefficients taken from GHW(2012) and GHW(2013). The speed-up before the recession is over-predicted. The later slowdown is under-predicted, explaining -0.73 pp of the -3.68 (20%)
Utilisation

• One explanation for the extent of the TFP slowdown is unobserved factor utilisation

• Basu et al (2006) develop utilisation correction to DlnTFP using annual actual hours per worker (H/N) and run:

\[ \Delta \ln TFP^{MEAS} = \hat{\alpha} + \hat{\beta} \Delta \ln(H / N) \]

• Then:

\[ \Delta \ln TFP^{ADJ} = \Delta \ln TFP^{MEAS} - \hat{\beta} \Delta \ln(H / N) \]

• In UK: \( \beta = 0.39 \) (compared to \( \beta > 1 \) in US) so adjustment to TFP is small
Approx 0.6% added to TFP.
Note: if $\beta(\text{UK})=\beta(\text{US})$, would explain around half of –ve TFP in 2009
Conclusions

• Evidence that it is high-skilled labour being hoarded

• Investment in intangibles has risen, whilst tangibles have fallen, increasing the bias to measured output

• Growth in the stock of intangibles and telecoms fell prior to the recession, which may have contributed to the TFPG slowdown

• A small amount of the TFP slowdown can be explained by a decline in factor utilisation
The bottom line

• Current measured DlnV understated by about 0.5%pa, so weak positive output growth if intangibles included

• Pre-recession trends means that measured DlnTFP would have fallen anyway
  – 2002-07 UK measured DlnTFP ≈ +1.4%
  – 2007-10, UK measured DlnTFP ≈ -2.3%
    • (2008-9= -5%, ≈0 since then)
  – Intangible spillovers => post07 slowdown in DlnTFP by 0.73pppa =20% of slowdown (0.73/3.7)

• Policy
  – Is slow DlnTFP a given? No
    • Additional knowledge investment boosts growth
    • DlnTFP depends on spillovers so maybe amenable to e.g. science or IP policy
Spares
## Intangible Assets

<table>
<thead>
<tr>
<th>Asset</th>
<th>Intang included in Nat Accounts?</th>
<th>Capitalization Factor</th>
<th>Depreciation rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Computerised Information</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchased Software</td>
<td>Yes</td>
<td>1</td>
<td>0.315</td>
</tr>
<tr>
<td>Own-Account Software</td>
<td>Yes</td>
<td>1</td>
<td>0.315</td>
</tr>
<tr>
<td>Databases</td>
<td>See note</td>
<td>1</td>
<td>0.315</td>
</tr>
<tr>
<td><strong>Innovative property</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Satellite for some</td>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>Design</td>
<td>No</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Mineral Exploration</td>
<td>Yes</td>
<td>1</td>
<td>0.075</td>
</tr>
<tr>
<td>Financial Innovation</td>
<td>No</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Artistic originals</td>
<td>EU yes; JA/US no; see note</td>
<td>asset-specific</td>
<td>asset-specific</td>
</tr>
<tr>
<td><strong>Economic Competencies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advertising</td>
<td>No</td>
<td>0.6</td>
<td>0.55</td>
</tr>
<tr>
<td>Marketing research</td>
<td>No</td>
<td>0.6</td>
<td>0.55</td>
</tr>
<tr>
<td>Own-Account Organisational Capital</td>
<td>No</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Purchased Organisational Capital</td>
<td>No</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Training</td>
<td>No</td>
<td>1</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Utilisation, Basu et al theory

• (taken from GHW, 2013)

• Consider a firm employing N workers for H hours per worker, working with effort E per hour.

• Labour input = N×G(E,H), where G transforms the bundle of E and H into per worker effort-hours.

• A firm wishing to raise E or H will face some costs of doing so. Assume they are optimising on all margins. Then the first order condition holds: (dG/dH)(H/G)=(dG/dE)(E/G).

• Log linearising, one can write the unobservable E/N in terms of the observable H/N as lnE/N=βln(H/N)
Spillovers and intangibles

- From Goodridge, Haskel, Wallis, 2012
Traditional Griliches-type approach to Intangible spillovers

Production function, industry i time t

\[ \Delta \ln Y_{it} = \Delta \ln A_{it} + \varepsilon_{M,i} \Delta \ln M_{it} + \varepsilon_{K,i} \Delta \ln K_{it} + \varepsilon_{L,i} \Delta \ln L_{it} \]
\[ + \varepsilon_{N,i} \Delta \ln N_{it} + \varepsilon_{-N,i} \Delta \ln N_{-it} \]

Definition

\[ \Delta \ln TFP_{it} \equiv \Delta \ln Y_{it} - \sum_{X=L_{it},K_{it},N_{it}} s_{X,it} \Delta \ln X_{it} \]

Assumption

\[ \varepsilon_{X,it} = s_{X,it} + d_{X,it} , X = M_{it}, K_{it}, L_{it}, N_{it} \]

\[ \varepsilon_{-N,i} \Delta \ln N_{-i,t} = \alpha_1 \left( M \Delta \ln N_{-i,t} \right) + \lambda_t \]

Estimating equation

\[ \Delta \ln TFP_{it} = \alpha_1 \left( M \Delta \ln N_{-i,t} \right) + \lambda_t + a_i + \sum_{X=L,K,N_{PRIV}} d_X \Delta \ln X + v_{it} \]
Interpretation of estim equation

\[ \Delta \ln TFP_{it} = \alpha_1 \left( M \Delta \ln N_{i,t} \right) + \lambda_t + a_i + \sum_{X=L,K,N^{PRIV}} d_X \Delta \ln X + \nu_{it} \]

• Industry and time effects as controls
• Outside effects might be
  – Non-pecuniary knowledge spillovers: e.g. learning from others
  – Pecuniary spillovers via mismeasurement e.g. more knowledgeable others are selling unmeasured better quality goods
• Within-ind effects
  – Spillovers, non-constant returns, mismeasurement e.g. of factor stocks
• Two weighting matrices M
  – Interindustry intermediate flows from IO tables
  – Interindustry labour flows from Labour Force Survey
• What do we do that’s new?
  – Other industry level findings: Uses R&D/Y as DlnN (assumes \( \delta(R&D)=0 \)). Most don’t capitalise R&D in Y. Uses manufacturing. Most find \( \alpha_1>0 \). Few UK studies. Griffiths et al interact M with R&D to test absorbtive capacity.
  – We use all intangibles, construct stocks, \( \delta \) from our micro-survey, capitalise Y and add intang inputs for consistent dlnTFP.
Data

- **Years, 2000-07**
- **7 industries**
  - Measurement: finance, agriculture
- **Output**: Gross output adjusted for own account intang
- **Inputs**: Tangible, intangibles

<table>
<thead>
<tr>
<th>SIC(2003)</th>
<th>Industry Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>Agriculture, Forestry and Fishing</td>
</tr>
<tr>
<td>D</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>E</td>
<td>Electricity, Gas &amp; Water Supply</td>
</tr>
<tr>
<td>F</td>
<td>Construction</td>
</tr>
<tr>
<td>GHI</td>
<td>Distribution; Hotels &amp; Restaurants; Transport, Storage &amp; Communications</td>
</tr>
<tr>
<td>J</td>
<td>Financial Services</td>
</tr>
<tr>
<td>K</td>
<td>Business Activities (excluding real estate)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Broad category of intangible asset</th>
<th>Includes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computerised information</td>
<td>Computer software, computer databases</td>
</tr>
<tr>
<td>Intellectual property</td>
<td>Artistic originals, Scientific R&amp;D, Non-scientific R&amp;D, Mineral exploration, Financial product innovation, and Architectural and engineering design</td>
</tr>
</tbody>
</table>
Measurement, contd

- **Tangibles**
  - Plant, building, vehicles. EU KLEMS. Capital service weighted

- **Intangibles**
  - Software: EUKLEMS
  - R&D: own calculations. BERD for own-account. R&D performed in R&D industry assigned to funder via IO tables. (IO performer data not used)
  - Finance: new method based on own-account
  - Design: own-account: software method. Purchased: IO tables. All purchased design in bus services excluded (assumed to be subcontracting). This reduces total design spend a lot
  - Training: own-account survey
  - Marketing: IO tables
  - Managerial: own-account plus purchased
Graphs

Note: all data is deviation from industry and time means
# Regressions using intermediate consumption and labour transition weights

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
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<tbody>
<tr>
<td><strong>ASSET IC TR IC TR IC TR IC TR IC TR</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External R&amp;D</td>
<td>0.43***</td>
<td>2.31**</td>
<td></td>
<td>0.38***</td>
<td>1.57**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4.61)</td>
<td>(3.05)</td>
<td></td>
<td>(7.42)</td>
<td>(2.52)</td>
<td></td>
</tr>
<tr>
<td>Internal R&amp;D</td>
<td>0.043</td>
<td>0.074*</td>
<td></td>
<td>0.0027</td>
<td>0.036</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.86)</td>
<td>(1.95)</td>
<td></td>
<td>(0.15)</td>
<td>(0.83)</td>
<td></td>
</tr>
<tr>
<td>Total External Intangibles</td>
<td></td>
<td></td>
<td>0.52**</td>
<td>0.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2.97)</td>
<td>(0.59)</td>
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<td></td>
</tr>
<tr>
<td>Total Internal Intangibles</td>
<td></td>
<td></td>
<td>-0.20***</td>
<td>-0.18***</td>
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<td></td>
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<td></td>
<td>(-5.06)</td>
<td>(-5.64)</td>
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<tr>
<td>Total External Intangibles excl. R&amp;D</td>
<td></td>
<td></td>
<td></td>
<td>0.39*</td>
<td>0.070</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.22)</td>
<td>(0.074)</td>
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</tr>
<tr>
<td>Total Internal Intangibles excl. R&amp;D</td>
<td></td>
<td></td>
<td></td>
<td>-0.17***</td>
<td>-0.16***</td>
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<td></td>
<td></td>
<td>(-5.26)</td>
<td>(-5.14)</td>
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</tr>
<tr>
<td>Observations</td>
<td>91</td>
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<tr>
<td>R-squared</td>
<td>0.185</td>
<td>0.147</td>
<td>0.287</td>
<td>0.228</td>
<td>0.372</td>
<td>0.273</td>
</tr>
<tr>
<td>Number of industries</td>
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</tr>
<tr>
<td>Elasticity of external R&amp;D</td>
<td>0.25</td>
<td>0.21</td>
<td>0.30</td>
<td>0.054</td>
<td>0.22</td>
<td>0.15</td>
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<tr>
<td>Elasticity of other external variable</td>
<td>0.22</td>
<td>0.0065</td>
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</table>
Schankerman (1982) type bias expressions

**Extended asset boundary**

\[ Y = F(X, R, t), X = K, L; R = \text{knowledge stock}, \Delta R = N - \delta^N R_{t-1} \]

\[ Y = C + I + N \quad \text{GDP includes } N. \]

**Measured**

\[ Y^M = F(X, t^M) \]

\[ Y^M = C + I, \Rightarrow d\ln Y = s_N d\ln N + (1 - s_N) d\ln Y^M \]

Define growth due to knowledge accum \( \equiv d\ln t + s_R d\ln R \)

Relation to measured TFPG, \( d\ln^M \)

\[
\frac{d\ln t + s_R d\ln R}{\text{Extended}} = \frac{d\ln^M}{\text{Measured}} + s_N (d\ln N - d\ln Y^M) + (s_X^M - s_X) d\ln X
\]

• **In recessions**
  – If \( d\ln X < 0 \), measured falls relative to true
  – If \( d\ln Y_m > d\ln N \) (intangible investment relatively stable), measured rises relative to \( d\ln t \) (but total effect depends on \( D\ln R \))