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Investment in knowledge-based capital and its contribution to productivity growth: a review of international and Irish evidence

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Abstract: This paper reviews the international evidence on measuring investment in knowledge-based capital (KBC) and its impact on productivity. On this evidence basis, it provides a conceptual framework to analyse Ireland's performance in this area on macroeconomic, industry and firm levels. The evidence reviewed in this paper indicates that investment in KBC is sizeable and has increased over time in many advanced economies, including Ireland. At the country, sectoral and firm level, the contribution of investment in KBC to productivity growth over and above other factors including investment in tangible capital is documented as important. This paper also reviews and discusses economic framework policies which could incentivise further investment in knowledge-based capital in Ireland.

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1 Introduction

There is growing evidence showing that economic growth in advanced economies is increasingly driven by investment in knowledge-based capital (KBC).¹ The importance of measuring investment in KBC has grown with the recognition that innovation-led growth is underpinned by investments in a broader range of intangible assets beyond R&D spending such as computerised information (computer software and data sets); intellectual property assets (designs, copyrights, patents, licences), brand equity, organisational know-how and employee's skills (Andrews and de Serres 2012).

Against this background, this paper reviews the international evidence on measuring investment in KBC and its impact on productivity growth and provides a conceptual framework to analyse Ireland's performance at the macroeconomic, industry and firm levels. The objectives of this paper are threefold:

- (i) to review the relevant international evidence and to provide an analytical framework for the analysis of investment in KBC and its impact on productivity in Ireland and other EU advanced economies;
- (ii) to better understand Ireland's performance with respect to investment in KBC and benchmark it against other EU countries;
- (iii) to assess the role of policy measures aiming at incentivising private investment in KBC and to identify Ireland's specific areas of strengths and weakness.

The literature on KBC has originated from the interest in measuring firm-level rates of return more accurately in the context of discussions on antitrust and tax policy in the 1960s and 1970s (Hulten 2013). In that context, it was recognised that sources of innovation are broader than R&D spending, and advertising was put forward as one of them.

However, the increased interest and focus on KBC as a source of innovation and productivity growth came in the late 1990s and 2000s and it was associated with the work done at the OECD (OECD 1998, 2013) and contributions from the research community (early contributions include Nakamura 1999, 2001; Basu et al. 2004; Corrado, Hulten and Sichel 2005, 2009; Oliner, Sichel and Stiroh 2008; Giorgio Marrano, Haskel and Wallis 2009; Fukao et al. 2009; more recent contributions include among others Baldwin, Gu and Macdonald 2012; Roth and Thum 2013; Dal Borgo et al. 2013; Haskel, Pesole, and Wallis 2013; Corrado et al. 2014; Niebel, O'Mahony, and Saam 2017). The KBC approach was driven by the rapid growth of information and communication technologies (ICT) as a new general purpose technology and the need to understand complementary investments (such as investment in skills and organisational change) required to exploit the opportunities the ICT offered.²

Specific features of intangible assets³ such as non-rivalry, and partial excludability lead to market and systemic failures and therefore underinvestment in such assets.⁴ The key market imperfections that are widely recognised in relation to investment in intangible assets include:

¹ Recent international evidence is reviewed by Hulten (2013) and Corrado et al. (2016).

² Karlsson et al. (2010) discusses the international evidence on the role of ICT as a new general purpose technology and complementary investments needed to exploit the growth opportunities ICT offer.

³ In this paper we use knowledge-based capital and intangible assets interchangeably.

- Knowledge spillovers
- Information asymmetry and incompleteness of capital markets
- Monitoring and enforcement costs

In addition, other market imperfections arise in the context of the interactions between enterprises and other institutions within the system of research and innovation:

- Network externalities
- Co-ordination failures

This paper is structured as follows. Section 2 discusses in more detail definitions and measures of KBC. Next, using a comparable data set, INTAN-Invest, Section 3 examines investments in KBC in Ireland and other advanced EU countries over the period 1995-2010 and on the basis of an updated version of the INTAN-Invest data set for Ireland analyses Ireland's investments in KBC over the period 1995-2014. Section 4 reviews the international macroeconomic evidence on the impact of investment in KBC on productivity. Further, this Section discusses firm-level evidence from Ireland and other EU countries on the impact of investment in KBC on productivity. Section 5 analyses the relationships between policy frameworks and investment in KBC in Ireland and other EU countries. This policy analysis highlights Ireland's strengths and weaknesses in relation to the policy mix required to incentivise investment in KBC. Section 6 summarises the main findings of this review and on the basis of this evidence discusses policy implications for incentivising enterprise investments in KBC in Ireland. Further research is suggested which could provide additional useful evidence for enterprise policies.

⁴ Recent reviews of market and systemic failures in the context of innovation and intangible assets are Ruane and Siedschlag (2013) and Andrews and de Serres (2012).

2 Definitions and Measures of KBC

Knowledge-based capital comprises a range of identifiable intangible fixed assets⁵ that have an useful life more than one year (OECD 2013). From an accounting perspective, intangible assets need to meet certain criteria in order to be recorded in the accounting system. These criteria are described in Box 1 below.

Box 1. Intangible Assets in the Accounting System

Following on from International Accounting Standards (IAS), intangible assets are recorded in the accounting system if they meet two sets of criteria:

1. Asset definition criteria

- **identifiability:** this criterion implies two features: (i) the asset can be separated or divided from an entity; (ii) the asset arises from contractual or other legal rights;
- **control:** an entity has the power to obtain the future benefits derived from the specific asset and to restrict the access of others to those benefits;
- **future economic benefits:** revenue from the sale of products or services, cost savings, or other benefits resulting from the use of the asset by the entity.

2. Asset recognition criteria

- **probability of arising economic benefits embodied in the asset** – presumably more than 50%
- **the cost of the asset can be measured reliably**

Source: Andrews and de Serres (2012).

Progress on measuring KBC has taken place following contributions from the research community and the OECD. The mostly used methodological framework on measuring KBC is the one proposed by Corrado, Hulten and Sichel (2005, 2009) known as the CHS framework. The CHS framework has been developed as a macroeconomic approach. However, measurement of investment in KBC at the firm level remains exploratory.

The CHS framework defines and measures three types of KBC assets:

- **Computerised information:** Knowledge codified in computer programmes and computerised datasets recorded in the official System of National Accounts (SNA) since 1993.
- **Innovative property:** Knowledge assets that are protected through intellectual property rights (IPR) such as patents, designs, copyrights and trademarks.
- **Economic competencies:** Knowledge embedded in a firm's human and structural resources such as firm-specific training, organisational capital, and brand equity.

⁵ This definition of knowledge-based capital excludes unidentifiable intangible assets such as goodwill which while having an indefinite useful life does not exist independent of an enterprise.

The CHS framework has helped to understand and acknowledge the importance of KBC in advanced economies. KBC measures have been initially constructed based on the available data for the US. It is an *expenditure-based* approach (rather than based on the value of the created asset) to measuring intangible assets: it quantifies the monetary value of the resources devoted by firms to these assets on a yearly basis. The basic assumption is that these annual investments feed into production for a number of years and should be capitalised rather than counted as current expenditures that are consumed within a year.

Following on from the CHS framework, the OECD has undertaken further work on the classification of intangible assets. Table 1 presents definitions and measures of investments in intangible assets and capitalised value created from these investments.

TABLE 1: Intangible assets: Definitions and measures of investment in KBC

Intangible asset type	Investment (input)	Measures of investment input	Created value (output)	Measures of capitalised output
Computerised information				
Computer software	- In-house development or acquisition of software;	-R&D in software industry and outlays on software purchases	- Better management of information and knowledge improved process efficiency	-New software applications (copyrights)
Computerised database	-In-house development or acquisition of database	- Included in outlays on software	-Better informed or data-driven decision-making	- Database with significant market value
Innovative property				
Mineral exploration	-Early stage exploration of natural resources	- R&D spending in mining industry	-Knowledge about underlying geology of specific areas	-Rights on future exploration of mineral reserves
Scientific R&D	-Science and engineering research	- In-house or outsourced R&D in manufacturing and selected industries	-Knowledge leading to new or higher quality products and production processes	-Patents, licences and industrial secrets
Creative property	-Development of entertainment or artistic originals	-Non-scientific R&D: Development costs in entertainment and book publishing industries	- Artistic and cultural creations	-Copyrights and licences
Design	-Physical appearances, quality and ease of use of product and on workspace layout	-Outsourced architectural and engineering designs and R&D spending in social science and humanities	-Better commercial appeal, product differentiation; improved planning and problem solving	-Design rights, blueprints
Economic competencies				
Brand equity	-Spending on advertising and market research	-Outsourced advertising market research services	-Better valued product, better market potential; good reputation and customer relationship	-Trademarks, customer base, internet domain names
Firm-specific human capital	-On site worker training, tuition payments for job-related education	-Direct wage costs of employee time in training; vocational training surveys	-Increased overall skills level, more productive workforce	
Organisational capital	-Organisational changes	-Outsourced management consulting services and company formation expenses	-Improved business practices, better management of internal knowledge; inter-firm knowledge	-Blueprints for business methods

Source: Conceptual framework provided by the OECD Secretariat reported in Andrews and de Serres (2012).

3 Investment in KBC in Ireland and other EU Countries

3.1 Cross-Country Descriptive Evidence

The CHS framework has been used to produce comparable estimates of investment in KBC across countries. Using common guidelines, an international data set was constructed, the INTAN-Invest data set which includes harmonised estimates⁶ of intangible investment for 27 EU countries, Norway and the United States for the period 1995-2007. The data set covers the market sector⁷ and includes measures for the following intangible assets:

- *Computerised information*: software and databases;
- *Innovative property*: R&D; new architectural and engineering design; product development in financial services; mineral exploration and spending on the production of artistic originals;
- *Economic competencies*: market research; advertising; training; organisational capital (own account and purchased).

The existing international evidence based on this comparable data indicates that investments in KBC are sizeable and they have increased over time (Corrado et al 2013; OECD 2013). In many advanced economies, including the US, and the UK the private investments in KBC are larger than investment in tangible capital (machinery and equipment). Another common feature across advanced countries is the large and growing share of investment in non-R&D related KBC.

Subsequently, a newly produced version of the INTAN-Invest data set including investment in intangibles by business sector⁸ was constructed for 14 EU countries covering the period 1995-2010.⁹ A description of the data sources and the measurement and estimation methodologies for the intangible assets is given in Table A1 in the Appendix.

Based on this most recently produced version of the INTAN-Invest data, Corrado et al. (2014b) find that investments in KBC have grown over 1995-2010 in both manufacturing and services, most strongly in services. On the basis of our analysis of this data for Ireland and other EU countries, we discuss below key features of Ireland's performance on investments in KBC in comparison with other EU countries' performance. To account for countries' size, we relate the investment in KBC to an adjusted gross value added which is consistent with the gross fixed capital formation inclusive of new intangible assets.

⁶ The same concepts, methods and data sources were used for each country to the possible extent. Details are available in Corrado et al. (2012).

⁷ The market sector includes the following NACE sectors: Agriculture, forestry and fishing; Mining and quarrying; Manufacturing; Electricity, gas, steam and air conditioning supply; Water supply, sewerage, waste management and remediation activities; Construction; Wholesale and retail trade, repair of motor vehicles and motorcycles; Financial and insurance activities; Transportation and storage; Information and Communication; Professional, scientific and technical activities; Administrative and support service activities; Arts, entertainment and recreation; Other service activities.

⁸ Agriculture; Mining; Manufacturing; Utilities; Construction; Trade; Financial Services; and Other Services.

⁹ INTAN - Invest" available at www.INTAN-Invest.net. The data set covers the following EU countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, the United Kingdom.

Table 2 shows the investment in KBC as percentage of the adjusted gross value added¹⁰ (the intensity of investment in KBC) in Ireland and other 13 EU countries in 1995 and 2010. Over the period, the intensity of Ireland's investments in KBC has increased by 2.1 percentage points, from 7.6% to 9.7%. Ireland ranks 9th in this respect in the group of 14 EU countries covered by the data set. The countries with higher increases in the intensity of investment in KBC are Denmark (3.8 pp.), Belgium (3.6 pp), Finland (3.5 pp.), France (3.2 pp.), Portugal (3.0), United Kingdom (2.3 pp), and Austria (2.2 pp).

The increase in the intensity of Ireland's investments in KBC by asset category, has been the largest in the case of economic competencies (1.6 pp.), while the intensity of investment in the other two KBC categories has been less sizeable (0.4 pp. in the case of computer software and 0.1 pp. in the case of innovative property assets).

TABLE 2: Business investment in KBC as percentage of adjusted gross value added in Ireland and other EU countries, 1995-2010

Countries	All KBC	Computer software	Innovative property	Economic competencies	All KBC	Computer software	Innovative property	Economic competencies
	1995				2010			
Austria	6.6%	0.4%	2.3%	3.9%	8.8%	1.1%	3.5%	4.2%
Belgium	9.0%	0.9%	2.9%	5.2%	12.6%	1.5%	3.5%	7.6%
Denmark	9.3%	1.4%	2.8%	5.1%	13.1%	4.2%	4.4%	4.6%
Finland	8.5%	1.3%	3.3%	4.0%	12.0%	2.1%	5.4%	4.5%
France	9.5%	1.2%	3.4%	4.8%	12.6%	2.4%	4.3%	5.9%
Germany	8.4%	0.8%	3.4%	4.2%	9.7%	1.1%	4.2%	4.4%
Greece	3.2%	0.4%	0.9%	1.9%	3.7%	0.7%	0.9%	2.1%
Ireland	7.6%	0.5%	2.6%	4.6%	9.7%	0.9%	2.6%	6.2%
Italy	5.9%	0.8%	1.7%	3.3%	6.9%	1.0%	2.4%	3.5%
Netherlands	9.2%	0.9%	2.8%	5.4%	10.7%	1.8%	2.7%	6.2%
Portugal	4.8%	0.3%	1.2%	3.3%	7.8%	1.2%	2.6%	4.0%
Spain	5.0%	0.8%	1.5%	2.6%	6.6%	1.4%	2.4%	2.8%
Sweden	11.3%	1.8%	5.0%	4.6%	13.4%	2.9%	5.4%	5.1%
United Kingdom	10.8%	1.5%	3.1%	6.2%	13.0%	2.6%	3.4%	7.0%

Source: Authors' calculations based on Corrado, Carol, Jonathan Haskel, Cecilia Jona-Lasinio and Massimiliano Iommi (2014). "Internationally comparable macro-estimates of investment in intangible assets at the industry level: INTAN - Invest" available at www.INTAN-Invest.net.

The statistics summarised in Table 2 highlight Ireland's performance in comparison to the group of the other 13 advanced EU economies. In 2010, Ireland's intensity of investment in KBC was the same as in Germany and ahead of Austria, Portugal, Italy, Spain, and Greece. However, Ireland's performance lagged behind the leading group countries including Sweden, Denmark, the United Kingdom, Belgium, France, Finland, and the Netherlands. Looking at the three components of KBC Ireland's best performance in 2010 was on the intensity of investment in economic competencies

¹⁰ The adjusted gross value added is consistent with the gross fixed capital formation in National Accounts which includes new intangible assets.

(Ireland ranks 4th). Ireland's weakest performance was on the intensity of investment in computer software (Ireland ranks 13th ahead of Greece).

3.2 Ireland's Investment in KBC since 2010

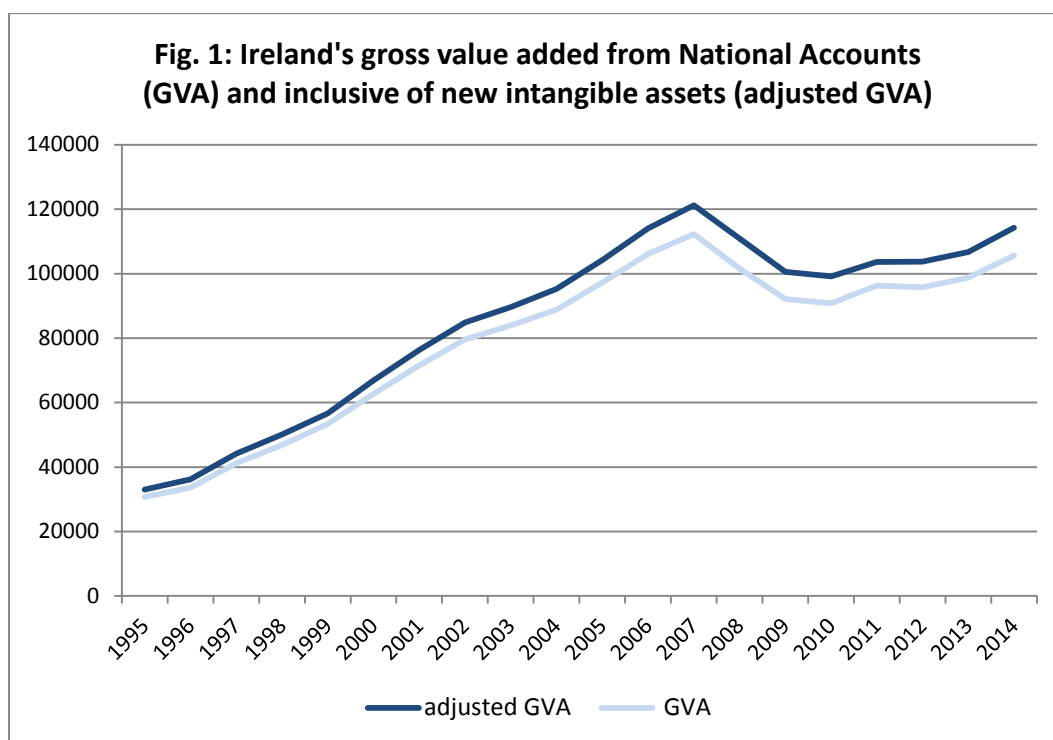
The cross-country data on KBC assembled as part of the INTAN project was collected up until 2010. In order to examine more recent trends in overall KBC investment and in the separate components, the data have been updated at the sector level for Ireland up until 2014.¹¹ This was done through a combination of direct data available and the extrapolation of some of the series in the INTAN-invest database using the most similar equivalent series to build a baseline growth rate. This approach was taken in order to keep all of the series as consistent as possible and thus avoid any discrete jumps in the series due to changes in the sources of the data. The underlying assumptions of the INTAN data, such as the derivation of organisational capital from expenditure on managerial expertise, were followed as closely as possible. It is important however to recognise that more in-depth work is currently being undertaken to develop these measures further and that more nuanced indicators may become available in the future. In order to follow the development of KBC investment across time, however, consistency in measurement approach is an important factor and was given priority in this updating exercise.

Detailed information about the data sources and methodology to update the INTAN data set for Ireland are given in Appendix B.

To put the investment in KBC into perspective we look first at the evolution of the GVA and adjusted GVA in Ireland over the period 1995-2014. Using the updated data for the aggregated business sector, Figure 1 shows that the GVA peaked in 2007 and declined sharply afterwards with the lowest level reached in 2010. Since 2010 the GVA has increased every year with a more accelerated pace since 2011. The gap between the GVA and the GVA consistent with the new intangible assets has widened compared to the beginning of the period in line with increased investment in intangible assets other than those included in the National Accounts.

¹¹ We thank Aonghus O'Coilain for his assistance to construct the updated version of the data set for Ireland.

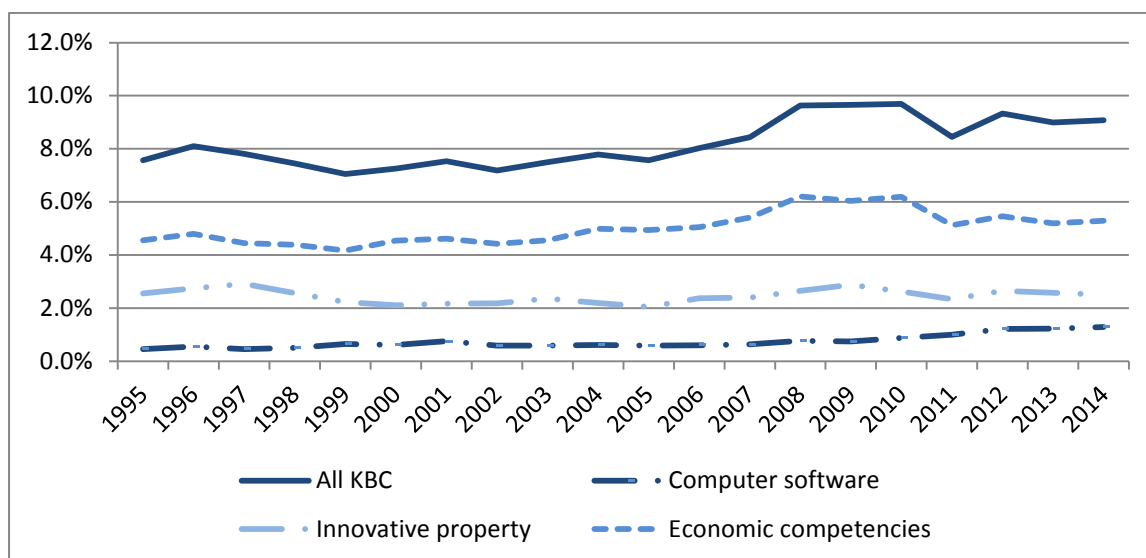
FIGURE 1: Ireland's gross value added from National Accounts (GVA) and consistent with new intangible assets (adjusted GVA)



Source: Authors' calculations based on the the updated INTAN-Invest data set for Ireland.

Figures 2 and 3 describe patterns of Ireland's intensity of investment in KBC over the period 1995-2014 at the aggregate business sector.

FIGURE 2: Investment in KBC as percentage of adjusted gross value added in Ireland, aggregate and by type of KBC, 1995-2014



Notes: Authors' calculations based on the updated INTAN-Invest data set for Ireland. *Innovative property* assets include: scientific R&D; new architectural and engineering designs; new product development in the financial services; entertainment, artistic and literary originals, and mineral explorations. *Economic competencies* include: brand equity, training and organisational capital.

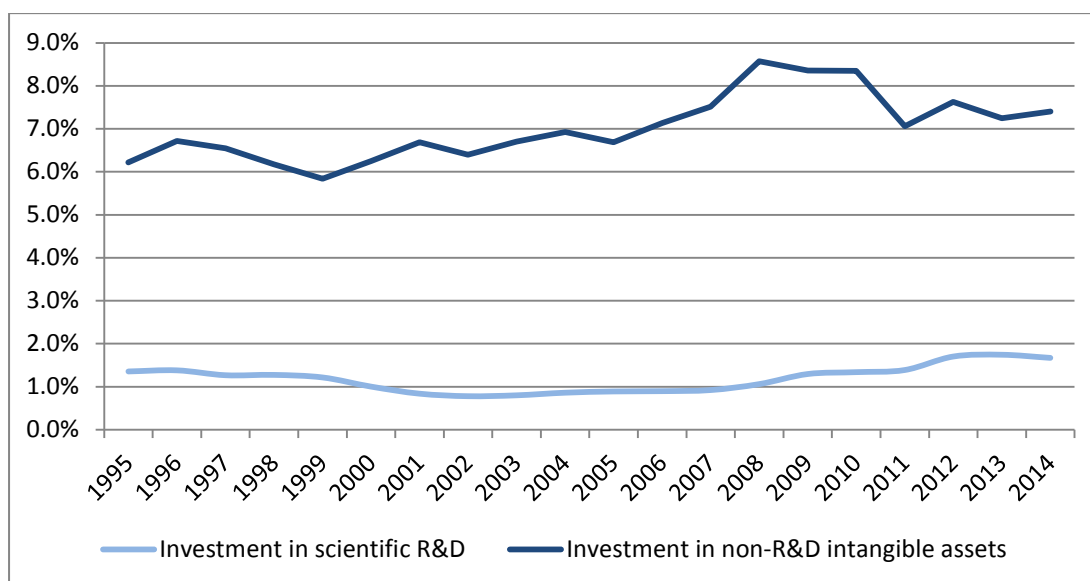
The intensity of business investment in KBC has increased over time. The most pronounced increase in the intensity of KBC investment in the business sector has taken place between 2005 and 2010 mainly due to the growing investment intensity in economic competencies and innovative property assets. Among the three main KBC asset categories, investment in economic competencies has had the largest intensity. The overall levels of investment in KBC as a share of adjusted value-added in the economy remained fairly stable in the period between 2010 and 2014. There was a slight dip in 2011 although this may reflect the changes in data sources used in the updating process and it was in any case a temporary reduction with the stable percentage of approximately 9 per cent returned to in the following year.

The steady level of investment in KBC despite the economic downturn is a robust pattern and applies to the three broad KBC assets categories as well as the overall investment rate. Along with the overall evolution of KBC, Figure 2 presents the three broad components of innovative property, economic competencies and computer software as shares of adjusted value-added. As discussed earlier, there is a noticeable increase in the share of KBC in value-added throughout the 2000s, reaching a peak of just under ten per cent in 2008 and 2009. During the entire extended period of data availability, total KBC investment is driven largely by investment in economic competencies, which comprise almost half of the investment. This highlights the value of the broader definition of intangible investment that falls under the KBC umbrella, as this type of investment in human, organisational and marketing would not be captured by more commonly used measures of investment.

When we consider the patterns across countries from Table 2 and the upward trend evident between 1995 and 2010 in all of the comparable economies, the flat performance of KBC investment shares in the interval since 2010 raises some concerns. In the absence of updated data for the other countries, it is not possible to say with certainty that Ireland has fallen behind but it is reasonable to infer that the stable investment rate is unlikely to have significantly closed the gap that was evident between Ireland and a wide range of other countries in 2010.

Looking deeper past the relatively smooth path of the totals shows that there are some significant changes in the shares of the different components of KBC, particularly when the data is broken down by sector. When we first split the KBC components in a different way into investment in R&D and into non-R&D, we see in Figure 3 that the investment in non-R&D intangibles as a share of value-added outstrips standard R&D investment by a considerable amount. Investment in standard R&D accounts for between 1 and 2 per cent of adjusted value-added across the almost twenty year span of data, whereas non-R&D investment in other types of KBC grows from six per cent to over 8 per cent in the same period. The large contribution of economic competencies to total KBC investment is the key factor in creating this gap.

FIGURE 3: Investment in scientific R&D and other components of KBC as percentage of adjusted gross value added in Ireland, 1995-2014



Notes: Authors' calculations based on the updated INTAN-Invest data set for Ireland. Non-R&D assets include: new architectural and engineering design; new product development in the financial industry; entertainment, artistic and literary originals; mineral explorations; advertising and market research; training; organisational capital.

We discuss next the results of updating the INTAN database of KBC investment for Ireland in the market sector to include the most recently available data for the business sectors, extending the original data up to 2014. The market sector includes the following sectors defined following the NACE Rev. 2 as shown in Table 3 below:

TABLE 3: The description of the market sector covered by the INTAN database

NACE Rev. 2 Section	Description
A	Agriculture, forestry and fishing
B	Mining and quarrying
C	Manufacturing
D	Electricity, gas, steam and air conditioning supply
E	Water supply, sewerage, waste management and remediation activities
F	Construction
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
K	Financial and insurance activities
H	Transportation and storage
J	Information and communication
M	Professional, scientific, and technical activities
N	Administrative and support service activities
R	Arts, entertainment and recreation
S	Other service activities

The sectors analysed in this section are composed as follows: *Agriculture, fishing, mining*: A and B; *Manufacturing*: C; *Utilities*: D and E; *Construction*: F; *Trade*: G; *Financial services*: K; *Other business services*: H-J; M-N; R-S.

Using the updated version of the INTAN-Invest data set, Table 4 shows the composition of Ireland's investment in KBC assets by asset category in the business sector and across sectors over the period 1995-2014.

TABLE 4: The Composition of Investment in KBC Assets by Asset Category

	1995	2000	2005	2010	2014
Total Business Sector					
Computer software	6.0%	8.4%	7.7%	9.0%	14.1%
Innovative property	33.7%	29.0%	27.1%	27.1%	27.6%
Economic competencies	60.2%	62.6%	65.3%	63.9%	58.3%
Agriculture, Fishing, Mining					
Computer software	35.8%	38.9%	39.7%	55.2%	46.0%
Innovative property	38.8%	31.0%	29.5%	28.7%	23.2%
Economic competencies	25.4%	30.0%	30.8%	16.1%	30.8%
Manufacturing					
Computer software	3.5%	4.5%	4.8%	3.0%	3.4%
Innovative property	46.2%	35.7%	36.1%	31.0%	28.7%
Economic competencies	50.3%	59.9%	59.1%	65.9%	67.9%
Utilities					
Computer software	36.9%	49.2%	52.0%	59.5%	77.4%
Innovative property	29.7%	34.2%	31.0%	29.5%	11.4%
Economic competencies	33.3%	16.6%	17.0%	10.9%	11.2%
Construction					
Computer software	0.3%	0.5%	0.2%	0.2%	0.2%
Innovative property	6.7%	5.2%	5.4%	3.7%	11.4%
Economic competencies	93.0%	94.3%	94.4%	96.1%	88.5%
Trade					
Computer software	6.5%	12.1%	12.1%	4.1%	4.9%
Innovative property	24.1%	22.3%	20.3%	20.0%	16.4%
Economic competencies	69.4%	65.6%	67.6%	75.9%	78.8%
Financial services					
Computer software	3.0%	7.4%	3.2%	1.7%	7.4%
Innovative property	23.3%	24.9%	20.3%	21.2%	21.0%
Economic competencies	73.7%	67.7%	76.5%	77.0%	71.6%
Other business services					
Computer software	4.8%	6.3%	5.1%	6.7%	7.0%
Innovative property	29.1%	28.2%	29.0%	30.7%	37.3%
Economic competencies	66.1%	65.5%	66.0%	62.6%	55.7%

Notes: Authors' calculations based on the updated INTAN-Invest data set for Ireland. *Innovative property* assets include: scientific R&D; new architectural and engineering designs; new product development in the financial services; entertainment, artistic and literary originals, and mineral explorations. *Economic competencies* assets include: brand equity, training and organisational capital. *Utilities*: Electricity, gas, steam and air conditioning supply; Water supply, sewerage, waste management and remediation activities. *Trade*: Wholesale and retail trade; repair of motor vehicles and motorcycles. *Financial services*: Financial and insurance activities. *Other business services* include the following services: Transportation and storage; Information and communication; Professional, scientific and technical activities; Administrative and support service activities; Arts, entertainment and recreation; Other service activities.

As shown in Table 4 above, overall in the total business sector, investments in economic competencies represent more than half or close to two thirds of total investment in KBC (ranging from 60.2% in 1995 to 58.3% in 2014). Investment in innovative property represents close or just above one third of the total investment in KBC (ranging from 33.7% in 1995 to 27.6% in 2014) while investment in computer software has the lowest share (ranging from 6% in 1995 to 14.1% in 2014). Over time, the shares of investments in economic competencies and in innovative property have declined (by 1.9 percentage points and 6.1 percentage points, respectively) while the share of investment in computer software has increased by 8.1 percentage points.

Looking at the composition of investments in KBC across sectors, a similar ranking pattern emerges in all sectors with the exception of two sectors where investment in software dominates investments in innovative property and in economic competencies. These are Agriculture, fishing, and mining; and Utilities. The share of investment in computer software in Utilities was particularly large in 2014, 77.4% of the total investment in KBC assets in this sector. In contrast, in Construction, the share of investment in computer software appears to be very low, 0.2% in 2014, while investment in economic competencies in this sector accounted for 88.5% of total investment in KBC. Other sectors with very large shares of investment in economic competencies in 2014 include Trade (78.8 %), and Financial services (71.6%).

Although the investment in overall KBC remained relatively flat as a share of adjusted value added in recent years, we observe considerable differences across sectors, both in terms of the overall investment in KBC and in the relative weights of the subcomponents across sectors.

Table 5 shows how overall KBC investment evolved across the seven broad economic sectors. Until the most recent years, investment in KBC has been highest in the other business services sector (i.e. services other than financial services), although it was in more recent years overtaken by utilities where KBC investment has been increasing rapidly since around 2006.

The analysis of the components shows that the rapid increase in KBC in the utilities sector comes largely from a dramatic rise in investment in software in that sector. Software investment in other sectors remained relatively stable in comparison. Investment in innovative property shows the highest degree of variation over time, suggesting a greater cyclical element to investment decisions in this component. The importance of KBC investment in the other services sector is evident in all of the sub-component graphs, with investment as a share of adjusted value-added approximately double those of the other sectors.

TABLE 5: Investment in KBC as percentage of adjusted gross value added by sector in Ireland

	1995	2000	2005	2010	2014
All KBC					
Agriculture, fishing, mining	2.0%	2.0%	3.0%	5.8%	4.9%
Manufacturing	7.9%	5.9%	5.7%	5.8%	5.2%
Utilities	6.6%	11.0%	12.1%	18.7%	27.2%
Construction	3.1%	2.8%	2.6%	7.0%	4.4%
Trade	5.9%	5.0%	6.8%	7.8%	8.8%
Financial Services	6.8%	7.1%	8.7%	8.8%	3.5%
Other Business Services	17.2%	17.6%	15.2%	17.8%	17.2%
Total Business Sector	7.6%	7.3%	7.6%	9.7%	9.1%
Computer Software					
Agriculture, fishing, mining	0.7%	0.8%	1.2%	3.2%	2.3%
Manufacturing	0.3%	0.3%	0.3%	0.2%	0.2%
Utilities	2.4%	5.4%	6.3%	11.1%	21.0%
Construction	0.0%	0.0%	0.0%	0.0%	0.0%
Trade	0.4%	0.6%	0.8%	0.3%	0.4%
Financial Services	0.2%	0.5%	0.3%	0.2%	0.3%
Other Business Services	0.8%	1.1%	0.8%	1.2%	1.2%
Total Business Sector	0.5%	0.6%	0.6%	0.9%	1.3%
Innovative property					
Agriculture, fishing, mining	0.8%	0.6%	0.9%	1.7%	1.1%
Manufacturing	3.7%	2.1%	2.0%	1.8%	1.5%
Utilities	1.9%	3.8%	3.7%	5.5%	3.1%
Construction	0.2%	0.1%	0.1%	0.3%	0.5%
Trade	1.4%	1.1%	1.4%	1.6%	1.4%
Financial Services	1.6%	1.8%	1.8%	1.9%	0.7%
Other Business Services	5.0%	5.0%	4.4%	5.5%	6.4%
Total Business Sector	2.6%	2.1%	2.0%	2.6%	2.5%
Economic competencies					
Agriculture, fishing, mining	0.5%	0.6%	0.9%	0.9%	1.5%
Manufacturing	4.0%	3.6%	3.3%	3.8%	3.5%
Utilities	2.2%	1.8%	2.1%	2.0%	3.0%
Construction	2.9%	2.7%	2.4%	6.7%	3.9%
Trade	4.1%	3.3%	4.6%	5.9%	6.9%
Financial Services	5.0%	4.8%	6.7%	6.8%	2.5%
Other Business Services	11.3%	11.5%	10.0%	11.1%	9.6%
Total Business Sector	4.6%	4.5%	4.9%	6.2%	5.3%

Notes: Authors' calculations based on the updated INTAN-Invest data set for Ireland. *Innovative property* assets include: scientific R&D; new architectural and engineering designs; new product development in the financial services; entertainment, artistic and literary originals, and mineral explorations. *Economic competencies* assets include: brand equity, training and organisational capital. *Utilities*: Electricity, gas, steam and air conditioning supply; Water supply, sewerage, waste management and remediation activities. *Trade*: Wholesale and retail trade; repair of motor vehicles and motorcycles. *Financial services*: Financial and insurance activities. *Other business services* include the following services: Transportation and storage; Information and communication; Professional, scientific and technical activities; Administrative and support service activities; Arts, entertainment and recreation; Other service activities.

4 The Impact of Investment in KBC on Productivity

4.1 Macroeconomic Evidence

International evidence indicates that in advanced economies, aggregate investment in KBC is positively associated with productivity growth.¹² Recent studies using a growth accounting methodology have estimated that investment in KBC is an important source of productivity growth (Corrado et al. 2012, 2014; 2016; Dal Borgo et al. 2013; Niebel, O'Mahony and Saam 2017).

Niebel, O'Mahony and Saam (2017) estimated that the output elasticity to intangibles over 1997-2007 ranged between 0.1 and 0.2 across ten EU countries. They also find that the contribution of intangibles to labour productivity growth tends to be highest in manufacturing and the finance sector. Dal Borgo et al. (2013) find that in the UK, intangible capital accounted for 23 per cent of the labour productivity growth over 2000-2008.

Recent evidence provided by Corrado et al. (2016) shows that over the period 2000-2013, the contribution of intangible capital deepening to the annual growth of labour productivity was 0.6 per cent in the US and 0.3 per cent in 18 EU countries¹³ included in the analysis. In the US and the UK, the contribution of intangible capital deepening to the annual labour productivity growth was higher than the contribution of tangible capital deepening. Among all countries included in the analysis, the contribution of intangible capital deepening to labour productivity growth was the highest in Ireland, 1.0 per cent of the 2.5 per cent annual growth of labour productivity. Broken down by categories of intangible assets, the highest contribution was from innovative property assets, 0.7 percent, followed by economic competencies, 0.2 per cent, and computer software, 0.1 per cent. Over the same period, the corresponding contribution of tangible capital deepening to the annual growth of labour productivity in Ireland was 1.9 per cent.

Investments in various forms of KBC such as R&D, data analytics and managerial quality could have complementary positive effects on productivity (OECD 2013). Goodridge, Haskel, and Wallis (2017) provide evidence on spillovers from external R&D and non-R&D intangible assets on total factor productivity growth in the UK.

Figures 4 and 5 link the intensity of investment in KBC in Ireland and other EU countries (based on the INTAN-Invest data set) to their innovation and productivity performance.

Figure 4 shows a strong and positive correlation between investment in KBC and an aggregated measure of innovation at country level, the *Summary Innovation Index* (SII) produced by the European Innovation Scoreboard.¹⁴ This index summarises the innovation performance of countries on the basis of three types of indicators: innovation enablers; firm innovation activities; and economic outputs. Detailed descriptions of the Summary Innovation Index and other policy relevant indicators are given in Table A2 in the Appendix.

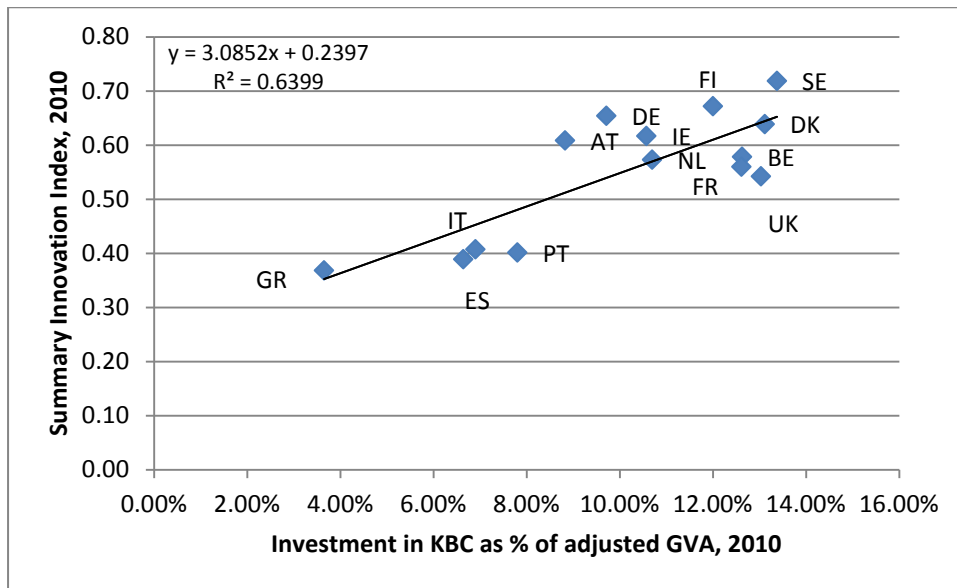
¹² Recent reviews of this evidence are by Hulten (2013) and Corrado et al. (2016) among others.

¹³ Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands, Portugal, Slovakia, Slovenia, Spain, Sweden, the United Kingdom.

¹⁴ The European Innovation Scoreboard provides a comparative analysis of the innovation performance in EU Member States based on a range of single and composite indicators. Details about the Measurement Framework and data sets are available from http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en.

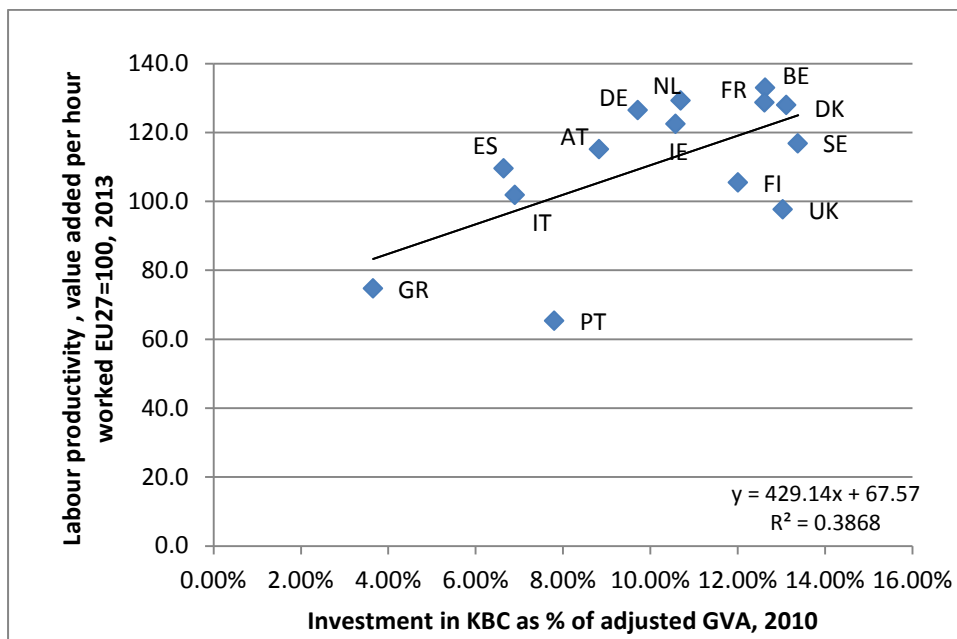
Figure 5 shows a positive link between investment in KBC and labour productivity (measured relative to the EU average).

FIGURE 4: Investment in KBC and innovation performance



Notes: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set.

FIGURE 5: Investment in KBC and labour productivity



Notes: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Commission Member States' Competitiveness Report 2014.

Overall, the key message emerging from this descriptive analysis is that investment in KBC is positively and strongly associated with the innovation and productivity performance of the analysed countries. In comparison to other advanced EU countries, Ireland ranks higher for its innovation and

productivity performance relative to its ranking for investments in KBC. This evidence suggests that incentivising more investment in KBC could lead to a stronger innovation and productivity performance in Ireland.

4.2 Firm-Level Evidence

Notwithstanding the progress made in measuring investment in KBC at the aggregate industry and macroeconomic levels, measures of investment at the firm-level remain exploratory. Existing firm-level evidence has focused mostly on the impact of R&D expenditures and more broadly innovation expenditures on innovation and productivity growth.¹⁵ To the best of our knowledge, firm-level evidence on the impact of investment in KBC on productivity is very limited. Only a small number of studies have distinguished and quantified investment in KBC assets other than R&D, such as computer software, and economic competencies.

Riley and Robinson (2011) analyse the relationship between intangible assets and firm productivity in the UK using linked employee and employer data for the period 1998-2006. The analysis focuses on intangible assets produced within the firm and embedded in knowledge workers: organisational workers (managers and marketing related occupations), measuring economic competencies; R&D workers, measuring innovative property; and IT workers, measuring digitised information. The results indicate a positive and significant link between these KBC assets and productivity. However, the uncovered effects are different for the various KBC assets examined, with organisational capital having a greater impact than either R&D or IT capital.

Using the CHS conceptual framework for measuring investment in KBC, Crass and Peters (2014) examine the effects of investment in a comprehensive range of KBC assets on firm productivity in Germany over the period 2006-2010. The evidence indicates strong positive links between productivity and investment in R&D, brand capital and firm-specific human capital. Their analysis also uncovers a long-term positive productivity effect following investment in innovative capital and branding equity. One innovative contribution of this paper is the evidence on complementary effects from investing in various types of KBC assets. Such complementarities were found for investment in R&D and the patent stock; investments in innovative capital and firm-specific human capital; and for investments in innovative capital and brand equity.

Higón, Gómez, and Vargas (2017) estimate the effects of investments in R&D, advertising and human capital on total factor productivity in Spanish manufacturing firms. They find evidence of complementarities between investments in R&D and advertising, and between investment in advertising and human capital. Further, they find no conclusive evidence for the case of investments in R&D and human capital.

Di Ubaldo and Siedschlag (2017) analyse the effects of firm-level investments in KBC on productivity in Ireland. This analysis uses two micro data sets over the period 2006-2012 provided by Ireland's Central Statistical Office (CSO), the Census of Industrial Production (CIP) and the Annual Services Inquiry (ASI). These firm-level data sets cover a range of KBC assets, including R&D and non-R&D intangible assets such as computer software, intellectual property assets (copyrights, patents and

¹⁵ Recent evidence is reviewed by Hall (2011).

licences, royalties) and organisational capital. The measures of investment in KBC and key findings of this analysis are discussed below.

Table 6 describes the firm-level measures of KBC investments constructed for this analysis. These measures are constructed using firm-level spending on R&D and non-R&D assets following the CHS framework.

TABLE 6: Measures of investment in KBC assets at firm-level

Investment in KBC assets	Description
R&D	Annual capitalised expenditure on R&D assets and current expenditures on purchased R&D services
Computer software	Annual capitalised expenditure on computer software assets
Intellectual property assets	Annual capitalised expenditure on copyrights, patents, licences for intellectual property assets and current expenditures on royalties and know-how
Organisational capital	Annual expenditure on management and marketing fees
Other intangible assets	Annual capitalised expenditures on other intangible fixed assets

Notes: The measures of investment in KBC are computed using information collected by the Central Statistics' Office (CSO) with the Census of Industrial Production and the Annual Services Inquiry.

Source: Di Ubaldo and Siedschlag (2017).

Table 7 shows the extent of firms' engagement in investment in KBC by ownership and export participation. Looking first at the figures for all firms, the share of firms with investment in KBC has increased by 6 percentage points from 42.5 per cent in 2006 to 52.2 per cent in 2012. This increase appears to be driven by the performance of Irish-owned firms. In the group of Irish-owned firms, the share of firms with investments in KBC in 2012 stood at 47.2 per cent, higher by 5.1 percentage points than in 2006. In comparison, the share of foreign-owned firms with investments in KBC in 2012 was 70.6 per cent, higher by 2 percentage points than in 2006. Looking at the breakdown of investment in KBC by R&D and non-R&D assets (computer software, intellectual property assets, organisational capital and other intangible assets), it is noteworthy that the increase in the share of firms with investment in R&D has been larger than the increase in the share of firms with investment in non-R&D assets, particularly for Irish-owned firms.

An additional feature worth to highlight is that the share of firms with investment in KBC is higher in the group of exporting firms in comparison to firms serving only the Irish market. Looking again first at all firms, in 2012 65.2 per cent of firms with exporting activities reported investments in KBC in comparison to 45 per cent in the group of firms serving only the Irish market. Among Irish-owned firms, in 2012, 59.6 per cent of exporters invested in KBC, down by 3.5 per cent relative to 2006. In comparison, among foreign-owned exporters, in 2012, 75.6 per cent reported investment in KBC, an increase by 3 percentage points compared to 2006.

TABLE 7: The shares of firms investing in KBC by ownership and export participation

	2006	2007	2008	2009	2010	2011	2012
	All firms						
Firms with investment in R&D	11.3%	11.2%	12.0%	12.0%	12.7%	12.4%	16.9%
Firms with investment in non-R&D	34.9%	36.4%	38.7%	39.7%	39.5%	40.0%	35.3%
Firms with investment in KBC	46.2%	47.6%	50.6%	51.7%	52.2%	52.4%	52.2%
Firms with no investment in KBC	53.8%	52.4%	49.4%	48.3%	47.8%	47.6%	47.8%
	Irish-owned						
Firms with investment in R&D	10.3%	10.1%	11.1%	10.5%	11.5%	11.1%	16.7%
Firms with investment in non-R&D	31.9%	33.4%	35.8%	37.0%	36.2%	36.7%	30.5%
Firms with investment in KBC	42.1%	43.5%	46.9%	47.5%	47.7%	47.8%	47.2%
Firms with no investment in KBC	57.9%	56.5%	53.1%	52.5%	52.3%	52.2%	52.8%
	Foreign-owned						
Firms with investment in R&D	16.7%	17.2%	16.9%	18.6%	17.5%	17.6%	17.6%
Firms with investment in non-R&D	51.8%	52.8%	53.7%	52.5%	52.4%	52.7%	53.0%
Firms with investment in KBC	68.6%	70.1%	70.6%	71.2%	69.8%	70.4%	70.6%
Firms with no investment in KBC	31.4%	29.9%	29.4%	28.8%	30.2%	29.6%	29.4%
	Exporters						
	All firms						
Firms with investment in R&D	24.8%	25.7%	23.8%	24.9%	24.2%	23.3%	24.5%
Firms with investment in non-R&D	41.2%	40.2%	42.9%	42.8%	43.2%	41.8%	40.7%
Firms with investment in KBC	66.0%	66.0%	66.7%	67.7%	67.3%	65.1%	65.2%
Firms with no investment in KBC	34.0%	34.0%	33.3%	32.3%	32.7%	34.9%	34.8%
	Irish-owned						
Firms with investment in R&D	26.2%	26.6%	24.6%	25.7%	25.0%	23.4%	25.9%
Firms with investment in non-R&D	37.0%	35.8%	38.7%	38.7%	39.1%	36.8%	33.7%
Firms with investment in KBC	63.1%	62.3%	63.2%	64.4%	64.1%	60.2%	59.6%
Firms with no investment in KBC	36.9%	37.7%	36.8%	35.6%	35.9%	39.8%	40.4%
	Foreign-owned						
Firms with investment in R&D	21.8%	23.7%	22.1%	23.2%	22.6%	23.2%	21.8%
Firms with investment in non-R&D	50.9%	51.1%	52.2%	51.2%	50.7%	51.7%	53.8%
Firms with investment in KBC	72.6%	74.9%	74.3%	74.4%	73.3%	74.9%	75.6%
Firms with no investment in KBC	27.4%	25.1%	25.7%	25.6%	26.7%	25.1%	24.4%
	Non-exporters						
	All firms						
Firms with investment in R&D	4.9%	5.0%	7.1%	5.9%	6.6%	6.3%	12.6%
Firms with investment in non-R&D	32.0%	34.8%	36.9%	38.3%	37.6%	39.0%	32.3%
Firms with investment in KBC	36.9%	39.8%	44.0%	44.2%	44.2%	45.3%	45.0%
Firms with no investment in KBC	63.1%	60.2%	56.0%	55.8%	55.8%	54.7%	55.0%
	Irish-owned						
Firms with investment in R&D	4.7%	4.6%	6.8%	5.1%	6.1%	5.8%	12.8%
Firms with investment in non-R&D	30.1%	32.7%	35.0%	36.3%	35.1%	36.7%	29.2%
Firms with investment in KBC	34.7%	37.3%	41.8%	41.5%	41.2%	42.5%	42.0%
Firms with no investment in KBC	65.3%	62.7%	58.2%	58.5%	58.8%	57.5%	58.0%
	Foreign-owned						
Firms with investment in R&D	8.0%	8.8%	9.6%	12.2%	9.9%	9.7%	11.6%
Firms with investment in non-R&D	53.6%	55.1%	55.9%	54.4%	54.8%	54.2%	51.9%
Firms with investment in KBC	61.5%	63.8%	65.5%	66.6%	64.8%	63.9%	63.5%
Firms with no investment in KBC	38.5%	36.2%	34.5%	33.4%	35.2%	36.1%	36.5%

Notes: Firms with investment in R&D: Firms with capitalised R&D expenditures and firms with purchased R&D. Firms with investment in non-R&D: Firms with capitalised expenditures on software, copyrights, patents, licences, other intangible assets; firms with expenditure on organisational capital (management fees), royalties and technical know-how. Firms with investment in KBC: Firms with investment in R&D and firms with investment in non R&D assets.

Source: Di Ubaldo and Siedschlag (2017).

TABLE 8: The shares of firms investing in KBC assets by ownership and size class

	2006	2007	2008	2009	2010	2011	2012
Small Irish-owned							
Firms with investment in R&D	9.3%	9.8%	10.5%	9.1%	11.9%	10.7%	18.4%
Firms with investment in non-R&D	29.3%	30.7%	33.6%	34.2%	32.3%	34.5%	26.4%
Firms with investment in KBC	38.6%	40.5%	44.1%	43.3%	44.1%	45.2%	44.8%
Firms with no investment in KBC	61.4%	59.5%	55.9%	56.7%	55.9%	54.8%	55.2%
Foreign-owned							
Firms with investment in R&D	14.4%	14.1%	13.2%	15.0%	12.9%	14.5%	19.1%
Firms with investment in non-R&D	47.8%	50.2%	52.4%	51.0%	51.5%	49.8%	48.6%
Firms with investment in KBC	62.2%	64.3%	65.6%	66.0%	64.3%	64.4%	67.6%
Firms with no investment in KBC	37.8%	35.7%	34.4%	34.0%	35.7%	35.6%	32.4%
Medium-sized Irish-owned							
Firms with investment in R&D	11.5%	9.8%	11.5%	13.0%	10.5%	11.8%	13.8%
Firms with investment in non-R&D	35.2%	37.1%	38.2%	40.3%	40.5%	38.1%	34.2%
Firms with investment in KBC	46.7%	46.8%	49.7%	53.2%	51.1%	49.9%	48.1%
Firms with no investment in KBC	53.3%	53.2%	50.3%	46.8%	48.9%	50.1%	51.9%
Foreign-owned							
Firms with investment in R&D	16.7%	18.0%	19.3%	19.9%	19.1%	17.9%	15.5%
Firms with investment in non-R&D	53.1%	53.5%	53.7%	52.3%	51.8%	54.7%	57.2%
Firms with investment in KBC	69.7%	71.5%	72.9%	72.3%	70.8%	72.6%	72.7%
Firms with no investment in KBC	30.3%	28.5%	27.1%	27.7%	29.2%	27.4%	27.3%
Large Irish-owned							
Firms with investment in R&D	17.6%	18.3%	18.3%	16.0%	12.6%	11.6%	13.3%
Firms with investment in non-R&D	50.3%	51.8%	58.1%	57.7%	57.9%	56.9%	60.2%
Firms with investment in KBC	67.9%	70.1%	76.3%	73.7%	70.5%	68.5%	73.5%
Firms with no investment in KBC	32.1%	29.9%	23.7%	26.3%	29.5%	31.5%	26.5%
Foreign-owned							
Firms with investment in R&D	20.4%	20.6%	17.9%	22.4%	21.8%	22.3%	19.5%
Firms with investment in non-R&D	55.2%	55.6%	56.2%	55.7%	55.3%	53.3%	51.5%
Firms with investment in KBC	75.6%	76.2%	74.1%	78.1%	77.2%	75.6%	71.0%
Firms with no investment in KBC	24.4%	23.8%	25.9%	21.9%	22.8%	24.4%	29.0%

Notes: *Firms with investment in R&D*: Firms with capitalised R&D expenditures and firms with purchased R&D. *Firms with investment in non-R&D*: Firms with capitalised expenditures on software, copyrights, patents, licences, other intangible assets; firms with expenditure on organisational capital (management fees), royalties and technical know-how. *Firms with investment in KBC*: Firms with investment in R&D and firms with investment in non R&D assets. Small firms are firms with 20 to 49 employees; medium-sized firms are firms with 50-249 employees; large firms are firms with 250 and more employees.

Source: Di Ubaldo and Siedschlag (2017).

Table 8 shows additional variation in the patterns of investment in KBC across firms in different size classes and ownership groups. Consistent with the patterns discussed above, small and medium-sized foreign-owned firms are more likely to invest in KBC than Irish-owned firms. However, the share of large Irish-owned firms with investments in KBC is slightly higher than in the case of large

foreign-owned firms, 73.5 per cent in 2012 compared to 71 per cent, respectively. This differential appears to be driven by the share of firms with investment in non-R&D assets, which is 60.2 per cent in the case of large Irish-owned firms, higher by 8.7 percentage points than the share of large foreign-owned firms with investments in non-R&D assets. It is also noteworthy that the share of large Irish-owned firms with investments in KBC has increased over the analysed period by 5.6 percentage points, while among large foreign-owned firms it has decreased by 5.4 percentage points.

Taken together the descriptive patterns discussed above, the message which emerges is the improvement of the performance of Irish-owned firms with respect to engagement in investments in KBC. This has been the case particularly for large firms and firms serving the Irish market.

Over the analysed period, as shown in Table 9 below, on average, the intensity of the investment in KBC was higher in foreign-owned firms in comparison to Irish-owned firms and in firms engaged in exporting in comparison to firms serving only the Irish market.

TABLE 9: The intensity of the investment in KBC, 2006-2012, thousand Euros per employee

	All Firms	Irish-owned	Foreign-owned
Exporters	58.99	9.92	145.44
Firm-year observations	8,302	5,296	3,006
Non-exporters	16.37	4.68	76.75
Firm-year observations	11,087	9,288	1,799
All firms	34.62	6.58	119.72
Firm-year observations	19,389	14,584	4,805

Notes: The figures are averages across firm-year observations for firms reporting positive investment. The intensity of investment in KBC is measured as investment in KBC in thousand Euros in constant 2010 prices per employee.

Source: Di Ubaldo and Siedschlag (2017).

Table 10 summarises the estimated impact of firms' investment in KBC on labour productivity. The results indicate that investment in knowledge-based capital is an important driver of labour productivity for all firms and groups of firms. Over the analysed period, a 10 per cent increase in investment in knowledge-based capital per employee increased firm productivity by 2 per cent. The effect is larger for Irish-owned firms in comparison to foreign-owned firms but it is stronger (statistically more significant) for foreign-owned firms. The estimated productivity gain related to investment in KBC higher by 10 per cent is 3.6 per cent in the case of indigenous firms and 2.4 per cent in the group of foreign-owned firms. Further, productivity gains linked to investment KBC are larger in manufacturing firms in comparison to firms in services.

Looking at the results for KBC specific assets, when all firms are analysed together, it appears that the largest and strongest productivity gains are related to investment in computer software. Raising investment in computer software per employee is associated with an increase in labour productivity

by 13 per cent. This proportionally larger effect than the increase in investment in computer software suggests possible complementary effects leading to larger productivity gains. Investments in R&D and in organisational capital are also positively and significantly linked to productivity gains.

The productivity effects of investment in specific KBC assets are also different for Irish-owned and foreign-owned firms. For Irish-owned firms, the largest productivity gains are in the case of investment in R&D intangible assets and in organisational capital while in the case of foreign-owned firms the largest productivity gains are linked to investment in computer software and in organisational capital. Investment in intellectual property assets such as copyrights, patents, licences and royalties are also positively and significantly associated with higher productivity in foreign-owned firms.

In the manufacturing sector, investment in all KBC types with the exception of other intangible assets are positively associated with productivity increases. The largest effect is for investment in computer software followed by investment in intellectual property assets, investment in R&D and investment in organisational capital. In the services sector, while investments in various KBC categories are positively linked to labour productivity, the strength of this link is statistically significant (albeit only marginally at 10 per cent) only in the case of investment in computer software.

TABLE 10 The impact of investment in KBC on firm productivity in Ireland 2006-2012, all firms and firm groups by ownership and sector of activity

Investment in KBC assets	All firms	Irish-owned	Foreign-owned	Manufacturing	Services
All KBC	0.185** (0.077)	0.363* (0.206)	0.240*** (0.044)	0.388*** (0.099)	0.119*** (0.045)
R&D	0.296* (0.174)	0.544** (0.219)	0.270 (0.168)	0.277*** (0.068)	0.164 (0.380)
Computer software	1.304*** (0.464)	-0.206 (0.968)	0.979*** (0.354)	0.890*** (0.143)	1.931* (0.992)
Intellectual property assets	0.069 (0.044)	0.070 (0.112)	0.080** (0.035)	0.290*** (0.065)	0.019 (0.044)
Organisational capital	0.201*** (0.055)	0.342** (0.137)	0.252*** (0.060)	0.276*** (0.074)	0.100 (0.065)
Other intangible assets	0.100 (0.160)	0.251 (0.297)	0.054 (0.108)	0.127 (0.095)	0.057 (0.121)
Number of obs.	25,674	20,729	4,945	7,809	17,336

Notes: Estimates obtained using a one step system GMM estimator. Standard errors clustered at industry level (2-digit NACE Rev. 2). *, **, ***, denote statistically significant at 10 per cent, 5 per cent and 1 per cent levels. Productivity is measured as valued added per employee. The regressions also include the following firm-level characteristics: one-year lagged productivity, investment in tangible capital assets per employee, wage per employee, as well as unobserved time-specific, industry-specific and firm-specific assets.

Source: Based on econometric analysis reported in Di Ubaldo and Siedschlag (2017).

Table 11 shows the estimated effects of investment in KBC on firm productivity for groups of firms by size class. Overall, it appears that the effects are larger and stronger for SMEs (firms with less than 250 employees) in comparison to large firms. Within the SMEs group, the productivity gains linked to investment in KBC assets are larger for medium-sized firms relative to small firms. Given the predominant Irish ownership of SMEs, we have further examined the performance of Irish-

owned firms. A large and statistically significant productivity effect for investment in KBC is found for Irish SMEs which appears to be driven by the performance of firms with 20 to 49 employees. For this group of Irish-owned firms, investment in KBC per employee higher by 10 per cent is translated in a 5.3 per cent productivity gain, over and above other factors which are likely to boost productivity such as investment in tangible capital and human capital.

TABLE 11: The impact of investment in KBC on firm productivity in Ireland 2006-2012, all firms and firm groups by size class

Investment in KBC assets	SMEs	Small	Medium-sized	Large	Irish-owned SMEs	Irish-owned Small	Irish-owned Medium-sized	Irish-owned Large
All KBC	0.235** (0.096)	0.139* (0.071)	0.213** (0.108)	0.088 (0.081)	0.542** (0.234)	0.530*** (0.187)	0.277 (0.173)	0.199 (0.331)
R&D	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)
Computer software	0.970 (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)
Intellectual property assets	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)
Organisational capital	0.196** (0.082)	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)
Other intangible assets	0.083 (0.096)	0.119 (0.122)	0.087 (0.1440)	0.307*** (0.069)	0.381 (0.257)	0.463 (0.573)	0.217 (0.209)	0.045 (0.311)
Number of obs.	23,629	14,560	9,069	2,045	19,756	12,966	6,790	973

Notes: Estimates obtained using a one step system GMM estimator. Standard errors clustered at industry level (2-digit NACE Rev. 2). *, **, ***, denote statistically significant at 10 per cent, 5 per cent and 1 per cent levels. Productivity is measured as valued added per employee. The regressions also include the following firm-level characteristics: one-year lagged productivity, investment in tangible capital assets per employee, wage per employee, as well as unobserved time-specific, industry-specific and firm-specific assets.

Source: Based on econometric analysis reported in Di Ubaldo and Siedschlag (2017).

The analysis of the productivity effects of investment in specific KBC assets provides further insights. For SMEs, the largest and strongest productivity effects are found for investment in R&D, in organisational capital and in intellectual property assets. The performance of large firms is different with the largest and strongest productivity effects found for investment in computer software, in other intangible assets and in organisational capital. Looking at Irish-owned firms, the only statistical significant effects are for investment in organisational capital which appears to be driven by small firms. In the group of small Irish-owned firms the other statistically significant productivity effect is in the case of investment in R&D. This latter effect is quite large, albeit only marginally significant at 10 per cent. In the group of Irish-owned large firms the only statistically significant productivity effect is in the case of investment in intellectual property assets.

5 Incentivising Investment in Knowledge Capital: The Role of Economic Framework Policies

As discussed in Section 1, it is widely recognised that investment in KBC is associated with market failures which lead to underinvestment. Existing empirical evidence¹⁶ suggests that a mix of support policies are needed to incentivise and foster investment in KBC. Such policies are focused on economic framework conditions that affect investment in KBC including: education and human capital; a developed and well functioning financial system; openness to trade and foreign direct investment; legal systems that protect intellectual property rights; pro-competitive product market regulations; flexibility of labour markets

Using comparable information across EU countries, Figures 6-16 illustrate the relationships between such framework conditions and investment in KBC in Ireland and other EU countries. To this purpose, we use information from the INTAN-Invest data set and link the intensity of investment in KBC in Ireland and the other advanced EU countries for which data is available with indicators which summarise countries' performance in the areas mentioned above. A detailed description of the indicators used in this analysis is given in the Appendix C. Since the comparable data on investment in KBC in Ireland and other advanced EU economies is available up to 2010 the indicators which capture countries' performance with respect to economic framework conditions are also for the same period. Where more recent data is available we use these to benchmark Ireland's performance in comparison with other EU countries.

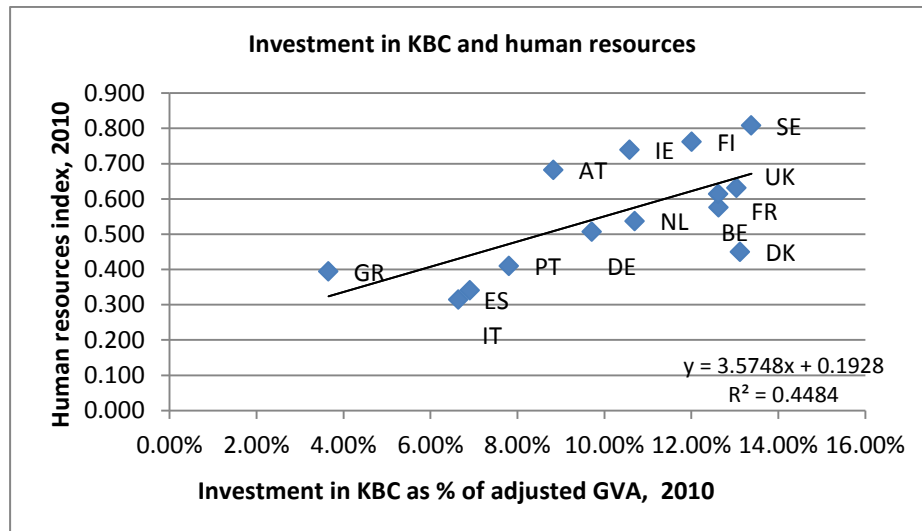
Figure 6 indicates that the intensity of investment in KBC is positively linked to the quality of human resources, measured by a composite indicator. More specifically this indicator summarises country's performance on new doctorate graduates; population aged 30-34 with completed tertiary education; population aged 20-24 having completed at least upper secondary education. On the basis of the scores for 2015,¹⁷ Ireland's performance in this area is very strong, above the EU average in all three dimensions and ahead of all countries with the exceptions of Sweden and Slovenia.

¹⁶ Andrews and de Serres (2012) discuss market failures associated with investment in intangibles and framework policies to address these.

¹⁷ These are taken from the European Union Innovation Scoreboard database available from:

http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en.

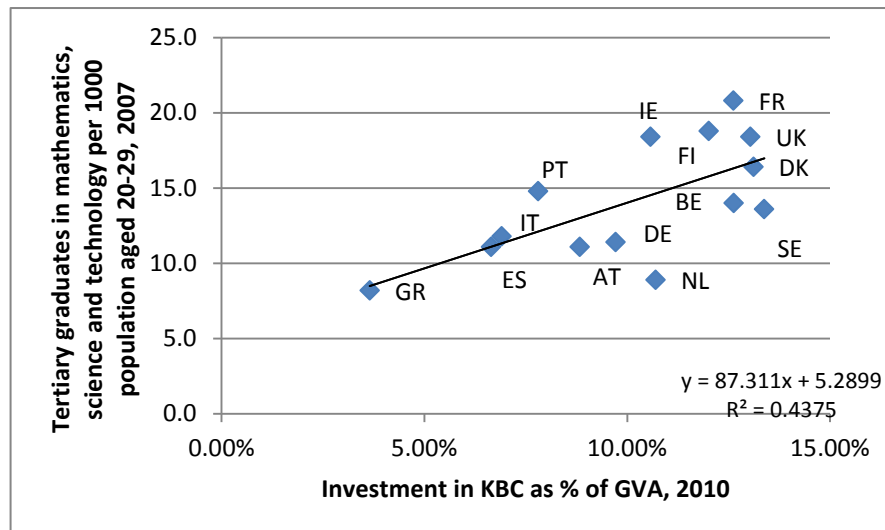
FIGURE 6: Human resources and investment in KBC



Source: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set.

Another indicator of the quality of human capital often used in international comparisons is the number of university graduates in mathematics, science and technology per 1000 population aged 20-29. As shown in Figure 7, the intensity of investment in KBC is higher in countries with higher numbers of graduates in these fields relative to the relevant population group. The latest available data for 2012¹⁸ indicates that Ireland performs very well in this dimension as well, ahead of all EU countries with the exceptions of Belgium and Lithuania.

FIGURE 7: Tertiary graduates in mathematics, science and technology and investment in KBC

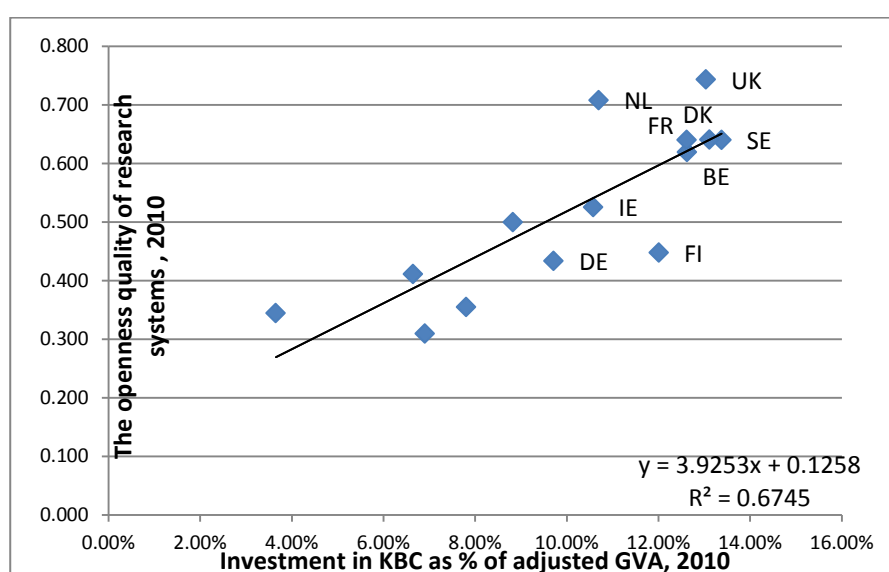


Source: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set.

¹⁸ European Commission Member States' Competitiveness Report 2014.

Figure 8 shows that the intensity of investment in KBC is strongly and positively linked to the openness and quality of research systems, a composite indicator which measures the competitiveness of countries' science base. More specifically, this indicator summarises countries' performance on the following dimensions: international scientific co-publications; most cited publications; non-EU doctorate students. The latest available data on the openness and attractiveness of research systems¹⁹ indicate that in 2015, Ireland's score in this competitiveness dimension was above the EU average but it lagged behind the group of leading countries including: Sweden, the United Kingdom, the Netherlands, Luxembourg, Belgium, Denmark, France and Finland. Ireland's performance is below the EU average with respect to non-EU doctorate students.

FIGURE 8: The openness quality of the research system and investment in KBC

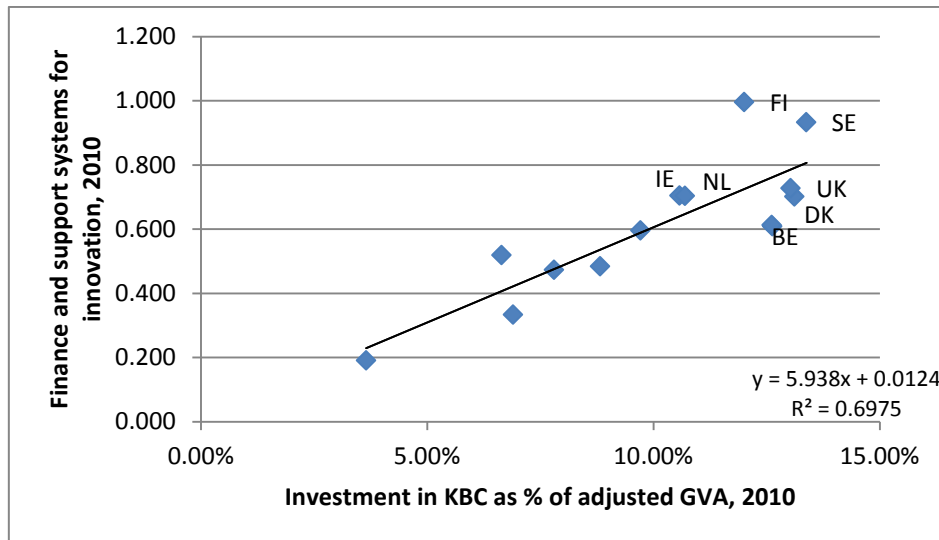


Source: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set.

Figure 9 shows that the intensity of investment in KBC is higher in countries with a well performing finance and support system for innovation. Countries performance in this dimension is measured by a composite indicator which summarises countries performance in the areas of public R&D expenditure and venture capital. Ireland's performance in 2015 in this area was below the EU average, ranked 17th lagging behind many EU countries with respect to its public R&D expenditure performance relative to its GDP.

¹⁹ The European Union Innovation data set available from: <http://ec.europa.eu/DocsRoom/documents/17823>.

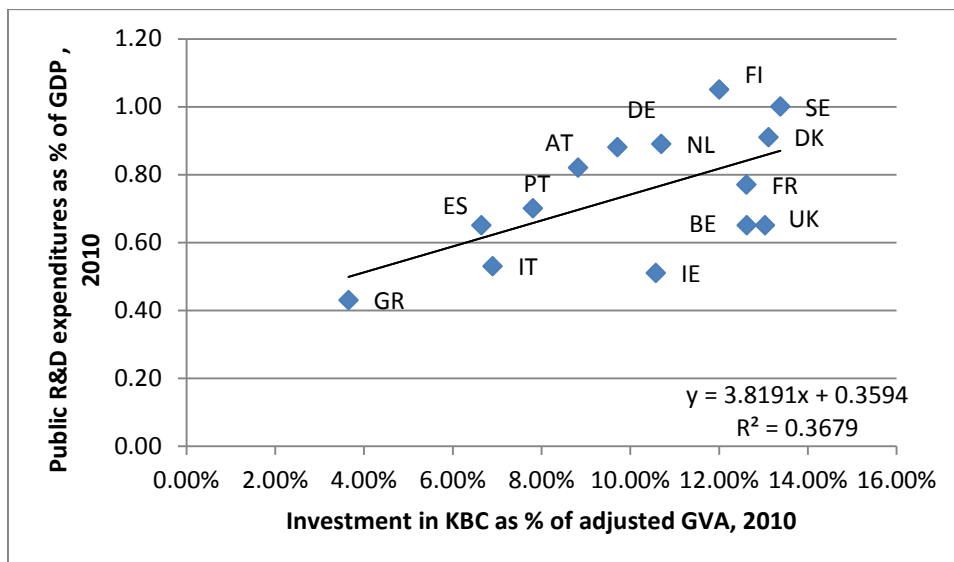
FIGURE 9: Finance and support systems and investment in KBC



Source: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set.

Figure 10 reinforces this message showing Ireland's performance lagging behind many EU countries. According to the score available from the European Union Innovation Scoreboard, Ireland's performance has improved from 2008 until 2011 and it has worsened afterwards. In 2015, Ireland ranked 23rd among EU countries.

FIGURE 10: Public investment in R&D and investment in KBC

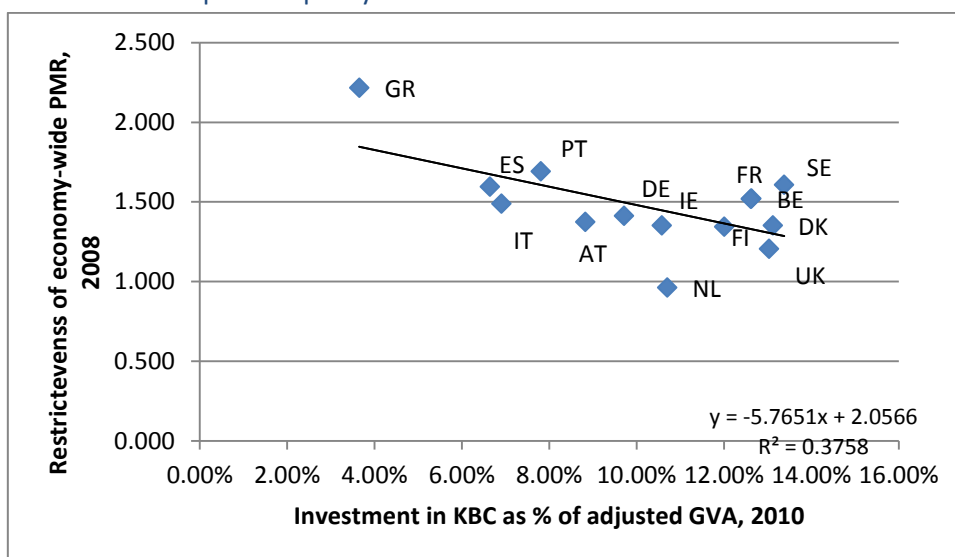


Source: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set.

Figure 11 highlights the role of competition as an enabling factor for the intensity of investment in KBC. Ireland's performance compares favourably to other countries with respect to the restrictiveness of product market regulations, a widely used measure of competition. However,

other EU small open economies including the Netherlands, Denmark, Austria, as well as Germany and the United Kingdom appear to have more competitive markets.

FIGURE 11: Competition policy and investment in KBC

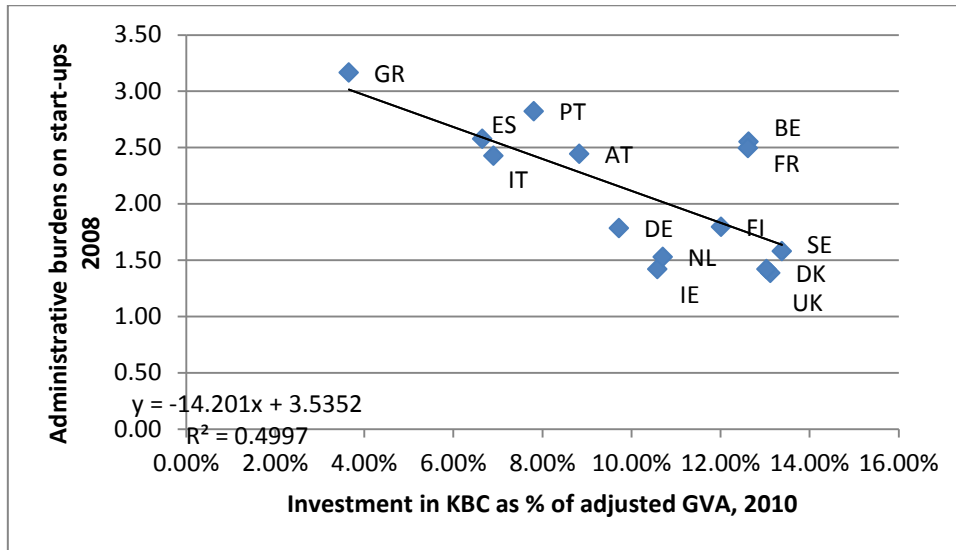


Source: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set..

Figure 12 indicates that administrative burdens to start-ups are negatively linked to investment in KBC. The intensity of investment in KBC is higher in countries where such administrative burdens are perceived to be low. The latest available data from the European Commission²⁰ show that in Ireland the time required to start a business in 2013 was 3.5 days. This performance compares favourably to countries such as France, Germany, Sweden, Austria, and Finland. However, other EU countries perform better than Ireland in this respect, including small open economies: Belgium, Denmark, the Netherlands, Estonia, Portugal, Hungary, Slovenia, as well as Italy, Spain and the United Kingdom.

²⁰ The European Commission Member States' Competitiveness Report 2014.

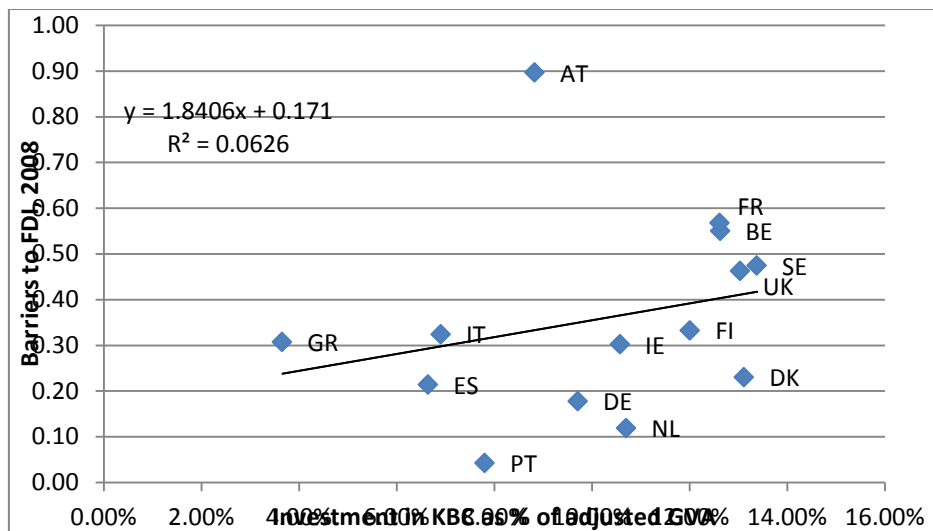
FIGURE 12: Administrative burdens on start-ups and investment in KBC



Source: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set.

Another indicator measuring the quality of the business environment which is often used to assess framework conditions is an index of the freedom from barriers to foreign direct investment (FDI). Figure 13 shows that the intensity of investment in KBC is higher in countries which are more open to FDI. Ireland's performance is very good in this respect. However, it appears that barriers to FDI are lower in Denmark, Spain, Germany the Netherlands, and Portugal.

FIGURE 13: Barriers to FDI and investment in KBC

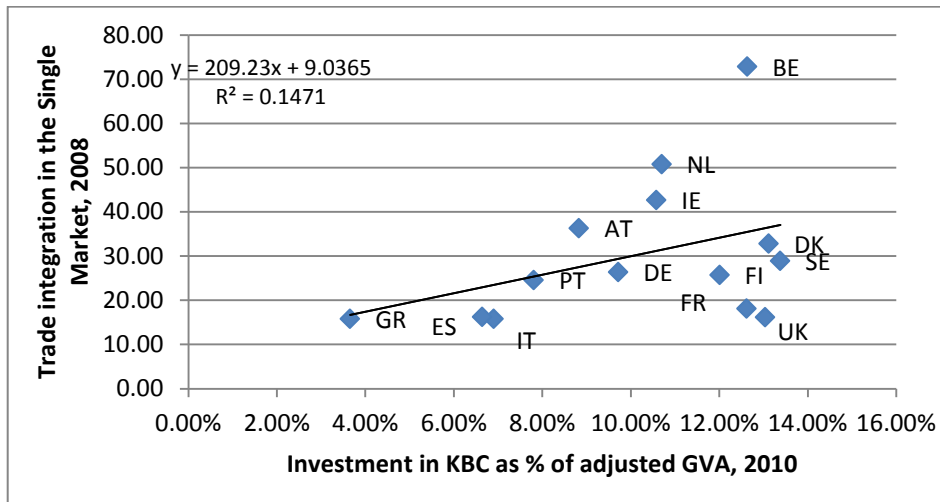


Source: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set.

Figure 14 shows that the intensity of investment in KBC is higher in countries with a higher degree of trade integration in the Single Market. In 2013 Ireland score was 51.7, well above the EU average, 26.0 and many other EU countries. EU countries with higher scores for trade integration in the Single

Market include Belgium, Slovakia, Luxembourg, Hungary, the Czech Republic, Estonia, and the Netherlands.

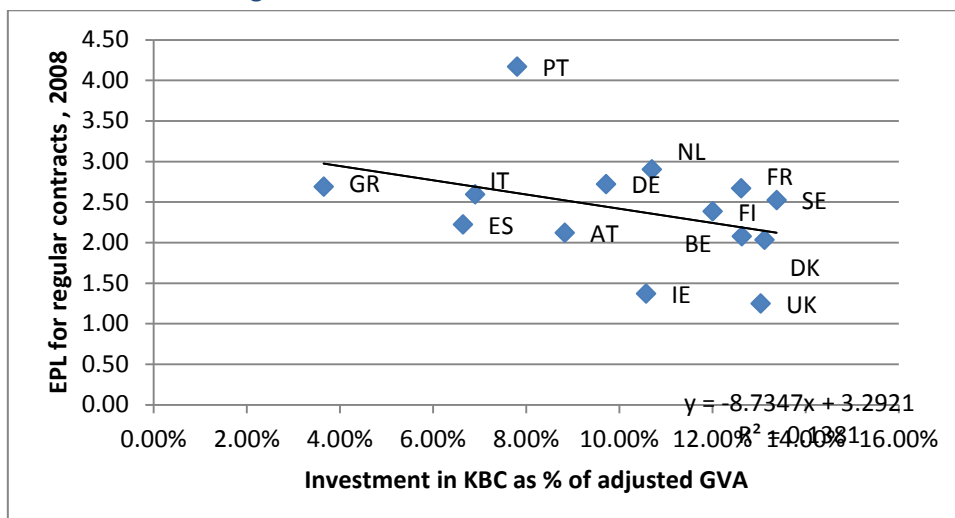
FIGURE 14: Trade integration and investment in KBC



Source: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set.

Figures 15 and 16 show that the intensity of investment in KBC tends to be higher in countries with more flexible labour markets. As shown in many studies,²¹ the flexibility of labour markets measured by the a less strictness of employment protection legislation, facilitate the introduction of more radical innovations and the adjustment to technological changes in particular in industries with a rapid technological change. As shown in Figures 15 and 16, Ireland performs very well in the area of labour market flexibility both with respect to the strictness of employment protection regulations for regular contracts and for temporary contracts.

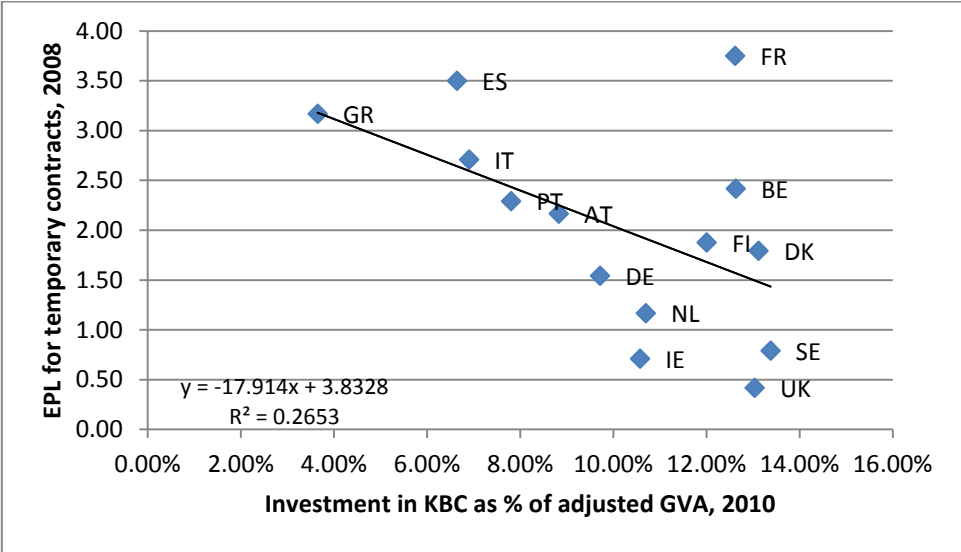
FIGURE 15: EPL for regular contracts and investment in KBC



Source: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set..

²¹ Recent evidence is discussed by Murphy, Siedschlag and McQuinn (2016).

FIGURE 16: EPL for temporary contracts and investment in KBC



Source: Own calculation of investment in KBC as percent of adjusted gross value added based on data from the INTAN-Invest data set and the European Union Innovation Scoreboard data set.

The evidence discussed above highlights Ireland’s performance with respect to the economic framework conditions needed to incentivise and support investment in KBC. In comparison to other EU countries, Ireland performs well on a number of dimensions including the quality of education and human capital, the openness and quality of its research system as well as an enabling business environment with respect to openness to trade and foreign direct investment, pro-competitive product market regulations, flexible labour markets and low administrative burdens to start-ups. The evidence suggests that strengthening the system of finance supports for innovation could incentivise additional investment in KBC.

6 Conclusions and Policy Implications

This paper reviews the international evidence on investments in KBC and their impact on productivity growth in advanced economies. On the basis of this evidence, it sets out a conceptual framework which is used to analyse Ireland's performance at the macroeconomic, industry, and firm levels. The key findings of this analysis are as follows:

Investment in KBC is an important driver of productivity over and above other factors including investment in tangible capital. This result has been established by numerous studies on the basis of analyses of comparable data at country and industry levels as well as firm-level analyses.

Ireland's performance on investment in KBC has improved over time. Using available data over the period 1995-2014, this analysis finds that the most pronounced increase in the intensity of KBC investment has taken place between 2005 and 2010 mainly due to the growing investment intensity in economic competencies and innovative property assets. Among the three main KBC asset categories, investment in economic competencies has had the largest intensity. This highlights the value of the broader definition of intangible investment that falls under the KBC umbrella, as this type of investment in human, organisational and marketing capital would not be captured by more commonly used measures of investment. The steady level of investment in KBC despite the economic downturn is a robust pattern and applies to the three broad KBC assets categories as well as the overall investment rate.

In comparison to other EU advanced economies for which comparable data is available, *in 2010 Ireland's intensity of investment in KBC was the same as in Germany*, and ahead of Austria, Portugal, Italy, Spain, and Greece. However, Ireland's performance lagged behind the leading group including Sweden, Denmark, the United Kingdom, Belgium, France, Finland, and the Netherlands.

Investment in knowledge-based capital is an important driver of labour productivity for all firms and groups of firms in Ireland. Over the analysed period, a 10 per cent increase in investment in knowledge-based capital per employee increased Ireland's firm productivity by 2 per cent. The effect is stronger (i.e. statistically more significant) for foreign-owned firms but it is larger for Irish-owned firms in comparison to foreign-owned firms. Further, productivity gains linked to investment KBC are larger in manufacturing firms in comparison to firms in services.

The productivity effects of investment in specific KBC assets are different for Irish-owned and foreign-owned firms. For Irish-owned firms, the largest productivity gains are in the case of investment in R&D intangible assets and in organisational capital while in the case of foreign-owned firms, the largest productivity gains are linked to investment in computer software and in organisational capital. Investment in intellectual property assets such as copyrights, patents, licences and royalties are also positively and significantly associated with higher productivity in foreign-owned firms.

In the *manufacturing sector*, investment in all KBC types with the exception of other intangible assets are positively associated with productivity increases. The largest effect is for investment in computer software followed by investment in intellectual property assets, investment in R&D and investment in organisational capital. In the *services sector*, while investments in various KBC categories are positively linked to labour productivity, the strength of this link is statistically

significant (albeit only marginally at 10 per cent) only in the case of investment in computer software.

Overall, the effects of investment in KBC on productivity are larger and stronger for SMEs (firms with 20 to 250 employees) in comparison to large firms. Within the SMEs group, the largest and strongest productivity effects are found for investment in R&D, in organisational capital and in intellectual property assets. The performance of large firms is different with the largest and strongest productivity effects found for investment in computer software, in other intangible assets and in organisational capital.

For Irish-owned SMEs, investment in KBC per employee higher by 10 per cent is associated with a 5.3 per cent productivity gain, over and above other factors which are likely to boost productivity such as investment in tangible capital and the stock of human capital.

Overall, the evidence reviewed in this paper suggests that incentivising more investment in KBC could lead to a stronger innovation and productivity performance in Ireland. It is widely recognised that investment in KBC is associated with market failures which lead to underinvestment. To the extent that a higher intensity of investment in KBC is desirable, a mix of support policies focused on economic framework conditions that affect investment in KBC is beneficial.

The evidence highlights that while investment in R&D is an important driver of productivity, a comprehensive policy approach is needed to include investments in intangible assets such as computer software, copyrights, patents and licences, as well as firm-specific human capital and organisational capital.

The evidence based on firm-level analysis suggests that *policy approaches to incentivise investment in KBC should be different for Irish-owned and foreign-owned firms.* Fostering investment in non-R&D intangibles in the indigenous sector and incentivising additional investment in R&D by foreign-owned firms in Ireland could increase productivity growth.

The results of this analysis also suggest that *a sectoral policy approach would be useful, particularly to incentivise additional investment in intangibles in the services sector.*

The evidence reviewed in this report also suggests that an integrated policy approach to supports would increase the impact of investment in KBC. An integrated approach includes strengthening the national innovation system and its links with the global innovation system as well as a system of complementary enterprise supports for investment in a broad range of intangible assets beyond R&D.

Further research to provide additional evidence on Ireland's investments in KBC could address the following questions:

- 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?

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Appendix A Data and Methodological Notes

Table A1 INTAN Data Set at the Industry Level and Updates for Ireland: Methodological Notes

Asset Type	INTAN data set		Updated data for Ireland	
	Data sources	1995-2010 Measurement/Estimation methods	Data sources	2011-2014 Measurement/Estimation methods
Computerised information				
Computer software	EU KLEMS, National Accounts, Supply and Use Tables		National Accounts	Available in National Accounts (NA). The difference in levels between the two sources was taken into account by using the NA growth rates to extrapolate the INTAN measures.
Innovative property				
Scientific R&D	Eurostat, BERD		National Accounts	NA used as BERD sectoral detail was not available for more recent years. The difference in levels between the two sources (which is largely due to the presence of contract manufacturing in the NA definition) was taken into account by using the NA growth rates to extrapolate the INTAN measures.
New architectural and engineering designs	Business expenditure data by industry available from Use Tables compiled according to NACE Rev. 2	Estimated detailed intangible investment in 2008. Applied the rate of change of value added by industry (from the National Accounts) to the estimated intangible investment in 2008.	National Accounts	Since output for the architectural and engineering sector is not available for all years, output from the Building and Construction sector from NA was used. The difference in levels between the two sources was taken into account by using the NA growth rates to extrapolate the INTAN measures. Allocated across other sectors on the basis of historic shares in the INTAN data (these are stable over time and originally based on supply and use tables)

New product development cost in the financial services industry	EU KLEMS, WIOD, OECD STAN database	Innovation expenditure estimated as 8% of the total labour compensation of highly skilled in the financial services industry	QHNS and EHECS	Numbers of managerial grade employees in financial services industry from QHNS combined with salary information based on the mid-point of the salary deciles collected in QHNS. Salaries cross-checked with average managerial and average financial services salary data from EHECS.
Entertainment, Artistic and Literary Originals + Mineral Explorations	National Accounts		National Accounts	Output directly measured in NA. Allocated across other sectors on the basis of historic shares in the INTAN data (these are stable over time and originally based on supply and use tables)
<i>Economic competencies</i>				
Market research + Advertising expenditure	Business expenditure data by industry available from Use Tables compiled according to NACE Rev. 2	Estimated detailed intangible investment in 2008 Applied the rate of change of value added by industry (from the National Accounts) to the estimated intangible investment in 2008	National Accounts	Since output for the advertising sector is not available for all years, output of Market Services available in NA was used. Allocated across other sectors on the basis of historic shares in the INTAN data (these are stable over time and originally based on supply and use tables)
Training – purchased and own account firm specific human capital	Continuing Vocational Training (CVT) Survey Labour Cost Survey – apprentice cost National Accounts – compensation of employees	Cost of CVT as a percent of total labour cost * compensation of employees Apprentice cost as a percent of total labour costs* compensation of employees	QHNS	Numbers of apprentices and employees undertaking in-work training measured in QHNS combined with salary information based on the mid-point of the salary deciles collected in QHNS. Most recent CVT survey in Ireland was 2005; new survey was carried out in 2015 but data not yet available.
Organisational Capital	Business expenditure data by industry available from Use Tables compiled according to NACE Rev. 2	Estimated detailed intangible investment in 2008 Applied the rate of change of value added by industry (from the National Accounts) to the	QHNS	Numbers of managerial grade employees in QHNS combined with salary information based on the mid-point of the salary deciles collected in QHNS.

		estimated intangible investment in 2008		No information available on spending on consultancy services so to avoid any discontinuity the INTAN total was adjusted using the growth rate from the QNHS series.
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Source: Corrado, Carol, Jonathan Haskel, Cecilia Jona-Lasinio and Massimiliano Iommi (2014). "Internationally comparable macro-estimates of investment in intangible assets at the industry level: INTAN - Invest" available at www.INTAN-Invest.net. The data set covers the following sectors: agriculture; mining; manufacturing; utilities; construction; trade; financial services; other services.

APPENDIX B Updating the INTAN-Invest Data Set for Ireland: Methodology and Data Sources

Updating the INTAN data for Ireland involved combining a number of different sources:

- **The software, databases and R&D investment growth rates** were taken from the national accounts, with an adjustment made for the difference in levels relative to the original INTAN estimates.
- **The figures for R&D** were taken from the National Accounts in order to update the INTAN data as detailed sectoral information is available from this source whereas breakdowns by sector were not available for the more recent years in the BERD release. The sectoral capital formations for R&D are all available at the CSO (although since 2015 some detail has been suppressed so further updating would not be able to rely on this source) <http://www.cso.ie/en/releasesandpublications/er/csfa/estimatesofthecapitalstockoffixedassets2014/>. As noted, this means that there is an additional element of R&D expenditure being included in the source data (spending abroad as noted below). An assumption was made that the overall R&D expenditure would grow by the same rate in the BERD and NA definitions and, in order to avoid a change in the level of the INTAN measure, the NA growth rate of R&D was used to extrapolate forward the INTAN R&D measure. The use of the growth rates as the basis to avoid a jump in levels should be quite reliable, particularly over the relatively short time period for which the extrapolation is applied. A comparison between the growth rates for the years 2008-2010 was undertaken to ensure this was a reasonable assumption to make. The change in the capital stock is taken as the indicator of investment spending.
- To keep the comparisons as close as possible with the original INTAN database, we used growth rates of our comparison series as the basis for the extended numbers, in order that the effects of changes in data source are kept to a minimum.
- **Mineral explorations and artistic originals** were also taken from the national accounts and allocated across sectors on the basis of the share of input-output tables.
- **New product development in the financial services** was estimated from expenditure in this sector on managerial and professional salaries, calculated from employment numbers in these occupational categories from the Quarterly National Household Survey (QHNS) and salary information from the Earnings, Hours and Employment Costs (EHECS) survey.
- **Architecture and engineering** investment was estimated by allocating the output of this sector across other economic sectors using input-output methods. There was no new level of investment calculated for 2008. In order to ensure that the data used to extend this sector forward was a reliable substitute, the growth rates were compared between both the INTAN and the new source from 2008 to 2010 before using the building and construction sector as a proxy for the output of architecture and engineering. Using the output of the architecture and engineering sector as the indicator of the economy's investment in new designs follows the methodology of Corrado *et al* (2012).

- **Brand equity** was extrapolated from 2010 to 2014 by exploiting the growth rate of output in the Market Services industry, available in the national accounts. The total value was allocated across the sectors based on their utilisation. As above, there was no new level of investment calculated for 2008. In order to ensure that the data used to extend this sector forward was a reliable substitute, the growth rates were compared between both the INTAN and the new source from 2008 to 2010 before using overall market services as a proxy for the sub-sector relating to market research and advertising. Corrado *et al* (2012) use estimates of the output of the market research and advertising sectors (with the former doubled to cover own-account spending) as a proxy for investment in brand equity by other sectors of the economy. In the absence of detailed information on these sub-sectors, we assume that they grow in line with the broader market services sector in extrapolating this series in the Irish update.
- **Training expenditure** was estimated based on the numbers of apprentices and employees undertaking training courses from the QNHS.
- **Organisational capital** was based on a percentage of management expenditure, calculated from the Quarterly National Household Survey (QHNS) employment numbers and the Earnings Hours and Employment Costs Survey (EHECS) salary results.

APPENDIX C Description of Policy Indicators

Indicator	Definition	Data Source
Summary Innovation Index	Composite indicator which measures innovation performance at country level on the basis of three types of indicators: innovation enablers; firm innovation activities; economic outputs	European Union Innovation Scoreboard data set
Knowledge intensive exports, % of GDP		Member States' Competitiveness Report 2014, European Commission
The openness and quality of research systems	Composite indicator measuring the international competitiveness of the science base. It summarises country performance on: international scientific co-publications; most cited publications; non-EU doctorate students	European Union innovation Scoreboard data set
Human resources index	Composite indicator which summarises country performance on new doctorate graduates; population aged 30-34 with completed tertiary education; population aged 20-24 having completed at least upper secondary education	European Union Innovation Scoreboard data set
Finance and support system	Composite indicator which measures the availability of finance for innovation projects. The indicator measures countries' performance in the areas of public investment in R&D and venture capital	European Union Innovation Scoreboard data set
Firms' investment in innovation	Composite indicator which captures: R&D expenditure in the business sector; non-R&D innovation expenditure	European Union Innovation Scoreboard data set
Administrative burdens on start-ups		Member States' Competitiveness Report 2014, European Commission
Restrictiveness of economy wide product market regulations	OECD indicator	Member States' Competitiveness Report 2014, European Commission
Barriers to FDI		Member States' Competitiveness Report 2014, European Commission

Year	Number	Title/Author(s) ESRI Authors/Affiliates <i>Italicised</i>
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