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Is Ireland the most intangible intensive economy in Europe? A growth accounting perspective.*

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Abstract

Assessing the contribution of intangible investment to growth is a challenging and complex task for any country. However, it has become increasingly difficult to determine both the exact magnitude of economic performance and its composition in the case of the Irish economy. This is mainly due to the impact of certain distortionary transactions by a select number of multinationals operating in the Irish jurisdiction. In this paper we address this issue by assessing, in a detailed manner, the contribution of intangible and tangible assets to the Irish growth story. We control for distortions in the official investment data series while also incorporating intangible assets which are not currently included in the National Accounts. Our results show that the observed unprecedented increase in the official intangible investment has a relatively minor contribution to the actual Irish labour productivity growth. Once the distortions are filtered out, Irish labour productivity growth is driven by tangible capital. More interestingly, non-national accounts intangible capital has a sizeable pro-cyclical impact on labour productivity growth.

Keywords: growth; investment; intangible assets
JEL Classification: E01; E22; O47

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1 Introduction

In this paper we consider the role of investment in the performance of the Irish economy over the period 2000 – 2016, focusing mainly on the impact of intangible assets. We believe the Irish case is a particularly interesting example of the role played by intangible investment for three separate but inter-related reasons. First, over the period in question, the Irish economy experienced some of the most volatile growth rates amongst OECD countries; after the high growth period of the 'Celtic Tiger' (1995 – 2007), the domestic economy sharply contracted following the emergence of a severe credit bubble in the residential and commercial property sectors. Since 2013, however, the economy has grown at a significant rate in both output and employment. Second, the Irish economy is one of the most open in international terms; much of the improved performance post-2013 was characterised by export-led growth (see McQuinn and Varthalitis (2020) and the references therein for more on this). Consequently, it has attracted some of the largest inflows of intangible capital across countries over a prolonged period of time. Finally, apart from estimates of domestic demand and the labour market, it is increasingly difficult to estimate both the magnitude of Irish economic growth and its composition. This mainly relates to the increased importance of the intangible investment category in the Irish national accounts and, more particularly, the impact of certain distortionary transactions by a select few multinational firms (MNEs) based in the Irish jurisdiction. The most significant of these distortions has to do with large capital assets of these MNEs and, in particular, the manner in which the depreciation of these assets impacts both headline investment and GDP data. Official national accounts data for Ireland indicates, for example, that real investment grew by 11.4% percent from 2000 to 2016 while real GVA also officially grew by 4.88% from 2000 to 2016.[1] Over the same period, according to the official statistics, Ireland became one of the most intangible intensive economies in the European Union, since the ratio of the official intangible investment with respect to tangible investment rose from 0.17 in 1995 to 2.45 2016. The latter constitutes an enormous change especially if contrasted with the associated change in the EU average ratio which saw an increase from 0.28 in 1995 to 0.46 in 2016.

In addition to the difficulties associated with the measurement of investment as presently defined in the national accounts, there is the equally important issue of the classification of various investment assets. In order to better understand the role played by intangible capital, Corrado et al. (2005) introduced a set of criteria based on which various types of expenditures can be classified as investment rather than intermediate inputs.[2] This led to an expansion of the definition of intangible assets and a corresponding modification of the output measure of the economy. Although there have been a number of amendments in the intangible asset definition of the official National Accounts –most recently, the 2008 revision introduced Research and Development and Artistic Originals into the set of Intellectual Property Products assets- there are still a number of assets (such as design, branding and training) that are excluded as noted by Corrado et al. (2018). The work of Corrado et al. (2005, 2009) has led to the publication of the INTAN-Invest database (henceforth INTAN), which provides unified time series for both categories of intangibles assets; namely, both those currently reported in National Accounts (henceforth NA intangibles) and the intangible assets that have not yet been included in National Accounts (henceforth non-NA intangibles).[3]

[1] Indicatively, the headline GDP had the well-known increase of 25 per cent in 2015 which prompted the famous leprechaun economics term by Krugman (2017).

[2] The increase in intangible capital across major developed economies in the present century has had a major impact on a number of significant macroeconomic issues - for a thorough analysis see Haskel and Westlake (2017).

[3] The Corrado et al. (2016) comprehensive database includes data for intangible assets for 19 EU countries and

All of this makes quantifying the exact growth rate of the economy particularly difficult and complex, leading to a number of issues. For example, apart from their usage in day-to-day commentary of the economy, official output estimates are essential for monitoring of the public finances as they are the official metric used to implement the EU fiscal rules. Also, the implementation of key elements of modern macroprudential policy relies on the relationship between the total stock of credit in an economy and GDP i.e. the degree of financial deepening in an economy.

Equally, it has become increasingly challenging to determine the composition of Irish growth over the past decades. From a standard growth accounting perspective, if both estimates of output and input (in particular, investment/capital) are subject to sizeable distortions, then accurately assessing the contribution of the factors of production and total factor productivity to economic growth becomes almost impossible.

The purpose of our paper is twofold; first, we wish to provide a more accurate account of the role played by tangible and intangible assets in the Irish economy by isolating and removing the distortionary transactions from the official data in the national accounts. Additionally, we quantify the impact of the INTAN estimates of non-NA intangible assets on Irish economic performance. Amongst other benefits, this will lead to an enhanced quantification of capital deepening in the Irish economy and will provide a more accurate measurement of the 'real' underlying rate of output growth.

Our paper also contributes to the rapidly growing literature that computes the contribution of intangible assets on economic growth in various countries; one strand of the literature focuses on using a standard growth accounting approach in order to decompose labour productive growth into the contributions of the factor shares; a non-exhaustive list includes Corrado et al. (2013, 2016, 2018), Niebel et al. (2017) and Piekkola (2018). Another branch utilizes panel econometric techniques in order to quantify the relationship between intangible capital and labour productivity growth – see, among others, Roth and Thum (2013), Roth (2020), Hintzmann et al. (2021), Roth and Sen (2021). Finally, Chen et al. (2016) and Corrado et al. (2017) focused on analyzing capital asset complementarities and spillover effects.[4] This paper focuses on the special case of Ireland and, to our knowledge, this is the only paper that takes into account both the effect of the well known distortions in Ireland's national accounts and non-NA intangible assets using a unified growth accounting framework.

Our analysis sheds light on the actual contribution of intangible investment in the Irish growth story. We find that the observed unprecedented increase in the official intangible investment has a relatively minor contribution to the actual Irish labour productivity growth. The largest share of NA intangible asset is related to the distortionary impact of a small number of foreign-affiliated enterprises and once this is taken into account the official intangible intensity of Ireland becomes rather normal and much closer (or even lower than) to EU averages. On the other hand, non-NA intangible assets, such as training, organizational capital and branding have a sizeable impact on labour productivity growth during the 2000-2016 period. Due to their specific nature, non-NA intangibles (taken from INTAN) are less likely to be distorted and thus their contribution to growth share constitutes a more reliable measure of the contribution of intangibles to the Irish labour productivity growth.

Regarding the effect of the distortions in Irish investment series, our analysis indicates that the overall size of the potential mismeasurement from a growth accounting perspective is quite substantial over the period 2000-2016. Specifically, once we remove the distortions, labour productivity growth falls by 2.17 p.p. and capital deepening falls by 1.38 p.p., i.e., a significant decrease of 60% and 39%, respectively. Total factor productivity is also reduced

the US.

[4]For a recent literature review see Roth and Sen (2021).

and actually turns negative, falling by 0.79 p.p. over the period 2000-2016. Thus, computing the sources of Irish growth by using the official statistics leads to a substantial overestimation of the Irish labour productivity growth and the contribution of capital deepening to it. The fall in TFP, which is used in the growth accounting literature (see e.g.,Barro (1999)) as a measure of the unexplained component of growth, clearly illustrates the magnitude of this mismeasurement and the size of the error in case one uses the unfiltered official Irish data.

Turning to the case when we use filtered data, that is, once we remove the distortions from Irish national accounts investment series, we find that the inclusion of non-NA intangible capital as a source of growth robustly affects labour productivity growth along the business cycle. In particular, the contribution of non-NA intangibles is pro-cyclical. Our results indicate that adjusting gross value added for non-NA intangible assets increases Irish labour productivity growth by 0.52 p.p. during the 2000-2007 boom period and reduced it by 0.98 p.p. during the 2008-2016 bust period.

Moreover, the inclusion of non-NA intangible assets substantially changes the relative importance of factors that explain Irish labour productivity growth. In particular, the share of the contribution of capital deepening to growth increases substantially from 77% to 93% during the 2000-2007 boom period and from 61% to 78% during the 2008-2016 bust period. On the other hand, the share of TFP as a source of growth falls substantially from 23% to 7% during 2000-2007 and from 39% to 22% during the 2008-2016 period.

Once we decompose capital deepening into its constituents, i.e., tangible, NA-intangible and non-NA intangible capital deepening, we find that the largest share of it is attributed to tangible capital followed by non-NA intangible capital. Perhaps more interestingly, the share of the contribution of NA-intangible capital becomes quite small. Thus, the remarkable NA-intangible intensity of Ireland, observed in the official statistics, does not translate to a similar in magnitude contribution to labour productivity growth.

The rest of our paper is laid out as follows: section 2 presents some descriptive evidence of the distortionary impact of MNEs in the Irish National Accounts. Section 3 describes the dataset and the approach followed in order to filter out the distortions, while section 4 presents the growth accounting framework. Section 5 presents the results and section 6 concludes.

2 Investment in the Irish economy

As noted in FitzGerald (2000), Honohan and Walsh (2002), Whelan (2014)) and more recently in McQuinn and Varthalitis (2020) and Klein and Ventura (2021), the significant improvement in the Irish economy over the past 25 years has been due to the increasingly globalised nature of the domestic economy. A key catalyst in attracting inward foreign investment into Ireland has been the low rate of corporation tax set by the Irish authorities with the present rate of 12.5 per cent on trading income being established in 2003. As a result, many large MNEs established subsidiaries in the Irish jurisdiction with, particularly, US firms transferring Intellectual Property Products (IPP) and profits to Ireland (see Conroy et al. (1998)). As such Irish official macroeconomic aggregates such as investment and output have always been problematic indicators of the domestic macroeconomic performance. Thus, their usefulness in decomposing the Irish sources of growth is at least limited.

The impact of globalisation on the official Irish investment series has been outlined in FitzGerald (2018). This includes, but is not confined to, changes in patents of pharmaceutical companies and the inclusion of Intellectual Property Products (IPP) in investment, interacting with changes in ownership of this IPP (see also de Haan and Haynes (2018)). The most significant development in this regard came in 2015 with the once-off transfer to Ireland of

IP owned by foreign MNEs. This resulted in the Irish capital stock increasing by 53 per cent, reaching a level almost three times that of GDP. There was also another sizeable increase in investment in IPP in 2016 which saw a further 10 per cent increase in the economy's capital stock.

Estimates of national output were also significantly impacted by this transfer of IPP by firms to the Irish jurisdiction. These firms then used the IPP now located in Ireland to manufacture goods in other countries. These transactions took place in these countries on a contractual basis rather than through wholly owned subsidiaries. The difference between this payment to the firm manufacturing the goods and the profit on the goods, which used the parent firm's IPP, is then recognized as output in the Irish national accounts where the IPP formally reside. This was the reason for the substantial increase in Ireland's GDP in 2015.

Figure 1 illustrates the severity of the problem over time. The dotted-black line depicts the distortion as a percentage of total investment which has risen considerably since 1995 from 1.6 per cent to 65 per cent at the end of 2016. The dark grey and light grey shaded areas decompose the aggregate distortion into the distortion related to intangible and tangible assets respectively. As can be seen, the distortion attributed to intangible assets is substantial since 2001 while from 2009 onwards it is consistently more than 10 per cent of the official figure of Irish investment series (see the dark grey shaded area). At the same time, a large part of tangible assets also distorts the official statistics, mostly during the 2009-2014 period. However, on average, over the 1995-2016 period the distortion attributed to tangible assets is much smaller in magnitude with respect to the associated share attributed to intangibles.

These distortions in domestic investment data on intellectual property are not just confined to Irish national economic data; they can also be observed in the growing relevance of certain related Irish macroeconomic data on the corresponding Euro area aggregates; e.g., Ireland's EU share of intangible investment in the official statistics rises from 1.21% over 1995-2003 to 4.87% in 2010-2016 which is the largest increase observed in the EU. Because of these distortions, most international policy institutes, e.g., ECB and IMF, usually publish their official forecasts both including and excluding Ireland's macroeconomic aggregates.

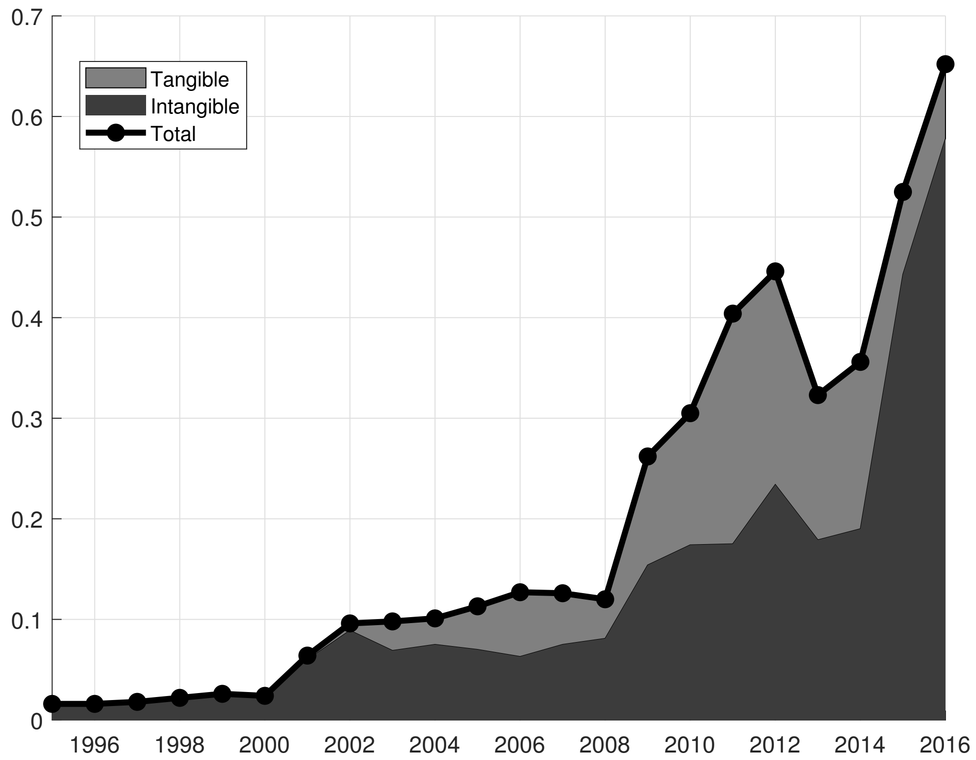
In summary, although Ireland is one of the most intangible intensive European economies, the official share does not accurately measure the share of intangible assets in the Irish economy, due to distortions in IPP data. One should adjust Irish investment data for these distortions to accurately measure the contribution of intangible capital to the Irish growth rate. In the next section, we explain in detail how we reconcile various databases to execute this task.

3 Data and Sources

The data for the Irish economy, covering the 1995-2016 period, are collected from the following databases: Eurostat, the Central Statistical Office of Ireland (CSO) and the INTAN-Invest database developed by Corrado et al. (2016, 2018). The time dimension of the analysis is largely dictated by the data availability of the INTAN database. In particular, we utilize its latest iteration (updated in April 2020), which contains nominal and real values for various investment assets -described in this section- up to 2016. For a detailed description of the INTAN database the interested reader is referred to the paper of Corrado et al. (2016). We note that since the INTAN data only cover the business sector of the economy,[5] we adjust our

[5] The business sector of the economy comprises the following NACE sectors: Agriculture, forestry and fishing (A), Mining and quarrying (B), Manufacturing (C), Electricity, gas, steam and air conditioning supply (D), Water supply, sewerage, waste management and remediation activities (E), Construction (F), Wholesale and retail trade: repair of motor vehicles and motorcycles (G), Transportation and storage (H), Accommodation and food service activities (I), Information and communication (J), Financial and insurance activities (K), Professional, scientific

Figure 1: Distortion as per cent of the official investment levels



Source: Authors' calculations based on data from CSO's Modified Total Domestic Demand database (Table NQQ50). For more details on the calculation of the distortion see section 3.

aggregate measures so that they are compatible with the INTAN definition. In the interest of space, we provide a detailed analysis only for the data which play a key role in our growth exercise below. Our data and the respective sources are listed in Table A2 in the Appendix B.

Regarding the investment data, which are at the core of our analysis, we follow national accounts conventions and the relevant literature (see, among others, Roth and Thum (2013) and Corrado et al. (2016, 2018)) and distinguish between three broad categories of assets: tangible assets, NA-intangible assets and non-NA intangible assets.

Starting with the assets that are already included in the National Accounts, the tangible assets category refers to the following assets: total construction, machinery and equipment and weapons systems, transport and information and communication technologies (ICT) equipment.[6] The relevant data are taken from the Eurostat National Accounts database on Gross Fixed Capital Formation by Industry.

The National Accounts intangible assets refer to the Intellectual Property Products (IPP) category, which mainly comprises research and development and computer software and databases.[7] As in the case of tangible investment, the relevant data were sourced from Eurostat's National Accounts database.

However, apart from this set of intangibles, there are certain expenditure categories (such as expenditures on design, branding, training, organisational capital and financial innovation) that have long been considered as part of capital formation in an economic sense but are not included in the National Accounts due to measurement issues (see Van Criekingen et al. (2021) for a recent overview of the main issues regarding intangible investment measurement). An insight into why these expenditures are not capitalized and, as such, not included in the investment categories of the National Accounts is provided in the following quote from the 1993 version of the System of National Accounts, reproduced here from Van Criekingen et al. (2021): '...However, expenditures on training and research or development do not lead to the creation of assets that can be easily identified, quantified and valued for balance sheet purposes.' Although R&D has since been included in the intangible assets reported in the National Accounts following the 2008 revision of the System of National Accounts (SNA), a number of assets are still excluded.

Corrado et al. (2005, 2009), in their seminal contributions, advocated an expenditures-based approach for the measurement of these new categories of intangible assets. Their core argument is that since investment can be defined as '...any use of resources that reduces current consumption in order to increase it in the future...' (Corrado et al. (2005)), then a number of expenditures undertaken by businesses for design, branding, training, organisational capital and financial innovation qualifies for classification under the intangible assets category. Once these expenditures, currently treated as intermediate costs in the National Accounts, are considered as capital formation they expand the asset boundary as defined by the SNA 2008 and the 2010 European System of Accounts (ESA 2010). Corrado et al. (2005, 2009) identify the following categories of intangible assets not currently included in the Na-

and technical activities (M), Administrative and support service activities (N), Arts, entertainment and recreation (R), Other service activities (S).

[6]We note here that in our analysis, ICT refers only to information and communication *equipment*, reflecting the asset classification of Eurostat - specifically, asset category AN.1132. This is in contrast to Niebel et al. (2017), who include ICT equipment as part of their NA intangibles category, implying that their broad category of intangibles also includes tangible assets.

[7]There is another category of National Accounts intangibles, namely Artistic Originals and Mineral Exploration. This category is not directly available in the National Accounts, rather, it is calculated as a residual by subtracting from IPP both R&D and Software&Databases. One problem is that for the case of Ireland, these data are not available at a sectoral level, implying that we cannot calculate the respective capital stocks for the sources of growth analysis. We note here that this category, for the time period under consideration, represents only 1.2% of Total Investment and 8.3% of NA Intangible investment (3.9% in the post-crisis period).

tional Accounts: innovative property and economic competencies.[8] We source data for the non-NA intangible assets from the INTAN database developed by Corrado et al. (2016, 2018).

It should be noted here that the introduction of these assets will have an impact on the measured level of output -in our case, Gross Value Added- reported in the National Accounts. In the next section 3.1 we present how the new adjusted GVA measure is computed.

3.1 Data adjustments

As already discussed in section 2, Ireland's main macroeconomic aggregates have been substantially impacted by certain distortionary transactions of a small number of multinational firms. In order to disentangle the actual contribution of tangible, NA- and non-NA- intangible capital to the growth performance of the Irish economy, we proceed with implementing two adjustments in the data: first, we remove the distortions from the macroeconomic aggregates reported in Ireland's national accounts; second, as in Corrado et al. (2005), Corrado et al. (2016, 2018) and Niebel et al. (2017), we take into account the non-NA intangible investment assets by adjusting the official level of gross value added.

In the next two paragraphs, we explain how we are stripping out the distortions from the official Irish time series, i.e., gross value added and tangible and NA-intangible investment, to come up with the associated filtered time series.[9]

Firstly, we need an approximation of the level of distortions in the official investment series of the Irish economy. To this end, we utilize two unique data series produced by the CSO, namely, gross domestic fixed capital formation on Aircraft related leasing and R&D imports and Trade in IPP, respectively. Both series are sourced from CSO's Modified Total Domestic Demand database. These series constitute the only publicly available proxies of the size of the distortion in Irish investment data. It should be noted that they are only available for the aggregate economy, that is, a sectoral breakdown is not available. As such, in what follows, we present the procedure adopted for allocating the aggregate estimates of the distortion to the NACE sectors included in our analysis.

Starting with the NA intangible investment, we identify from the official data the sectors that are the most intangible-intensive in Ireland for the time period under consideration. As a measure of sectoral intangible intensity we use the ratio of NA-intangible assets to total investment in each sector. Based on this metric, the most intangible-intensive sectors in Ireland for this time period are Manufacturing (C), Information and communication (J), Financial and insurance activities (K), Professional, scientific and technical activities (M) and Administrative and support service activities (N). Based on this set of evidence, in a second step, we allocate the aggregate distortion related to intangible investment across these five sectors. To do this we use weights based on the intangible intensity of each sector. In particular, the distortion $D_{i,t}$, allocated to each sector i mentioned above in year t, is given by:

$$D_{i,t} = w_{i,t} * D_t^I \tag{1}$$

where the weights are computed as $w_{i,t} = \frac{X_{i,t}}{\sum_i X_{i,t}}$ with $X_{i,t}$ denoting NA-intangible investment in sector i, $\sum_i X_{i,t}$ is the sum of intangible investment for the five sectors and D_t^I is the aggregate measure of the distortion related to NA intangible assets (that is, R&D imports and Trade in IPP). By definition, $\sum_i w_{i,t} = 1$ thus the distortion related to NA-intangibles is fully

[8]A third category mentioned by Corrado et al. (2005), namely, Computerized Information consisting of Software and Databases is, as already mentioned, included in the National Accounts.

[9]Throughout the paper we refer to the national accounts investment and GVA as *official* or *distorted* interchangeably; the data that have been adjusted for distortions are referred to as *filtered*.

allocated across these five sectors. Then, to compute the filtered NA-investment series we deduct the distortion, $D_{i,t}$ from each sector's official investment series.[10]

Given that the investment series are in nominal terms, we need to deflate them before proceeding with the calculation of the capital stocks. Since the investment series for these sectors are highly distorted we expect that the associated investment deflators bear these distortions as well. As such, and in accordance with the literature (see e.g., Corrado et al. (2009) and Niebel et al. (2017)), we construct a GVA deflator common for all industries and all assets . In particular, we proxy the Irish GVA deflator by constructing a GVA price index for the total business sector of the rest of the EU countries included in the INTAN dataset.

For the tangible investment series, we assume that since the distortion, as identified by the CSO, relates to Aircraft Leasing, it only affects the Transportation and Storage sector (H). Therefore, we focus on this sector only and simply subtract the distortion from the official level of investment. Again, we deflate this series using the above mentioned GVA deflator.[11] The impact of the distortions in the official Irish investment series is quite substantial. To illustrate this, Figure 2 depicts the ratio of NA intangibles to tangibles over the period 1995-2016. In particular, in the left panel we present the NA intangible to tangible assets ratio in Ireland using the official data (see red line) and compare it with the associated ratio using the filtered data (see black line). To benchmark Ireland's intangible intensity before and after filtering the official data we compare the ratio with the associated EU average (see green dotted line in the left panel) as well as with the relevant average ratios for two different group of European countries (see right panel). In the first group we include the main large European economies, namely France, Germany, Italy and Spain, while in the second group we include selected small open European economies, namely Austria, Belgium and Netherlands. The two averages are labeled as 'Large' and 'SOE' in the right panel of Figure 2 respectively.

Using the official (but distorted) series one would conclude that Ireland, since the early-2000s, has emerged as one of the most intangible intensive economies in the European Union. Ireland's official intangible intensity depicted by the red line is consistently above the EU average since 2001. It increases significantly above the EU average after 2008 while the difference becomes striking toward the end of the sample period, where Ireland's official ratio exceeds unity. However, once we use the filtered data depicted by the black line, one would conclude that Ireland's intangible intensity is consistently below the associated averages of both the EU average as well as the average of the selected groups of countries.

For the reasons analyzed above, the official Gross Value Added time series needs to be adjusted and filtered. First, to include non-NA intangibles, we follow Corrado et al. (2009) and Niebel et al. (2017) and adjust the official measure of GVA as follows:

$$Y^*_{j,t} = Y_{j,t} + \sum_{n \in INTAN} I_{n,j,t} \tag{2}$$

where $Y^*_{j,t}$ denotes the adjusted gross value added for sector j in time t, $Y_{j,t}$ is the associated official gross value added, augmented by the level of the non-NA intangible investment for asset n obtained from the INTAN database ($I_{n,j,t}$).

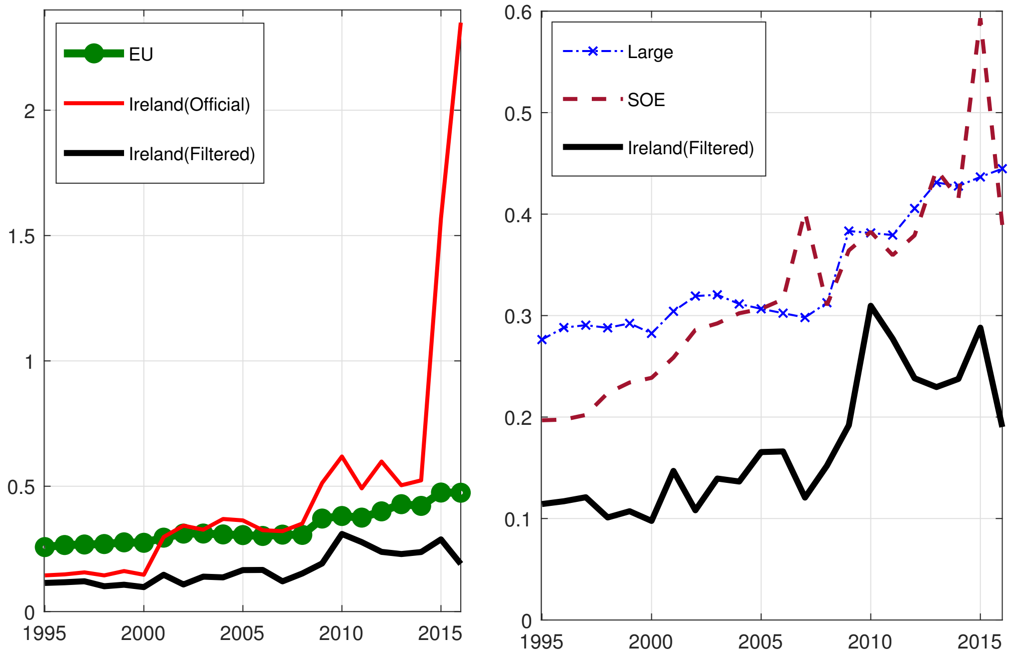
Second, to strip out the distortions we compute the filtered (and adjusted) GVA as follows:

$$Y^{*f}_{j,t} = Y_{j,t} - D_{j,t} + \sum_{n \in INTAN} I_{n,j,t} \tag{3}$$

[10]As official investment series we use Gross Fixed Capital Formation taken from Eurostat. The reason for using Eurostat data in this case is that the CSO does not provide a breakdown of investment data by asset (IPP etc.) and sector, whereas we get that directly from Eurostat – series Gross capital formation by industry (up to NACE A*64) (nama_10_a64_p5).

[11]Figure 3 in the Appendix B presents the distortion per sector affected, as a share of the official level of investment)

Figure 2: Ratio of National Accounts Intangibles to Tangibles for Ireland and Select Country Groups



Source: INTAN Invest and own calculations.

where $Y_{j,t}^{*f}$ denotes the adjusted and filtered level of GVA in sector j. That is, we subtract the distortion, $D_{j,t}$, associated with sector j from the official gross value added, $Y_{j,t}$, of sector j. Note that $D_{j,t}$ is positive only for the sectors reported above, namely Manufacturing (C), Information and communication (J), Financial and insurance activities (K), Professional, scientific and technical activities (M), Administrative and support service activities (N) and Transportation and Storage sector (H), while for the remaining sectors the distortions are simply set to zero, i.e., $D_{j,t} = 0$. Subsequently, we adjust the filtered gross value added, $Y_{j,t}^{f} \equiv Y_{j,t} - D_{j,t}$, for the inclusion of non-NA intangibles. In both equations (2) and (3), all variables are in real terms.

3.2 Capital Stocks

One of the contributions of this paper is that, by proposing a method to remove the distortionary impact of large multinationals on Irish macroeconomic data, we can obtain a filtered series that provide a more accurate depiction of (sectoral) investment activity in Ireland, both for tangible and intangible assets. However, this adjustment necessitates the calculation of new, filtered capital stock series for the affected sectors, as these constitute a key input to the sources of growth analysis of the following section.

In line with the literature (see, among others, Roth and Thum (2013), Corrado et al. (2016), Niebel et al. (2017) and Roth (2020)) all filtered capital stock series are computed using the standard Perpetual Inventory Model (PIM) approach. The capital stock K for asset k in industry j and period t is computed by using the following general law of motion:

$$K_{j,t}^{f,k} = (1-\delta_k) * K_{j,t-1}^{f,k} + I_{j,t}^{f,k} \tag{4}$$

where, $K^{f,k}$, denotes the filtered capital stock series, k denotes the three types of capital assets included in our analysis, namely, tangible (T), NA-intangibles (I) and non-NA intangibles (I, no). Additionally, $I^{f,k}_{j,t}$ denotes the real, filtered level of investment for each asset k while δ_k is the asset-specific, time-invariant, depreciation rate that is assumed to be the same across industries j. Below we use equation (4) to construct filtered capital stocks for each of the affected asset in the associated affected sectors.

Starting with NA-intangible capital stock series, as already mentioned in section 3.1, the aggregate distortion is allocated across the five sectors. For these sectors, the capital stocks are computed using the following equation:

$$K^{f,I}_{i,t} = (1-\delta_I) * K^{f,I}_{i,t-1} + I^{f,I}_{i,t} \tag{5}$$

where $K^{f,I}_{i,t}$ denotes the filtered level of NA intangibles capital stock for each of the i affected sectors, while $I^{f,T}_{i,t}$ denotes the filtered level of investment in each of these sectors, i.e. $I^{f,I}_{i,t} = I^{I}_{i,t} - D^{I}_{i,t}$ where $D^{I}_{i,t}$ is the level of the distortion for sector i, as computed in section (3.1). The initial level of the capital stock series is the 1994 level reported by the CSO. Regarding the depreciation rate, δ_I, given that the available investment data refer to the Intellectual Property Products category, a weighted average of the relevant depreciation rates (namely, Software and Database, R&D and Mineral Exploration and Artistic Originals) is utilized, based on the rates reported in Corrado et al. (2016) - for ease of exposition, the depreciation rates are reproduced in Table A1. Finally, for the unaffected sectors, the respective capital stocks are directly obtained from the CSO Capital Stock of Fixed Assets database (see Table CSA02).[12]

Turning to the tangible capital stock series, as mentioned in the previous section, we assume that the impacted sector is that of Transportation and Storage (sector H). As such, the filtered capital stock for this sector is computed as follows:

$$K^{f,T}_{H,t} = (1-\delta_T) * K^{f,T}_{H,i,t-1} + I^{f,T}_{H,t} \tag{6}$$

For the depreciation rate, δ_T, we assume that it is equal to 6 per cent. The use of alternative depreciation rates commonly found in the literature, such as a 5 per cent and a 7 per cent rate, leaves the results essentially unaltered. As in the case of the NA intangibles, for the unaffected sectors, the respective capital stocks are directly obtained from the CSO Capital Stock of Fixed Assets database.

Finally, we construct the non-NA intangibles capital stocks as follows:

$$K^{f,I,no}_{i,t} = (1-\delta_{I,no}) * K^{f,I,no}_{i,t-1} + I^{f,I,no}_{i,t} \tag{7}$$

where $I^{f,I,no}_{i,t}$ denotes real investment in non-NA intangibles obtained from the INTAN database.[13] The initial level of the capital stock is assumed to be equal to zero as in Corrado et al. (2009).As a robustness check, we calculated the initial capital stock following the approach of Niebel et al. (2017). We report that the resulting capital stocks are quite similar and the results of our analysis remained essentially unaltered. The values for the depreciation rate, $\delta_{I,no}$, are again taken from Corrado et al. (2016).

[12] In order to obtain real levels of the CSO capital stocks, we deflate the nominal capital stock of each sector using the Gross Fixed Capital Formation (GFCF) deflators of the respective sectors. Then, we aggregate the sectors to obtain our total economy capital stock measure. To check the robustness of our results we have also deflated all the nominal capital stocks using a single deflator across all sectors, i.e., the GVA deflator. We report that the results are largely unaffected.

[13] We use the April 2020 version of the INTAN database which does not provide estimates of capital stocks.

3.3 Income Shares

As already mentioned, the inclusion of the non-National Accounts intangibles leads to the increase of the output measure –in this case, GVA- and, as such, necessitates the adjustment of the income shares. In order to compute the new adjusted income shares we proceed as follows (see also Niebel et al. (2017)): firstly, we calculate the new level of capital compensation at the sector-level

$$\text{CAP}^{*,f}_{j,t} = Y^{*,f}_{j,t} - \text{LAB}_{j,t} \tag{8}$$

where $\text{CAP}^{*,f}_{j,t}$ is the adjusted level of total capital compensation in sector j in period t, $Y^{*,f}_{j,t}$ is the level of filtered and adjusted GVA and $\text{LAB}_{j,t}$ is the level of labour's compensation (i.e. compensation of employees). Then, the internal rate of return is calculated as follows:

$$r_{j,t} = \frac{\text{CAP}^{*,f}_{j,t} + \sum_k (p^k_{j,t} - p^k_{j,t-1}) * K^{f,k}_{j,t} - \sum_k (p^k_{j,t} * \delta_k * K^{f,k}_{j,t})}{\sum_k p^k_{j,t} * K^{f,k}_{j,t}} \tag{9}$$

where $p^k_{j,t}$ is the price index (deflator) for asset k in sector j and time t, δ_k is the asset-specific depreciation rate and $K^{f,k}_{j,t}$ is the real level of the capital stock for asset k.

Using the internal rate of return we can calculate the asset-specific user cost for all types of capital assets:

$$q^k_{j,t} = p^k_{j,t-1} + p^k_{j,t} * \delta_k - (p^k_{j,t} - p^k_{j,t-1}) \tag{10}$$

Finally, capital compensation for each asset is computed as:

$$\text{CAP}^{*,f}_{j,t} = q^k_{j,t} * K^{f,k}_{j,t} \tag{11}$$

The income shares of capital (s_K) and labor (s_L) are obtained by dividing the level of capital compensation and compensation of employees over adjusted and filtered GVA, respectively.

4 Growth Accounting

Our growth accounting analysis is based on the well-established Solow (1956) methodology. That is, we decompose the growth in gross value added into the components associated with the contribution of factor inputs and total factor productivity. Following Corrado et al. (2009) and Niebel et al. (2017), we assume a generalized production function augmented with intangible capital:

$$Y^{*,f}_t = A_t F(K^{T,f}_t, K^{I,f}_t, K^{I,no}_t, L_t) \tag{12}$$

where $Y^{*,f}_t$ denotes the filtered and adjusted gross value added as computed in section 3.1. Equation (12) assumes that $Y^{*,f}_t$ is produced utilizing four factor inputs; namely the three types of capital, tangible, $K^{T,f}_t$, NA-intangible, $K^{I,f}_t$, non-NA intangible capital, $K^{I,no}_t$, and hours worked, L_t. That is NA-intangible and non-NA intangible capital are included as two separate factor inputs. Finally, A_t denotes total factor productivity. Equation (12) serves as the main specification in the growth accounting analysis conducted in section 5. The superscript f denotes that all the respective variables refer to the filtered data, that is, data that have been stripped off the distrortionary impact of MNEs.

We can write equation (12) in intensive form:

$$y^{*,f}_t = A_t f(k^{T,f}_t, k^{I,f}_t, k^{I,no}_t) \tag{13}$$

where $y^{*,f}, k^{T,f}, k^{I,f}, k^{I,no}$ are quantities per hour worked.

By taking the log of equation (13) and differentiating we derive the growth accounting equation (time subscripts are omitted for ease of notation):

$$g_{y^{*,f}} = s_{k^{T,f}} g_{k^{T,f}} + s_{k^{I,f}} g_{k^{I,f}} + s_{k^{I,no}} g_{k^{I,no}} + g_A \tag{14}$$

where $s_{k^{T,f}}$, $s_{k^{I,f}}$ and $s_{k^{I,no}}$ denote tangible, NA-intangible and non-NA intangible capital income shares respectively and since we assume constant returns to scale:

$$s_{k^{T,f}} + s_{k^{I,f}} + s_{k^{I,no}} = 1 - s_L$$

where s_L denotes the income share of labour.
In equation (14), $g_{y^{*,f}}$, is the measure of labour productivity growth, i.e. the growth rate of real adjusted and filtered GVA per hour worked, while $g_{k^{T,f}}, g_{k^{I,f}}$ and $g_{k^{I,no}}$ are measures of tangible, NA-intangible and non-NA intangible capital deepening, i.e., growth in capital stocks per hour worked.

For comparison purposes, we also conduct the growth accounting analysis with two alternative specifications of the production function. First, a production function which is consistent with the current state of national accounts, i.e., a production function augmented only with NA-intangibles given by the following intensive form:

$$y_t^f = A_t f(k_t^{T,f}, k_t^{I,f}) \tag{15}$$

Notice that specification (15) differs with respect to our main growth accounting equation (13) since it does not take into account the non-NA intangibles as a source of growth. This means that, y_t^f, is the gross value added officially reported in national accounts (i.e., not augmented with non-NA intangibles) while it is produced by using only two types of capital, i.e., tangible capital and NA intangible capital. As before, we can derive the growth accounting equation which takes the following form:

$$g_{y^f} = s_{k^{T,f}} g_{k^{T,f}} + s_{k^{I,f}} g_{k^{I,f}} + g_A \tag{16}$$

It should be noted that, in this case, given that the measure of output is GVA, Y^f, and not the adjusted GVA, $Y^{f,*}$, the factor income shares $s_{k^{T,f}}$ and $s_{k^{I,f}}$ need to be recomputed, as the level of capital compensation is directly affected by this change - see equation (8).

Second, we consider a standard neoclassical production function with two factors of production, i.e., one homogeneous capital asset and hours worked. In this case, homogeneous capital is the total capital stock of the economy as reported in the national accounts, without distinguishing between tangible and NA intangible assets. The specification in intensive form is given by:

$$y_t^f = A_t f(k_t^f) \tag{17}$$

As before, y_t^f is the gross value added reported in the national accounts, adjusted for distortions while we assume that k_t^f includes both tangible and NA-intangible capital. The rest is as before. The growth accounting equation takes the following form:

$$g_{y^f} = s_{k^f} g_{k^f} + g_A \tag{18}$$

where g_i denotes the growth rates of GVA, capital and TFP respectively while s_{k^f} denotes the capital income share which, as above, needs to be recomputed.

In what follows, the full intangible-capital augmented production function given by equation (13) is referred to as ‘PF’, the production function which is consistent with the current state of national accounts given by equation (15) is referred to as 'NA-PF' and the classic production function given by equation (17) is referred to as 'CL-PF'.

Finally, we conduct growth accounting by using both Irish official and filtered data as those have been computed in section 3.1. In what follows, unless otherwise stated, we present results with the filtered data. When we present results with the official (but distorted) data we substitute the filtered time series indicated with a superscript f with the official ones.

5 Results

In this section we present our main results. We organize our analysis as follows. In sections 5.1 and 5.2, we present growth accounting results by using Irish filtered data, i.e. data obtained after the adjustments undertaken in section 3.1. These results allow us to assess the actual contribution of each factor input to the Irish labour productivity growth. In section 5.3, we quantify the magnitude of the distortions from a growth accounting perspective. That is, we compare growth accounting results when we use the official Irish national accounts data with the case in which we use filtered data. The difference provides us with an estimate of the mismeasurement that these distortions might cause in quantifying labour productivity growth as well as its decomposition into factor inputs and TFP.

5.1 Growth accounting in the full sample

We start by computing the contribution of each factor input to labour productivity growth for the full sample. Table 1 decomposes labour productivity growth over the period 2000-2016 into capital deepening and TFP. The presentation of our results closely follows the analysis of section 4. Results from our main growth accounting equation (14) are presented in the last column of Table 1 (entitled as PF). For comparison purposes, in Table 1 we also present results from the two alternative growth accounting equations (16) and (18), i.e., "NA-PF" which is consistent with the national accountant's definition of intangible assets (see third column) and the "CL-PF" (see second column) which allows us to benchmark our results with the standard growth accounting literature (see e.g.,Barro (1999)).

Table 1: Growth accounting over 2000-2016

	CL-PF	NA-PF	PF
Labour Productivity Growth	1.73	1.73	1.46
TFP	-1.64	-1.61	-0.67
Capital Deepening	3.37	3.34	2.13
Decomposition of Capital Deepening			
Tangible Capital	3.37	3.10	3.11
NA Intangible Capital		0.24	0.18
non-NA Intangible Capital			-0.16

Table 2 measures the relative importance of the factors that explain Irish growth in percentages.[14] Using the "CL-PF", TFP negatively contributes 33% of labour productivity growth

[14] In our sample factor inputs have both negative and positive contributions thus the sum of the absolute change of all factors exceeds the associated labour productivity growth. For comparisons purposes across different production functions and time periods, we implement a normalization to compute the actual share of the contribution of each factor. In particular we define the contribution share of each factor with respect to the sum of the absolute change of all factors.

while capital deepening contributes positively 67% of labour productivity over the full sample period. Turning to the "NA-PF" which distinguishes between tangible and NA-intangible capital, we find that TFP contribution falls by just 1% compared to the classic production function case, which is now allocated to capital deepening. On the other hand, when we use the "PF" we find that the inclusion of non-NA intangibles into our analysis causes a sizeable change in the relative importance of TFP and capital deepening as sources of growth. The importance of capital deepening rises substantially vis-à-vis the importance of TFP. In particular, the (negative) contribution of TFP declines by 11 percentage points, which are allocated to capital deepening, with 5 p.p. being attributed to non-NA intangibles.

Table 2: Factors' contribution full sample (%)

	CL-PF	NA-PF	PF
TFP	-33	-32	-21
Capital Deepening	67	68	79
Decomposition of Capital Deepening			
Tangible Capital	67	62	68
NA Intangible Capital		6	6
non-NA Intangible Capital			5

The Irish growth rate was quite volatile during 2000-2016 since this period includes two rather different faces of the business cycle, i.e., a boom period from 2000 to 2007 and a bust period triggered by the Global Financial Crisis (henceforth GFC). In the next section, we separate our sample into two sub-periods motivated by this observation.

5.2 Growth accounting before, during and post GFC

In this section, we split the 2000-2016 period into two sub-periods. Results from the pre-GFC period are presented in Tables 3 and 4, respectively; while results for the period over 2008-2016 which includes the GFC and the post-GFC period are presented in Tables 5 and 6. The growth accounting exercise over the two sub-periods allows us to disentangle the actual contribution of each factor to the labour productivity growth without averaging together positive and negative contributions of the boom-and-bust cycle which cancel out and might lead to a misinterpretation of the actual contribution.

Table 3: Pre-crisis 2000-2007 (%)

	CL-PF	NA-PF	PF
Labour Productivity Growth	2.28	2.28	2.8
TFP	-1	-1	-0.25
Capital Deepening	3.28	3.07	3.06
Decomposition of Capital Deepening			
Tangible Capital	3.28	3.07	2.28
NA Intangible Capital		0.2	0.16
non-NA Intangible Capital			0.62

As can be seen from the analysis of Tables 3 and 5, the inclusion of non-NA intangibles affects labour productivity growth in a robust manner along the business cycle, meaning that

Table 4: Pre-crisis factor's contribution (%)

	CL-PF	NA-PF	PF
TFP	-23	-23	-7
Capital Deepening	77	77	93
Decomposition of Capital Deepening			
Tangible Capital	77	72	69
NA Intangible Capital		5	5
non-NA Intangible Capital			19

the contribution of non-NA intagible capital to growth is quite pro-cyclical. Splitting the sample into the two subperiods, we find that the inclusion of non-NA intangibles increases labour productivity growth by 0.52 percentage points during the 2000-2007 boom period while it reduces it by 0.98 percentage points during the 2008-2016 bust period. Thus, non-NA intangibles (as those taken from the INTAN database) constitute a key contributor to Irish labour productivity growth.

Similarly with the full sample analysis, the inclusion of non-NA intangibles as a factor of production substantially decreases the contribution of TFP. The reduction in the unexplained component of labour productivity growth is remarkable in both sub-periods, i.e., the TFP contribution reduces by 75% and 58% in 2000-2007 and 2008-2016 respectively, solely by including non-NA intangibles as a factor input (compare the third and fourth column in Tables 3 and 5).

Tables 4 and 6 show a substantial change in the relative importance of factors that explain labour productivity growth once we include non-NA intangible capital. The capital deepening share rises from 77% to 93% during the 2000-2007 boom period and from 61% to 78% during the 2008-2016 bust period. Decomposing capital deepening into the three different capital factors, we find that it is mostly driven by changes in tangible 69% (48%) and non-NA intangible capital 19% (-24%) for 2000-2007 (2008-2016). Perhaps more interesting is that NA-intangible capital deepening contribution share is actually relatively small and equal to 5% for both sub-periods. This is in sharp contrast with what one finds by looking at the national accounts statistics. Our growth accounting framework indicates that once we take into account distortions and non-NA intangibles, the relative contribution of NA-intangible capital reduces substantially.

Table 5: Crisis and post-crisis 2008-2016 (%)

	CL-PF	NA-PF	PF
Labour Productivity Growth	1.24	1.24	0.26
TFP	-2.15	-2.15	-0.91
Capital Deepening	3.39	3.39	1.17
Decomposition of Capital Deepening			
Tangible Capital	3.39	3.11	1.95
NA Intangible Capital		0.28	0.2
non-NA Intangible Capital			-0.98

Table 6: Crisis and post-crisis factor's contribution 2008-2016 (%)

	CL-PF	NA-PF	PF
TFP	-39	-39	-22
Capital Deepening	61	61	78
Decomposition of Capital Deepening			
Tangible Capital	61	56	48
NA Intangible Capital		5	5
non-NA Intangible Capital			-24

5.3 Quantifying the effects of the distortions

Table 7 presents growth accounting results by contrasting results obtained with official Irish data with results obtained with the filtered Irish data used in section 3.1. This comparison allows us to quantify the magnitude of the mismeasurement in Irish national accounts from a growth accounting perspective. In the interest space we present results only from equation (14).[15] Comparing the sources of growth computed with filtered data with those computed with the official data, labour productivity growth falls by 2.17 p.p., i.e., a 60% decrease, and capital deepening falls by 1.38 p.p., i.e., a 39% decrease, while TFP turns to negative.

Table 8 compares the relative importance of the different factors for labour productivity growth using official and filtered data. The size of the potential mismeasurement from using the Irish national accounts data is clearly illustrated in the share of capital deepening and its decomposition. The contribution of capital deepening to labour productivity growth with official data amounts to 97%. Filtering the official investment series reduces the contribution of the capital deepening share by 18 percentage points, that is, it falls from 97% to 79%. The decomposition of capital deepening into the three different capital inputs clearly illustrates the erroneous perception about the relative importance of NA-intangibles on the Irish growth story. That is once we clean the Irish data from the distortions the importance of the contribution of NA-intangible collapses from 42% to just 6%.

Table 7: Growth accounting using distorted and filtered data (%)

	Official data	Filtered data	Difference
Labour Productivity Growth	3.63	1.46	-2.17
TFP	0.12	-0.67	-0.79
Capital Deepening	3.51	2.13	-1.38
Decomposition of Capital Deepening			
Tangible Capital	2.03	2.11	0.08
NA Intangible Capital	1.64	0.18	-1.46
non-NA Intangible Capital	-0.16	-0.16	0

[15] We report that our main results remain robust when we use equation (16).

Table 8: Factor's contribution using distorted and filtered data (%)

	Official data	Filtered data
TFP	3	-21
Capital Deepening	97	79
Decomposition of Capital Deepening		
Tangible Capital	51	68
NA Intangible Capital	42	6
non-NA Intangible Capital	4	5

6 Conclusions

In this paper we assess, in a detailed manner, the role of investment in the Irish economy over the period 2000 - 2016. In particular, we focus on the growth contribution of tangible and intangible assets after removing the distortionary transactions from the official data, using information provided by the Central Statistics Office of Ireland. We incorporate into our analysis a set of intangible assets from the INTAN Invest database that is not currently included in the National Accounts. This comes at a time when it is increasingly difficult to accurately quantify both the actual rate of growth of the Irish economy and its composition.

The sources of the Irish growth analysis, based on the filtered data, reveal that tangible capital deepening followed by non-NA intangible capital deepening are the two main drivers of labour productivity. In contrast, NA-intangible capital contributed only marginally to the Irish growth performance. Finally, it appears that TFP is contributing negatively to the recent Irish growth story.

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A Appendix

A Intangible assets

Intangible assets can be broadly defined as those investments that allow firms to commercialize knowledge. Despite the fact that the importance of innovation activities and intangible capital as a source of economic growth was identified early on both by policy institutions (see OECD (2008)) and academic researchers (see, among others, Nakamura (1999, 2001), Jorgenson and Stiroh (2000) and Oliner and Sichel (2000, 2003), these assets were not up until recently included into the measures of an economy's output.

In particular, most types of intangible assets were recognized as being an intermediate expense rather than investment and as such they were not measured as part of GDP. This omission had direct implications for any analysis that attempted to decompose GDP growth into its main sources, as many factors related to innovation and knowledge-based capital were excluded from the analysis.

The first step in incorporating some types of intangible capital came with the 2008 revision of the System of National Accounts (SNA08) – and, subsequently, the European System of National Accounts (ESA2010) – which introduced the Intellectual Property Products (IPP) category as part of the investment account, thus expanding the boundary of fixed assets included in the National Accounts. In particular, the IPP category consists of the following assets: Research and Development, Computer Software (which was already a part of the National Accounts since 1993), Mineral Exploration and Artistic Originals.

One of the seminal contributions regarding the measurement of intangible assets is introduced in the articles by Corrado et al. (2005, 2009). They define three broad categories of investment in intangible assets:

1. *Computerized information*, which includes knowledge embedded in computer programs and computerized databases

2. *Innovative property*, which refers to knowledge acquired through scientific research and development and other creative and inventive activities. Moreover, to account for the increased importance of financial services, this category of assets includes products related to financial innovation

3. *Economic competencies*, which includes knowledge embedded in firm-specific human and structural resources; that is, assets on which firms invest but which have no intellectual property, like brand names, marketing, investment in management of human capital etc.

Of these categories, Economic Competencies and part of Innovative Property are still not included in the National Accounts. Table A1, reproduced from Corrado et al. (2016), presents all the categories of intangible assets and classifies them depending on whether they are part of the National Accounts.

Table A1: Intangible asset categories

Asset	Included in National Accounts?	Depreciation rate
Computerized Information		
Purchased Software	Yes	0.315
Own-account Software	Yes	0.315
Databases	Yes	0.315
Innovative Property		
R&D	Yes	0.15
Design	No	0.2
Mineral Exploration and Artistic Originals	Yes	0.075
Financial Innovation	No	0.2
Economic Competencies		
Advertising	No	0.55
Marketing Research	No	0.55
Own-Account Organizational Capital	No	0.4
Purchased Organizational Capital	No	0.4
Training	No	0.4

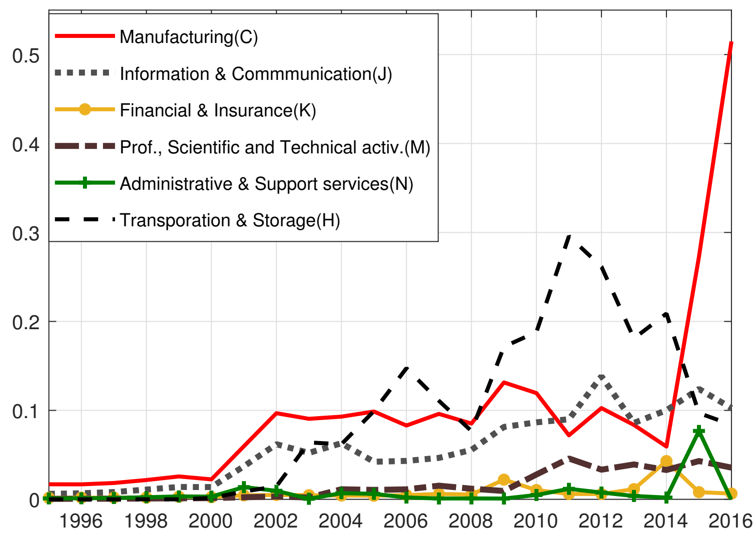
Source: Corrado et al. (2016)

B Tables and Figures

Table A2: Data sources

Variable	Symbol	Type	Frequency	Period	Source
Input Data					
Hours Worked	L_t	Real	Annual	1995-2016	Eurostat
Investment data					
Gross Fixed Capital Formation (GFCF)		Nominal and real	Annual	1995-2016	Eurostat and CSO
National Accounts Intangible GFCF		Nominal and real	Annual	1995-2016	Eurostat
Aircraft leasing		Nominal	Quarterly	1995Q1-2016Q4	CSO
R&D imports and Trade in IP		Nominal	Quarterly	1995Q1-2016Q4	CSO
non-National Accounts Intangible GFCF		Real	Annual	1995-2016	INTAN
Capital stock data					
Total capital stock	K_t	Nominal	Annual	1995-2016 with exceptions, see text	CSO
NA intangible capital stock	K_t^I	Nominal	Annual	1995-2016 with exceptions, see text	CSO
Tangible capital stock	K_t^T	Nominal	Annual	1995-2016 with exceptions, see text	Own Calculations
non-NA intangible capital stock	$K_t^{I,no}$	Real	Annual	1995-2016	Own calculations
Output Data					
GVA	Y_t	Real	Annual	1995-2016	Eurostat
GVA adjusted	Y_t^*	Real	Annual	1995-2016	Own Calculations

Figure 3: Sectoral allocation of distortions in the Irish investment series



Source: CSO, Eurostat and own calculations.

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