

Investment in Knowledge-Based Capital and its Impact on Productivity: Firm-Level Evidence from Ireland

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IGEES Annual Conference 2017

8th June 2017

This research is part of the Joint Research Programme on “Enterprise Exporting, Innovation and Productivity” undertaken by the ESRI, Enterprise Ireland and the Department of Jobs, Enterprise and Innovation. This research uses statistical data from the Central Statistics Office (CSO) of Ireland. The use of these statistical data does not imply the endorsement of the CSO in relation to the analysis or interpretation of the statistical data.

Research and Policy Context

- Investment in knowledge-based capital – increasingly recognised as a major source of innovation and productivity growth
- Knowledge-based capital (KBC) – a broad range of intangible assets beyond R&D (Corrado, Hulten, Sichel, 2005, 2009):
 - **Computerised information:** computer software and data sets
 - **Innovative property:** R&D and intellectual property assets
 - **Economic competencies:** branding, organisational know-how and firm-specific human capital

The Impact of Investment in KBC on Productivity- Existing Firm-Level Evidence

- **UK - Riley and Robinson (2011)**
 - Intangible assets embedded in knowledge workers (managers and marketing related; IT workers; R&D workers) are positively linked to productivity
- **Germany – Crass and Peters (2014)**
 - Productivity is positively linked to investment in R&D, branding and firm-specific human capital
- **Spain – Higón, Gómez and Vargas (2017)**
 - Complementarities between investments in R&D and advertising; between investment in advertising and human capital

Novelties of this Contribution

- **Dynamic econometric model to estimate the relationship between investment in KBC and productivity**
 - Accounts for productivity persistence and path-dependency
- **Allows for firm heterogeneity in the key relationships**
 - Manufacturing vs services;
 - Irish-owned vs foreign-owned; SMEs vs large;
 - Exporters vs non-exporters
- **Evidence from a small open economy**

Data

- Two linked firm-level data sets provided by the Central Statistics Office
 - **Census of Industrial Production (CIP)**
 - Firms with activity in mining, manufacturing and utilities (NACE 5 – 39).
 - **Annual Service Inquiry (ASI)**
 - Firms with activity in service sectors (NACE 45 – 96)
- The reporting requirements restrict the analysed sample to firms with **20+** employees, surveyed over **2006-2012**
 - **11,346** firms (38,647 firm-year observations)
 - **2419** from the CIP, **9052** from the ASI
 - **9935** Irish firms, **1817** foreign firms.
 - **8436** firms with 20-49 employees (*small*), **3904** firms with 50-249 employees (*medium*), **664** firms with over 250 employees (*large*)
- Key variables: turnover, employment, wages, changes in capital assets, purchases of materials and services, ownership and export activity

Measuring Investment in KBC – using data from the CIP and ASI

Investment in computer software: capital expenditure on computer software

Investment in organisational capital and branding: current expenditure on management and marketing fees

Investment in intellectual property: capital expenditure on patents, copyrights and licenses, current expenditures on royalties and licences

Investment in R&D: capital R&D expenditure, current expenditure on purchased R&D services

Investment in non-R&D: investment in computer software, organisational capital and branding, intellectual property assets

Econometric Methodology

Dynamic econometric model

$$\ln(VA/Empl_{ij,t}) = \beta_0 + \beta_1 \ln(VA/Empl_{ij,t-1}) + \beta_2 \ln(Intangibles/Empl_{ij,t}) + \beta_4 \ln(Tangibles/Empl_{ij,t}) \\ + \beta_5 \ln(Wage/Empl)_{ij,t} + \beta_5 \ln(Age)_{ij,t} + \beta_5 \ln(Foreign)_{ij,t} + \delta_t + \sigma_i + \rho_j + \mu_{ijt}$$

- Productivity is measured as value-added per employee
- The relationship between investment in KBC and productivity is conditioned on the amount invested in tangibles, the average wage, the age and the ownership of the firm.
- All other time constant unobservable factors are also taken into account

Empirical Results – Aggregate Intangible Assets

Investment in intangibles and firm productivity – all intangible assets

	(1)	(2)	(3)	(4)	(5)
Dependent variable	Value-added per employee				
Estimator	System GMM				
GMM lag structure	t-2, t-3, t-4				
Sample	All firms	Irish	Foreign	Service	Manuf.
Ln (VA/Employee) _{t-1}	0.637*** (0.038)	0.720*** (0.066)	0.611*** (0.056)	0.651*** (0.065)	0.495*** (0.103)
Ln (Intang. /Empl.)	0.185** (0.077)	0.363* (0.206)	0.240*** (0.044)	0.119*** (0.045)	0.388*** (0.099)
Ln (Tang. /Empl.)	0.023 (0.086)	-0.229*** (0.087)	0.120 (0.095)	-0.001 (0.099)	0.101 (0.145)
ln(Wage/Employee)	0.260 (0.308)	-0.487 (0.479)	0.859*** (0.307)	0.647' (0.420)	0.546** (0.259)
ln(Age)	0.016** (0.007)	0.026*** (0.008)	0.023 (0.019)	0.012' (0.008)	0.009 (0.009)
Foreign-owned	0.069*** (0.017)			0.022 (0.018)	0.098*** (0.020)
Time dummies	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y
N observations	25674	20729	4945	17336	7809
GMM instruments	72	71	71	72	72
P value AR2 test	0.735	0.526	0.888	0.864	0.695
P value Hansen test	0.522	0.513	0.827	1.000	1.000

Source: Authors' estimates based on CIP and ASI data provided by the CSO

Empirical Results – Aggregate Intangibles by Firm Size

Investment in intangibles and firm productivity – aggregate intangibles, by size groups

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
					Only Irish firms			
	SMEs	Small	Medium	Large	SMEs	Small	Medium	Large
$\ln(\text{VA}/\text{Employee})_{t-1}$	0.561*** (0.047)	0.508*** (0.047)	0.662*** (0.057)	0.707*** (0.063)	0.614*** (0.067)	0.536*** (0.090)	0.665*** (0.070)	0.836*** (0.138)
$\ln(\text{Intang.}/\text{Empl.})$	0.235** (0.096)	0.139* (0.071)	0.213** (0.108)	0.088 (0.081)	0.542** (0.234)	0.530*** (0.187)	0.227 (0.173)	0.199 (0.331)
$\ln(\text{Tang.}/\text{Employee})$	0.129 (0.103)	0.061 (0.099)	-0.070 (0.066)	-0.097 (0.178)	-0.241*** (0.091)	-0.286*** (0.099)	-0.101 (0.077)	-0.046 (0.095)
$\ln(\text{Wage}/\text{Employee})$	0.695* (0.395)	1.187*** (0.412)	0.461 (0.494)	0.481 (0.594)	0.214 (0.546)	0.334 (0.450)	0.960** (0.442)	-0.323 (1.151)
$\ln(\text{Age})$	0.013** (0.006)	0.009 (0.008)	0.013 (0.010)	0.006 (0.024)	0.015** (0.007)	0.017** (0.008)	-0.007 (0.009)	0.093' (0.060)
Foreign-owned	0.057** (0.024)	0.084*** (0.021)	0.030 (0.035)	0.059** (0.024)				
Constant	-0.024** (0.010)	-0.034** (0.016)	-0.029* (0.015)	-0.033 (0.040)	-0.015* (0.008)	-0.020** (0.009)	-0.033** (0.014)	-0.076*** (0.025)
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
N observations	23629	14560	9069	2045	19756	12966	6790	973
GMM instruments	72	72	72	72	71	71	71	71
P value AR2 test	0.723	0.412	0.681	0.555	0.696	0.725	0.898	0.495
P value Hansen test	0.353	0.572	0.752	0.883	0.509	0.509	0.787	0.932

Source: Authors' estimates based on CIP and ASI data provided by the CSO

Empirical Results – Specific Intangible Assets

Investment in intangibles and firm productivity – specific intangible assets

	(1)	(2)	(3)	(4)	(5)
Dependent variable	Value-added per employee				
Estimator	System GMM				
GMM lag structure	t-2, t-3, t-4				
Sample	All firms	Irish	Foreign	Service	Manuf.
Ln (VA/Employee) _{t-1}	0.635*** (0.028)	0.716*** (0.056)	0.646*** (0.037)	0.647*** (0.026)	0.509*** (0.080)
Ln (R&D/Employee)	0.296* (0.174)	0.544** (0.219)	0.270' (0.168)	0.164 (0.380)	0.277*** (0.068)
Ln (Software/Employee)	1.304*** (0.464)	-0.206 (0.968)	0.979*** (0.354)	1.931* (0.992)	0.890*** (0.143)
Ln (Organis. Capital/Employee)	0.201*** (0.055)	0.342** (0.137)	0.252*** (0.060)	0.100' (0.065)	0.276*** (0.074)
Ln (IP Assets/Employee)	0.069' (0.044)	0.070 (0.112)	0.080** (0.035)	0.019 (0.044)	0.290*** (0.065)
Ln (Other Intangibles/Empl.)	0.100 (0.160)	0.251 (0.297)	0.054 (0.108)	0.057 (0.121)	0.127 (0.095)
Time dummies	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y
N observations	25674	20729	4945	17336	7809
GMM instruments	140	139	139	140	140
P value AR2 test	0.665	0.502	0.788	0.944	0.572
P value Hansen test	1.000	1.000	1.000	1	1

Source: Authors' estimates based on CIP and ASI data provided by the CSO

Empirical Results – Specific Intangible Assets by Firm Size

Investment in intangibles and firm productivity – specific intangibles, by firm size groups

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable	Value added per employee							
Estimator	System GMM							
GMM lag structure	t-2, t-3, t-4							
					Irish firms only			
Sample	SMEs	Small	Medium	Large	SMEs	Small	Medium	Large
Ln (VA/Employee) _{t-1}	0.595*** (0.035)	0.602*** (0.047)	0.721*** (0.051)	0.693*** (0.038)	0.647*** (0.076)	0.577*** (0.081)	0.778*** (0.072)	0.865*** (0.086)
Ln (R&D/Employee)	0.325** (0.129)	0.217** (0.089)	0.276** (0.115)	0.005 (0.212)	0.126 (0.312)	1.224* (0.700)	0.152 (0.246)	-0.743 (0.723)
Ln (Software/Employee)	0.970' (0.627)	0.043 (0.935)	2.179 (1.569)	0.830*** (0.236)	-0.437 (1.349)	-2.664' (1.719)	1.452 (1.231)	-1.089 (0.774)
Ln (Organis. Cap. /Employee)	0.196** (0.087)	0.286*** (0.086)	0.122 (0.095)	0.174*** (0.053)	0.448*** (0.109)	0.599*** (0.104)	0.094 (0.112)	0.036 (0.126)
Ln (IP Assets/Employee)	0.168** (0.082)	0.114 (0.148)	0.119** (0.046)	-0.013 (0.067)	0.149 (0.132)	-0.038 (0.169)	0.068 (0.126)	0.474* (0.251)
Ln (Other Intangibles/Empl.)	0.083 (0.096)	0.119 (0.122)	0.087 (0.144)	0.307*** (0.069)	0.381' (0.257)	0.463 (0.573)	0.217 (0.209)	0.045 (0.311)
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y
NACE 2-dig FE	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
N observations	23629	14560	9069	2045	19756	12966	6790	973
GMM instruments	140	140	140	140	139	139	139	139
P value AR2 test	0.828	0.478	0.539	0.547	0.688	0.565	0.791	0.363
P value Hansen test	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Source: Authors' estimates based on CIP and ASI data provided by the CSO

Key Findings

Investment in KBC is an important driver of firms' productivity in Ireland

- 10 per cent higher investment in KBC per employee is associated with 2 per cent higher productivity

Aggregate KBC investment and productivity

- Productivity responsiveness is larger for Irish-owned firms than for foreign-owned firms
- SMEs benefit more relative to large firms
- The sensitivity of productivity to investment in KBC is larger in manufacturing firms than in services firms

Specific KBC assets and productivity

- Irish-owned firms – productivity is mostly responsive to investment in R&D and organisational capital and branding
- Foreign-owned firms – productivity is mostly responsive to investment in non-R&D assets (computer software, organisational capital and branding, IP assets)

Implications for Enterprise Policies

- **A comprehensive policy approach** to enterprise supports for investment in knowledge-based capital beyond R&D could be beneficial for productivity performance
- **A targeted enterprise policy approach**
 - Irish-owned/foreign-owned
 - SMEs/large
 - Manufacturing/services
- **An integrated set of supports for enterprises with similar characteristics** in the areas of exporting and investment in knowledge-based capital could increase effectiveness

Further Research

- What factors influence firms' choices to invest in different KBC assets?
- Are investments in different KBC assets complementary or substitutes and how does this investment mix affect firm productivity?
- What is the impact of investment in KBC on firms' engagement in innovation and exporting?