Private and Public Intangible Investment Spillovers, Imperfect Competition, Returns to Scale and Product and Process Innovation

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Much work suggests productivity slowdown is TFP slowdown. What might cause that?
   - Mismeasurement?
   - If intangibles have spillovers then intang slowdown means slowdown in TFP?

Need framework for intangibles and spillovers

So far: put intangibles as additional arguments in a production function and consider extra outputs and inputs
   - Makes sense for intangibles like business process innovation or process R&D
   - But what about branding/marketing? Or R&D product innovation?

Purpose of paper
   - New framework for process and product innovation
   - New data
   - Econometric issues in estimating spillovers: imperfect competition, returns to scale, division bias
   - Estimates
If $\Delta \ln R$ has slowed down, less spillovers means $\Delta \ln TFP$ slows down?
Three sector model

Upstream $N^S$ and $N^D$ sectors, producing process and product new intangibles

\[ N_S = F^{N_S}(L^{N_S}, K^{N_S}, R_{A}^{N_S}) \] (1)

\[ dn_S = \varepsilon_L^{N_S} dl^{N_S} + \varepsilon_K^{N_S} dk^{N_S} + \varepsilon_R^{N_S} dr_{A}^{N_S} \]

and

\[ N_D = F^{N_D}(L^{N_D}, K^{N_D}, R_{A}^{N_D}) \] (2)

\[ dn_D = \varepsilon_L^{N_D} dl^{N_D} + \varepsilon_K^{N_D} dk^{N_D} + \varepsilon_R^{N_D} dr_{A}^{N_D} \]

where elasticity of output is $\varepsilon$ and lower case letters are logs and "d" is a time derivative.

Downstream $C$ sector, renting process intangibles in production

\[ C = F^{C}(L^{C}, K^{C}, R_{S}^{C}, R_{A}^{C}) \] (3)

\[ dc = \varepsilon_L^{C} dl^{C} + \varepsilon_K^{C} dk^{C} + \varepsilon_R^{C} dr_{S}^{C} + \varepsilon_R^{C} dr_{A}^{C} \]

Capital stocks and investment flows

\[ R_{t}^{a} = N_{t}^{a} + (1 - \delta^{Ra})R_{t-1}^{a}, \quad a \in S, D \quad \text{and} \quad K_{t} = I_{t} + (1 - \delta^{K})K_{t-1}, \] (4)

Rental and asset prices

\[ p_{t}^{Ra} = p_{t}^{Na}(r_{t} - \pi_{t}^{Ra} + \delta^{Ra}) \quad a \in S, D \quad p_{t}^{K} = p_{t}^{I}(r_{t} - \pi_{t}^{K} + \delta^{K}) \] (5)
Demand and product innovation

- Quality-adjusted output $C^e$ is "more" output.
- Let $C^e$ trade at price $P^{Ce}$. Define units:
  
  $P^C C \equiv P^{Ce} C^e$, $\implies C^e \equiv C(P^C/P^{Ce}) \equiv C\Theta$

  
  $dc^e = dc + d\theta$ \hspace{1cm} (6)

- What is $\Theta$? = endog quality price premium
- Arrow/Nerlove. Demand curve $C^D = C(P^C, R_D)$, where $R_D$ is (intangible) stock of reputation/goodwill
- Firms sell $Q^*$ of branded perfume/superior light bulb at $P_2 > P_1$ for unbranded/standard bulb by spending on $R_D$ to shift $C^D$. 

  - Log differentiation of demand
    
    $dc^D = -\eta dp + \phi_{R_D} dr_D$ ($\eta$ = elasticity of demand, $\phi$ = elasticity of output with respect to $R_D$. So $\Theta$ sustained by product investment $R_D$

    $d\theta = \frac{\phi_{R_D}}{\eta} dr^D$. \hspace{1cm} (7)
Suppose output only partially quality-adjusted. Quality-adjustment implicit and explicit

\[ dc_m = dc + \nu d\theta \]  

(8)

Demand and supply in the downstream sector. Using (1), (2), (3), (6), (7) and (8) gives

\[ dc_m = \varepsilon^C L dL^C + \varepsilon^C K dk^C + \varepsilon^C R_S dr_S^C + \nu \frac{\phi^D}{\eta} dr_D + \varepsilon^C R_A dr_A^C \]  

(9)

- Process inputs: weighted by output elasticity
- Product term: weighted by output elasticity divided by demand elasticity.
- Final term is the output effects of knowledge spillovers: free knowledge times their output elasticity.

Usually we write (9) in terms of shares...so what’s the relation?
Endogenise these elasticities: firm optimisation

- First-order conditions for $L$, $K$ and $R_S$ (arguments in prod functions)

$$
\varepsilon_X^C = \left( \frac{1}{1 - \frac{1}{\eta}} \right) \sigma_X^C = \mu \sigma_X^C, \ X = L, K, R_S
$$

where $\sigma_X^C$ are competitive labour and capital rental payments as a share of revenue in the $C$ sector and $\mu$ is the mark-up of price over marginal costs ($\mu = 1/(1-1/\eta)$).

- Arrow-Nerlove condition for $R^D$ (demand function)

$$
\phi_{RD} = \eta \sigma_{RD}^C = \frac{\mu}{\mu - 1} \sigma_{RD}^C
$$
Model of downstream sector only

- Downstream equation:

\[
dc_m = \mu \sigma_L^C dl^C + \mu \sigma_K^C dk^C + \mu \sigma_R^C d\ell_S^C + \nu \sigma_R^C d\ell_D^C + \varepsilon_R^C d\ell_A^C \tag{12}
\]

Ex ante approach: if we can measure \( \sigma \) we can calculate/estimate (12).
Ex post, no data on competitive factor shares

In practice we don’t have raw data on capital payments. Assume
- nominal value added, $P_Q Q$ observed (correctly capitalise all investment spending)
- Measured labour shares are right
  \[ \sigma_L^C = s_L^C \] (13)
- Measured factor shares add to unity (Jorgenson/Grilliches)
  \[ s_L^C + s_K^C + s_{RS}^C + s_{RD}^C = 1 \] (14)
- True incomes in the economy include imperfect competition
  \[ \sigma_L^C + \sigma_K^C + \sigma_{RS}^C + \sigma_{RD}^C + \sigma_{\pi}^C = 1 \] (15)
  where $\sigma_{\pi}$ is the share of abnormal profits in the sector.
- Economies of scale (note: no term in $\varepsilon_{RD}^C$)
  \[ \varepsilon_L^C + \varepsilon_K^C + \varepsilon_{RS}^C = \psi \] (16)
- Measured capital shares are residuals $= 1 - s_L$. Combining gives
  \[ 1 - s_L^C = \sigma_K^C + \sigma_{RS}^C + \left( 1 - \frac{\psi}{\mu} \right) \] (17)
Downstream, ex post shares

- Substituting in elasticities gives

\[
\begin{align*}
    dq^C &= \mu \left( s_L^C dl^C - (1 - s_L^C)dk^+,C \right) + (\psi - \mu)dk^+,C \\
    &\quad + \nu \sigma^C_{RD} dR^C_{RD} + \varepsilon^C_{RA} dR^C_{RA}
\end{align*}
\]  

(where \(dk^+\) is \(dk\) and \(dr_S\) weighted by the rental shares of total payments to \(K\) and \(R_S\)).

- *Ex post* \(Q\) grows with spillovers and

- first two terms because if \(\mu > 1\), output elasticities differ from factor shares, and if \(\psi \neq 1\) then \(dc\) is affected by capital

- Product innovation.
  - no quality adjustment, \(\nu = 0\) so firms spending to boost quality, but the statistics office is missing the extra output (in terms of TFP, measured TFP is too small)
  - full quality adjustment, \(\nu = 1\): in which case measured \(Q\) reflects product innovation spend

- Sector aggregation gives similar result, see paper
Data are by industry, country, institutional sector, year

<table>
<thead>
<tr>
<th>Industry (NACE, Revision 2)</th>
<th>Sector</th>
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<tbody>
<tr>
<td></td>
<td>All</td>
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<tr>
<td>A Agriculture, forestry and fishing</td>
<td>X</td>
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<tr>
<td>B Mining and quarrying</td>
<td>y</td>
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<tr>
<td>C Manufacturing</td>
<td>y</td>
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<tr>
<td>D Electricity, gas, steam and air conditioning supply</td>
<td>y</td>
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<tr>
<td>E Water supply; sewage, waste management and remediation activities</td>
<td>y</td>
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<tr>
<td>F Construction</td>
<td>y</td>
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<tr>
<td>G Wholesale and retail trade; repair of motor vehicles and motorcycles</td>
<td>y</td>
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<tr>
<td>H Transportation and storage</td>
<td>y</td>
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<tr>
<td>I Accommodation and food service activities</td>
<td>y</td>
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<tr>
<td>J Information and communication</td>
<td>y</td>
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<tr>
<td>K Financial and insurance activities</td>
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<tr>
<td>L Real estate activities</td>
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<td>M Professional, scientific and technical activities</td>
<td>y</td>
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<tr>
<td>N Administrative and support service activities</td>
<td>y</td>
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<tr>
<td>O Public administration and defence; compulsory social security</td>
<td>y</td>
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<tr>
<td>P Education</td>
<td>y</td>
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<tr>
<td>Q Human health and social work activities</td>
<td>y</td>
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<tr>
<td>R Arts, entertainment and recreation</td>
<td>y</td>
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<tr>
<td>S Other service activities</td>
<td>y</td>
</tr>
<tr>
<td>T Activities of households</td>
<td>X</td>
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<tr>
<td>U Activities of extraterritorial organisations and bodies</td>
<td>X</td>
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</tbody>
</table>

- **Years:** 1995-2013.
- **Countries:** United States (US), big Northern European (DE, FR and UK), Scandinavian (FI, SE), Small European (AT, NL) Mediterranean (IT, ES).
- **Inputs and outputs:** Tornquist-weighted ln growth rates
Knowledge

- Knowledge term

\[
(\varepsilon_{RA} \cdot d\varepsilon_{RA})_i = \gamma_{MKT}^i (\Delta \ln R_{MKT}^i) + \gamma_{MKT}^i \left( \sum_{j \neq i} \omega_{MKT}^j \Delta \ln R_{MKT}^j \right) + \gamma_{NonMKT}^i \left( \omega_{NonMKT}^i \Delta \ln R_{NonMKT}^i \right)
\]

- Zero public sector depreciation

\[
(\varepsilon_{RA} \cdot d\varepsilon_{RA})_{i,c,t} = \gamma_{MKT}^i (\Delta \ln R_{MKT}^i)
\]

\[
+ \gamma_{MKT} \left( \sum_{j \neq i} \omega_{MKT}^j \Delta \ln R_{MKT}^j \right) + \rho_{i,c,t} \left( \omega_{NonMKT}^i \frac{N_{NonMKT}^c,t}{Q_{i,c,t}} \right)
\]

- \( \sum_{j \neq i} \omega_{MKT}^j \) from I/O tables
- \( \omega_{NonMKT}^i \) share of ind R&D, co-operation
Estimating equation

- See paper for discussion of endogeneity, meas error/division bias
- Estimating equation, for long and short differences $n$ and lags $s$

$$\Delta_n \ln Q_{c,i,t} = a_t + a_c + a_i + \gamma_{1}^{\text{MKT}} \Delta_n \ln R_{i,c,t-s}^{\text{MKT}}$$

$$+ \gamma \Delta_n \ln R_{i,c,t-s}^{\text{OUT,MKT}} + \rho \left( \frac{N^{\text{NonMKT}}}{Q^{\text{MKT}}} \right) \Sigma_{n,i,c,t-s}$$

$$+ \rho_1 \Delta_N \left( \frac{N^{\text{NonMKT}}}{Q^{\text{MKT}}} \right) \Sigma_{n,i,c,t-s}$$

$$+ (\mu - 1) \left( s_L^Q \Delta_n \ln (L/K^+) \right)_{c,i,t} + (\psi - 1) (\Delta_n \ln K^+)_{c,i,t}$$

$$+ (\nu \zeta_{RD} - 1) \left( s_{RD}^Q \Delta_n \ln R_{D} \right)_{c,i,t} + u_{c,i,t}$$

- Consistently find that change in $N(\text{nonMKT})$ appears
- In principle should be able to estimate rates of return $(\gamma, \rho)$, $\mu$, $\psi$, $\nu$.
- Useful if we think e.g. $\mu$ has risen post 2007. Meas error biases suggest $\mu$, $\psi$, $\nu$ biased downwards
- Substantial policy interest in $\gamma$, $\rho$; e.g. does $\rho$ vary by country?
Regressions: Dependent variable $\Delta lnQ_{i,c,t}$

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<tbody>
<tr>
<td>Industries</td>
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<td>Year dummies</td>
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<tr>
<td>Industry dummies</td>
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<tr>
<td>$\Delta lnR_{rd}^{i,c,t-3}$</td>
<td>0.25**</td>
<td>0.25**</td>
<td>0.00</td>
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<tr>
<td></td>
<td>(2.24)</td>
<td>(2.20)</td>
<td>(0.13)</td>
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<tr>
<td>$\Delta lnR_{outside}^{rd}^{i,c,t-3}$</td>
<td>-0.05</td>
<td>-0.06</td>
<td>-0.09*</td>
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<tr>
<td></td>
<td>(-0.28)</td>
<td>(-0.35)</td>
<td>(-1.88)</td>
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<tr>
<td>$\Delta lnR_{intan}^{i,c,t}$</td>
<td>-0.01</td>
<td>0.20***</td>
<td>0.21***</td>
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<tr>
<td></td>
<td>(-0.08)</td>
<td>(5.28)</td>
<td>(5.36)</td>
<td></td>
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<tr>
<td>$\Delta lnR_{intan}^{i,c,t}_{outside}$</td>
<td>-0.04</td>
<td>0.09*</td>
<td>0.09**</td>
<td></td>
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<tr>
<td></td>
<td>(-0.21)</td>
<td>(1.88)</td>
<td>(2.03)</td>
<td></td>
</tr>
<tr>
<td>shRD*(GovRD/PqQ)$_{i,c,t-2}$</td>
<td>-0.44</td>
<td>-0.45</td>
<td>0.30**</td>
<td>0.32***</td>
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<tr>
<td></td>
<td>(-0.62)</td>
<td>(-0.63)</td>
<td>(2.50)</td>
<td>(2.65)</td>
</tr>
<tr>
<td>$\Delta shRD \times (GovRD/PqQ)_{i,c,t-2}$</td>
<td>4.15***</td>
<td>4.03***</td>
<td>0.34</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td>(3.04)</td>
<td>(2.85)</td>
<td>(0.34)</td>
<td>(0.33)</td>
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<tr>
<td>$s^Q_L \Delta ln(L/K_+)$</td>
<td>0.75***</td>
<td>0.76***</td>
<td>0.39***</td>
<td>0.40***</td>
</tr>
<tr>
<td></td>
<td>(5.01)</td>
<td>(4.97)</td>
<td>(10.16)</td>
<td>(10.28)</td>
</tr>
<tr>
<td>$\Delta ln(K_+)$</td>
<td>0.64***</td>
<td>0.64***</td>
<td>0.42***</td>
<td>0.42***</td>
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<tr>
<td></td>
<td>(3.68)</td>
<td>(3.42)</td>
<td>(10.84)</td>
<td>(10.58)</td>
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<tr>
<td>$s^Q_RD \Delta lnR^D_{i,c,t}$</td>
<td>0.26</td>
<td>0.27</td>
<td>0.87*</td>
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<tr>
<td></td>
<td>(0.33)</td>
<td>(0.32)</td>
<td>(1.71)</td>
<td>(1.71)</td>
</tr>
</tbody>
</table>

Observations 182 182 1,432 1,432

R-squared 0.83 0.82 0.49 0.49

CHJR
Intangibles, Spillovers, Process/Product Innovation
World KLEMS, 2018
Summary

- Framework for estimating spillovers, taking account of imperfect competition and different roles for intangibles, process and product innovation
- New data
- Findings
  - Suggestion of spillovers/excess returns to intangibles both public and private varying by manufacturing and services
  - Point estimates outside manufacturing suggest negative mark-ups: measurement, DRS, biased?
- Scope for further investigation e.g. by industry, country