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PATTERNS OF FIRM LEVEL PRODUCTIVITY IN IRELAND

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ABSTRACT/RÉSUMÉ

Patterns of Firm Level Productivity in Ireland

Productivity is the ultimate driver of sustainable increases in living standards. While Ireland is a high productivity country, it has not been immune from the global productivity slowdown, with the pace of growth on a downward trend throughout the 2000s. Little research has been carried out as to the determinants behind the productivity slowdown in Ireland, and even less so with microdata. To fill the gap, we use a firm-level panel dataset based on production surveys from Ireland's national statistics office, together with the OECD MultiProd model, in order to identify productivity patterns and trends distributed by percentile, sector, ownership, as well as measures of the efficiency of resource allocation. Our results show a widening of the productivity gap between the most and least productive firms, with the majority of firms experiencing a decline in productivity since the mid-2000s, and also confirm that aggregate results are driven by the impact of foreign dominated sectors, with foreign firms typically larger and more productive. These results are significant in terms of enterprise policy and featured prominently in the OECD's 2018 Economic Survey of Ireland.

JEL classification: F23, O30, O40, O43, O57, M13

Keywords: Firm level productivity, labour productivity, multifactor productivity, productivity distribution, productivity dispersion, MultiProd, productivity frontier, resource allocation

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Variations et tendances de la productivité dans les entreprises en Irlande

La productivité est le déterminant par excellence d'une élévation durable des niveaux de vie. Si l'Irlande est un pays à forte productivité, elle n'a pas été épargnée par le tassement mondial des chiffres de productivité, dont le rythme de croissance est orienté à la baisse depuis les années 2000. Peu de travaux de recherche ont été menés sur les facteurs à l'origine du ralentissement observé en Irlande, et encore moins à partir de microdonnées. Afin de combler cette lacune, nous utilisons un ensemble de microdonnées de panel constitué à partir d'enquêtes de production réalisées par l'office national de statistique d'Irlande auprès des entreprises, ainsi que le modèle MultiProd de l'OCDE, dans le but d'identifier des schémas de variation et des tendances dans la productivité en fonction des centiles de distribution, des secteurs et de l'origine des capitaux, nationale ou étrangère, ainsi que des indicateurs pour mesurer l'efficience allocative. Nos résultats montrent un creusement de l'écart de productivité entre les entreprises les plus et les moins productives, la plupart connaissant un repli de cet indicateur depuis le milieu des années 2000 ; ils confirment en outre que les chiffres de productivité globale sont essentiellement déterminés par l'impact des secteurs à prédominance de capitaux étrangers, les sociétés étrangères étant généralement plus grandes en taille et plus productives. Ces résultats sont importants au regard de l'action publique en faveur des entreprises et figurent en bonne place dans l'*Étude économique* 2018 de l'OCDE sur l'Irlande.

Classification JEL : F23, O30, O40, O43, O57, M13

Mots-clés : Productivité microéconomique, productivité du travail, productivité totale des facteurs, distribution de productivité, dispersion des niveaux de productivité, modèle MultiProd, frontière de productivité, allocation des ressources.

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Patterns of Firm Level Productivity in Ireland

By Javier Papa, Luke Rehill and Brendan O'Connor[12]

1. Introduction

1.1. Context

1. A country's ability to increase its living standards over time depends to a large extent on its ability to improve its output per worker, in other words its productivity level. Indeed, disparities in living standards, commonly measured by output per capita, are largely reflected in the different levels of productivity across countries. For example, Hall and Jones (1999), find that output per worker, the traditional measure of labour productivity, is 35 times greater in the United States than in Niger. Disparities in productivity growth have been magnified by the Great Recession of 2008, with many countries experiencing a substantial contraction in their aggregate output (OECD, 2014). In the United Kingdom, labour productivity has remained weak following the recession, with firm level evidence suggesting it is 17 percentage points below its pre-recession trend (ONS, 2017).

2. Advanced economies have experienced a trend decline in productivity growth in recent years, a phenomenon that predates the financial crisis (OECD, 2015, 2016). This 'productivity puzzle', so-called as it comes despite rapid technological advancement, is one of the factors behind the global low growth environment, and to the extent that labour productivity growth remains sluggish, will act as a drag on real wage growth (and hence in living standards) in the years to come. The underlying reasons for the slowdown are complex and research aimed at understanding the global slowdown has begun to focus on firm level dynamics, with a number of projects turning to this method as micro data become more available over time (Bartelsman, 2004; Bartelsman, et al., 2005; Bartelsman, Haltiwanger, et al., 2009, Andrews et al., 2015, Berlingieri et al, 2017).

3. The accepted channels for aggregate productivity growth include innovation and productivity growth amongst firms at the productivity frontier, a diffusion of technology from frontier firms to the rest of the economy, and a reallocation of resources (i.e. capital and labour) from the least productive to the most productive firms through competition (see

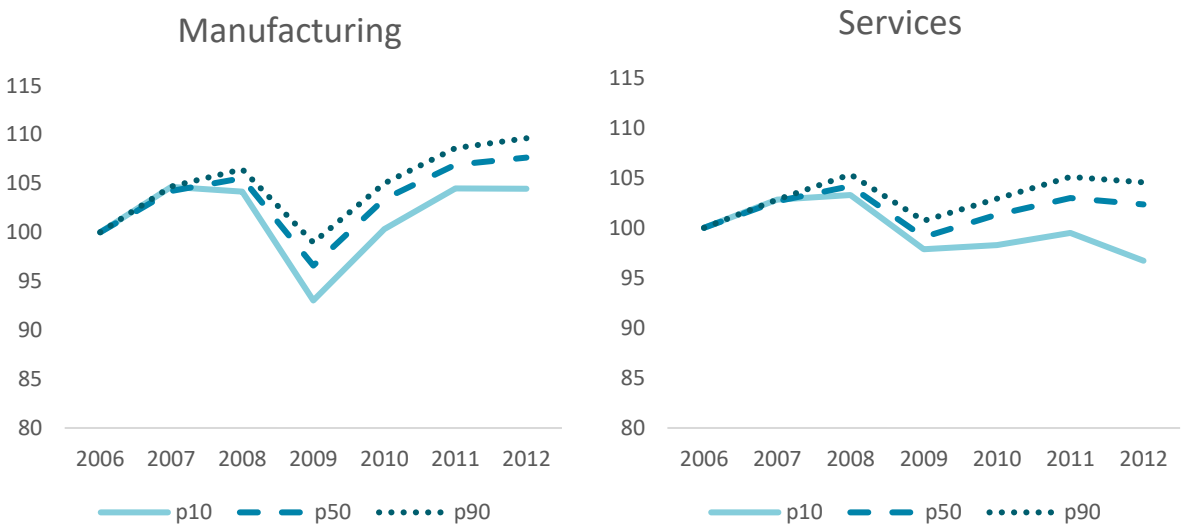
[1] Corresponding authors are: Javier Papa, Department of Business, Enterprise and Innovation (Ireland); Luke Rehill and Brendan O'Connor, Department of Finance (Ireland).

[2] An earlier version of this technical paper was produced to inform the OECD 2018 Economic Review of Ireland, with some results since changed due to the availability of updated deflators. The authors would like to thank the Central Statistics Office (Ireland) for provision of data under an Officer of Statistics agreement and support, in particular, Gerard Doolan, Andrew Murray, Stephanie Kelleher, Barry Sobey, Keith McSweeney and Joe Treacy. We also acknowledge the support provided by the OECD-STI team, namely Chiara Criscuolo, Giuseppe Berlingieri and Sara Calligaris. We also recognise the support and comments provided by Ben Westmore and Yosuke Jin of the OECD Economics Department. We also acknowledge the valuable insight gained through discussions with Iulia Siedschlag, Martina Lawless and Mattia Di Ubaldo of the Economic & Social Research Institute (ESRI, Ireland). We also thank John FitzGerald of the ESRI for his helpful suggestions and feedback. The authors also recognise the contribution of Brian Corcoran, formerly Department of Finance, as well as helpful comments from John McCarthy and colleagues at the Department of Finance.

OECD, 2015). Empirical evidence suggests there is no slowdown in innovation at the frontier – consider, for instance, the continuous innovations amongst the most well-known firms in the ICT and other R&D-intensive industries. Indeed, firm level analysis by the OECD has found strong productivity growth amongst the firms at the global frontier throughout the 2000s (see Figure 1). However, amongst laggard firms, there has been limited productivity growth (and negative growth in services), and no evidence of catch-up, suggesting that it may be a breakdown in the diffusion mechanism and/or a misallocation of resources that is giving rise to the aggregate slowdown in productivity.

Figure 1. Trends for top, median and bottom decile of the (log) labour productivity distribution

(OECD MultiProd countries)



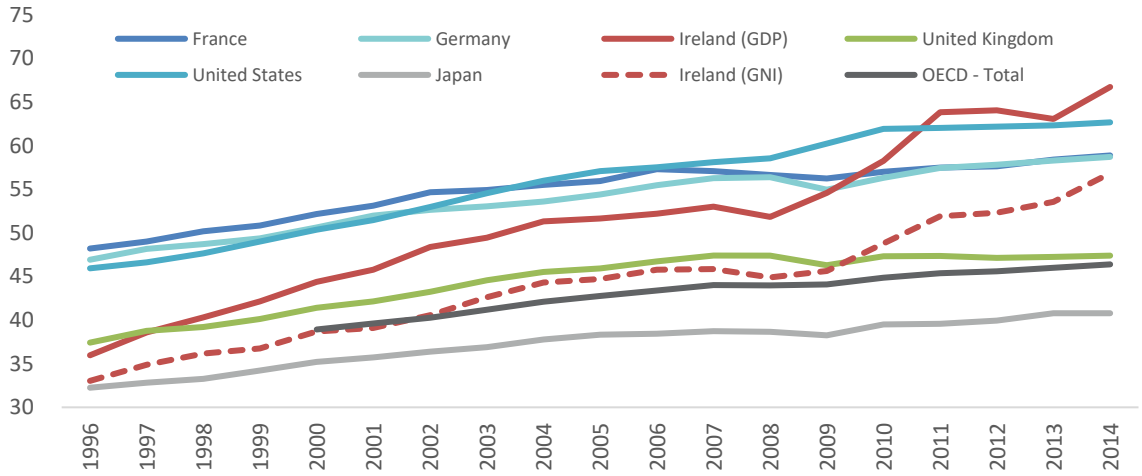
Note 1: The selected OECD countries included are AUS, AUT, BEL, CHL, DNK, FIN, FRA, HUN, ITA, JPN, NLD, NOR, NZL, SWE.
Note 2: p10, p50 and p90 refer to the 10th, 50th and 90th percentiles of the productivity distribution.
Source: Authors' calculations based on Berlingieri et al (2017).

1.2. Recent Macro Trends in Ireland

4. While the large level shift in Ireland's GDP figures in 2015 gave rise to an elevated productivity level and growth rate,[3] as measured on a GDP basis, OECD data already showed that in the preceding years Ireland had one of the highest levels of labour productivity among EU Member States, and was close to, and in some years possibly even above, the international productivity frontier as depicted by some selected advanced economies (see Figure 2).

[3] See CSO (2016a)

Figure 2. Labour Productivity, GDP and GNI Per Hour Worked (USD - 2010 PPPs)

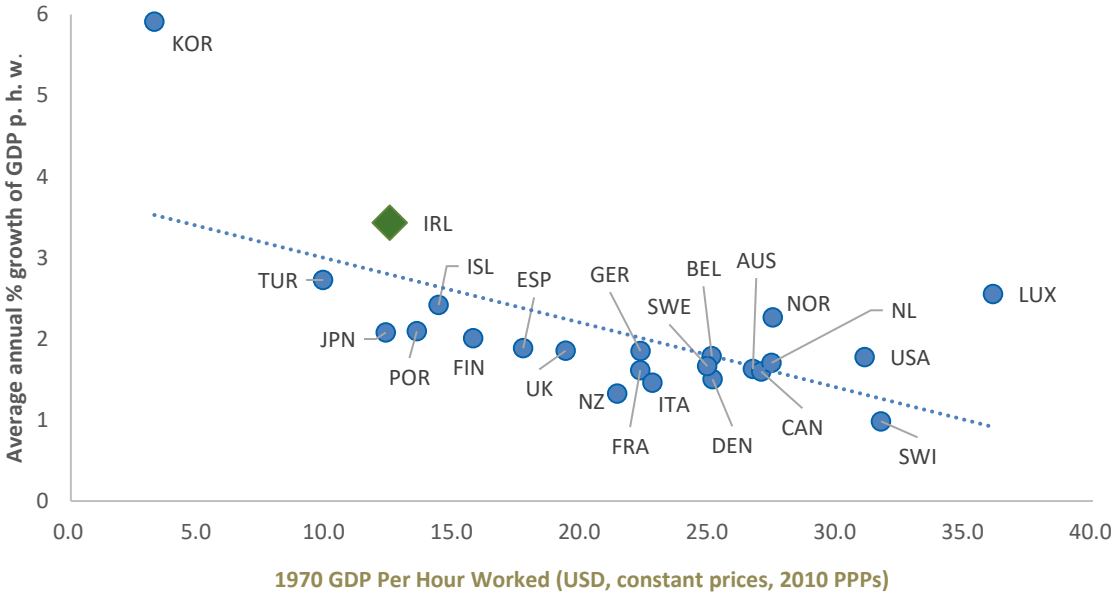


Source: OECD Productivity Statistics

5. Looking deeper, three periods of different productivity growth rates have been observed in Ireland since the mid-1990s. Fast growth averaging just over 4.6 per cent per annum during the catch-up period 1996-2004, a relative stagnation averaging close to zero growth in the four years preceding the 2008 crisis, and a recovery in productivity levels averaging 4.4 per cent per annum thereafter (2008-2014), driven largely by capital deepening (i.e. increases in capital per worker).[4] Indeed, Ireland's remarkable catch-up in the mid-1990s is consistent with the theory of economic catch-up and convergence depicted by Baumol (1986) and DeLong (1988) among others, whereby economies that start off with low levels of productivity tend to experience faster growth rates as they catch up to the frontier. Figure 3 below shows that Ireland had a relatively low level of GDP per hour worked in 1970 but saw the highest growth rate on average GDP per hour worked between that year and 2016 (second only to Korea).

[4] Growth in labour productivity can be decomposed into growth in MFP and capital deepening, the latter of which experienced a spike between 2008 and 2011.

Figure 3. Convergence in OECD countries: GDP per hour worked (1970) vs Average GDP per hour worked growth rate (1970-2016)



Note: The annual average growth rate of GDP per hour for Ireland excludes 2015.
Source: OECD Productivity Statistics Database

6. However, the slowdown in the pace of Ireland's productivity growth observed since the early 2000s (Figure 2), is consistent with the global slowdown in productivity growth. The OECD productivity estimates for Ireland (see Figure 4), measured in GDP per hour worked, show a downward, and at times negative, pace of productivity growth over the period 1995-2014. Moreover, the slowdown in labour productivity growth is consistent with another widely used measured of productivity, known as Multifactor Productivity (MFP),[5] which is a proxy of disembodied technical change as it measures the efficiency by which given inputs (i.e. capital and labour) are used together in production.[6]

[5] See Hulten (2001) for a short background of MFP, the concept of which is described elsewhere in the literature as total factor productivity (TFP) or the "Solow residual".

[6] Solow (1957) and Swan (1956) were the pioneers of the MFP measure, before Olley-Pakes (1996), Petrin-Levihnson (2003) and Wooldridge (2009) proposed ways to overcome problems of simultaneity and selection bias when estimating MFP. However, while MFP measures are preferable to labour productivity in that they control for differences in capital intensity across firms, they are prone to measurement error issues.

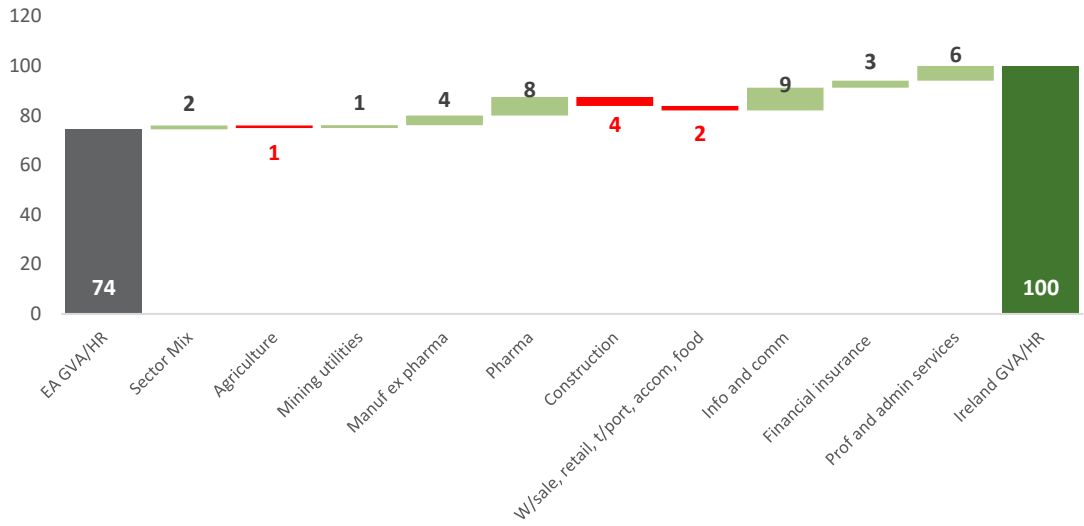
Figure 4. Productivity in Ireland, year on year growth 1995-2014



Source: OECD productivity database

7. A note of caution is needed when measuring Irish productivity. On a GNI basis, which strips out some - though not all - of the impacts of the foreign owned sector, Ireland's labour productivity (prior to the 2015 level shift) was below a number of 'frontier' economies, though still above the UK, Japan and the OECD average (see Figure 2). Indeed, Ireland's productivity performance (in common with other countries) is built upon a narrow base of mainly foreign-owned sectors, and in some of these sectors, a small group of firms. This is illustrated in Figure 5 below based on Allas (2016), which shows that whilst average labour productivity in the euro area stood at 74 percent of Ireland's productivity in 2014, almost two thirds of the gap is explained by Pharma-Chem and ICT services, accounting for 8 and 9 percentage points respectively of the 26 percentage point gap. A negative productivity gap between Ireland and the euro area is however observed in a number of domestic sectors such as agriculture, construction and domestic services (wholesale, retail, transportation, accommodation and food services). Lastly, the distribution of sector shares in Ireland, the 'sector mix' in Figure 5, also results in a productivity dividend for Ireland, indicating that the labour shares in Ireland are higher in more productive sectors, relative to the euro area.

Figure 5. Decomposing the euro area (EA) - Ireland productivity gap into sectoral contributions (2014)



Note: Labour productivity expressed as GVA per hour worked (based on persons engaged), expressed in 2010 prices. Labour productivity in Ireland in 2014 is indexed to 100 and all other components expressed relative to Ireland. Aggregate productivity estimates cover NACE sectors A to N, excluding sector L (real estate activities). Also excludes NACE sectors O-U (community, social and personal services).
Source: EU KLEMS.

8. In part, this is an FDI story, with productivity levels in foreign-owned enterprises far in excess of domestic firms, even on a within-sector basis. However, it is also a function of the highly concentrated nature of the Irish economy whereby a small number of sectors and firms, most of which are foreign owned, are responsible for a disproportionately large share of output and value-add, and therefore productivity. For instance, CSO data show that a small number of sectors dominated by foreign multinationals accounted for 40 per cent of gross value added in 2016.[7]

9. Therefore, more granular analysis is needed to understand the underlying features of aggregate productivity in Ireland as well as the ultimate drivers of productivity growth.

1.3. The need for firm level analysis

10. Empirical evidence has found substantial variation across firms' productivity, even within the same industries (Dosi et al., 2010). For example, in the US manufacturing sector, productivity in the 90th percentile firm was on average 1.92 times higher than the 10th percentile firm, implying that given the same inputs, the 90th percentile firm makes nearly twice as much output as that of the 10th percentile firm (Syverson, 2004). One potential explanation behind the growing productivity dispersion may be due to differences in the rates of adoption of new technology (Caselli, 1999). Such large dispersion in firm productivity suggests that analysing total economy or industry average productivity will not offer the full picture. This is because countries, or industries within countries, might display the same productivity on average but yet have very different underlying distributions. This is important, as low average productivity can be explained by too few

[7] These are NACE sectors 18.2, 20, 21, 26, 27, 32.5, and 58-63. See CSO (2017b)

firms operating at the frontier, indicating a lack of innovation, or too many firms at the bottom due to weak market selection (i.e. inefficient resource allocation). Both scenarios would require very different policy responses. Micro-data based research is therefore essential to help inform on the types of firms operating at the national, and possibly global, frontier in Ireland, and those that lag behind.

11. Such firm level evidence, coupled with the fact that productivity growth rate has recently slowed down, motivates a number of questions. Is this trend persistent, have we seen the end of the productivity growth rates experienced in previous years, and what might the drivers be? To help answer these questions and to inform policy, the Department of Finance has engaged in a joint research project with the OECD. The collaboration has sought to understand what is happening at the firm level in Ireland in order to better depict what types of firms operate at the national frontier, how productivity is distributed across firms and how the dispersion has evolved over time, and how resources are allocated across firms. This is in line with leading research in the field which has moved over time from macro- to micro- analysis. The research has involved accessing confidential firm level data at the CSO, and analysing the data using the OECD MultiProd model,[8] a model designed to exploit existing official sources of confidential data at the firm level within countries.

12. Outputs from this research are presented herein, including estimates of productivity, both labour productivity and multifactor productivity, at different percentiles of the firm productivity distribution, including the 'frontier', as well as various measures of productivity dispersion. Estimates of within-industry and across industry productivity dispersion as well as measures of the efficiency of resource allocation are presented, along with the respective contributions of the largest, and the most productive firms to aggregate productivity.

1.4. What follows

13. The remainder of the paper is structured as follows. Section 2 discusses the data and the MultiProd model. Section 3 presents some measures of industry concentration as well as a '*market concentration analysis*' of the importance of a small number of large firms in overall economic activity, and in turn aggregate productivity estimates, referred to in the literature as the 'granular hypothesis'. This analysis sets the scene for some of the results to follow in subsequent sections. Section 4 examines how productivity is distributed across firms, including measures of productivity dispersion between so called frontier firms and laggards (or productivity leaders and followers). Section 5 provides static and dynamic measures on the efficiency of resource allocation; and finally, section 6 concludes.

2. Data and Methodology

2.1. Data description

14. Researchers were provided with three firm level datasets by the Central Statistics Office (CSO), which were accessed on site at the CSO under an Officer of Statistics agreement due to the confidential nature of the data. These were the Census of Industrial

[8] See Section 2.2 and Box 1 for a brief description of the OECD MultiProd model.

Production (CIP), the Annual Services Inquiry (ASI) and the Business Register (BR).[9] For research purposes, all three datasets were merged together through firm identifiers.

15. The CIP contains data on firms in the manufacturing, utilities, mining and quarrying industries, while the ASI covers firms in market and non-market services, excluding financial services.[10] These surveys contain a range of data including key input and output variables such as wages, employment, investment, gross output and value added. The CIP surveys all enterprises with ten or more employees and a portion of enterprises with between 3 and 9 employees, while the ASI surveys all firms with more than 20 employees and uses a stratified random sample to survey enterprises reporting between 2 and 20 persons engaged. The actual microdata underlying the publicly available aggregated results from the CIP and ASI also includes administrative data (from the Revenue Commissioners) for enterprises with less than 3 (CIP) and less than 2 (ASI) persons engaged, though this data was not released by the CSO under the micro data access agreement. Therefore the sample used in this analysis is comprised of survey respondents only.[11]

16. The CSO has recently revised the methodology for the compilation of structural business statistics (including CIP, ASI and BR), with the new approach applied back to 2008, though not before.[12] Accordingly the final sample in the analysis, which is comprised of a panel of firms spanning from 2006 to 2014, required a number of transformations to ensure consistency in the series. These transformations are discussed in the Appendix A3. The average number of annual observations is 10,300, of which 2,500 are industrial firms and 7,800 are service firms.

17. The BR collects information on the entire population of firms, but only for a limited set of variables, such as employment, industry, age and ownership. The MultiProd model, described below, uses the BR in combination with the CIP and ASI to reweight the surveyed data in order to construct statistics representative of the whole population of firms, thus improving the comparability of the results with those of other MultiProd countries. Additionally, the BR enables a more efficient treatment of entry and exit of firms over the period, while it can assign more precise industry codes in the case of changes in the industry classification at the firm level, or changes in the whole industry classification system. BR register data is provided at 4-digit industry level as per the classification NACE Rev 2.

18. To give an idea of the coverage of the sample provided, around 4 per cent of the entire population of firms as reported in the BR are represented by the combined CIP+ASI sample each year, with these firms accounting for around 40 per cent of employment reported in the BR. This sample is then augmented by MultiProd with the entire population of firms from the BR to reweight the sample of surveyed enterprises into a representative sample for estimating key output statistics.

[9] See CSO (2016b, 2016c, 2016d).

[10] In the rest of the paper we analyse results from the non-financial market services sector, which, for simplicity, we refer to as services.

[11] Comparisons of the sample and the full population from the Business Register are outlined in Appendix A1.

[12] See CSO (2016e).

2.2. Methodology

19. The outputs in this paper were generated by using the OECD MultiProd model,[13] which is briefly summarised in Box 1 below. The model runs a standardised STATA routine on confidential firm level data, which can be only accessed at national statistical offices. It uses a harmonised methodological framework to generate non-confidential micro-aggregated statistics and productivity analysis, thus overcoming the confidentiality problem, thereby allowing cross-country comparisons by the OECD. The model uses national administrative data or production surveys, namely the equivalents of the CIP and ASI, along with a Business Register which is used to reweight production surveys in order to construct statistics representative of the whole population of firms.

20. The key input variables are gross output, value added, employment (in terms of headcount or FTE), investment and labour costs on a yearly basis, which are further refined by year of birth, NACE economic sector, size class, foreign ownership as well as quantiles of productivity and size (in terms of gross output and employment) distribution. The widely used labour productivity measure is generated on value-added basis. MultiProd also generates multifactor productivity (MFP) estimates.[14]

21. The MFP measures presented herein are a gross output based 'Solow index number'.[15] The Solow measure relates gross output to a weighted sum of inputs (capital, labour, intermediates) generally assuming constant returns to scale.[16] The weights used are cross-country-year median factor shares for each industry from the OECD STAN database.

22. Productivity variables are estimated, in levels and growth rates, at the broad industry level (manufacturing, utilities, non-financial market services, and non-market services), and at the detailed A38 sector level, which is roughly equivalent to the 2-digit NACE industry level. Basic moments are computed (e.g. mean, median, standard deviation) and productivity statistics are distributed into productivity and size quantiles (e.g. 10th percentile, 50th percentile, 90th percentile), age, size class, ownership, and other demographic factors (entrants, exitors, incumbents, etc.). The model also produces a number of measures of allocative efficiency, including that derived from the Olley-Pakes (1996) decomposition method, along with measures of granularity and concentration, and employment dynamics. A series of basic consistency checks as well as outlier filtering and cleaning of the data are also carried out by the model. All monetary variables in current prices are then transformed into real 2005 U.S. dollars, in purchasing power parity terms, using the OECD STAN database. The STAN database is also used to provide sectoral deflators for the variables, which are based on each countries national accounts data. Double deflation is used where possible, otherwise single deflation is applied.

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[13] A full description of the model can be seen in Berlingieri, G., et al. (2017), "The MultiProd project: A Comprehensive Overview", OECD Science, Technology and Industry Working Papers, No. 2017/04, OECD Publishing, Paris.

[14] For a more comprehensive discussion on MultiProd MFP methods see Section 2.3 of Berlingieri et al (2017)

[15] Although not reported here, the MFP measure generated using the Wooldridge GMM method is also produced by MultiProd. Its correlation with the Solow Residual results reported herein are 0.73 and 0.54 for manufacturing and services respectively.

[16] The gross output measure used in the MFP estimate based on the Solow identity may be impacted by transfer pricing practices of foreign multinationals. However given that the MFP estimate also accounts for intermediate inputs, which will also be impacted by transfer pricing, the inclusion of transfer pricing in both the output and intermediate inputs variables for a firm should lessen the impact.

23. As of May 2017, 18 countries had been successfully included in the MultiProd database (namely, Australia, Austria, Belgium, Canada, Chile, Denmark, Finland, France, Hungary, Italy, Indonesia, Japan, Luxembourg, Netherlands, Norway, New Zealand, Portugal and Sweden). A first version of the output has also been received from China, Costa Rica, Germany, Switzerland, United Kingdom and Ireland. It is understood that Brazil and Spain have also used the code. The data for each of the countries included so far are collected annually, from the early 2000s (depending on country level data availability) to 2012.

3. Market Concentration – the large contribution of a few large firms

3.1. The granular hypothesis

24. In large economies it is generally assumed that uncorrelated micro shocks, on average, cancel each other out. In an economy like Ireland, where a small group of large firms dominate certain sectors, this is unlikely to be the case, suggesting that aggregate (productivity) variation is likely to be the result of (large) firm level variation. Indeed, the so-called 'granular hypothesis' (Gabaix, 2011) suggests that aggregate (productivity) fluctuations are the result of microeconomic (firm level) shocks rather than economy-wide shocks.[17]

25. This section outlines the extent to which a small group of large firms contribute to aggregate outcomes, including productivity estimates. A number of measures of the concentration of the Irish economy are presented here, which help to contextualise the productivity estimates that follow in subsequent sections.

3.2. Concentration measures

26. The first concentration measure MultiProd constructs is the market share (either in terms of value added or employment) that is accounted for by the top decile of firms as ranked by their sales (gross output). Figure 6 below contains three ranges in the sales distribution, namely the top 10 per cent of firms, the bottom 10 per cent, and the rest (i.e. the middle 80 per cent). For each range it provides the share of value added and total employment accounted for by these groups over the period 2006-2014.

27. The top 10 per cent of firms, by gross output, account for 87 per cent of value added and 73 per cent of employment in manufacturing. In services the contributions to value added and employment from the largest firms is higher than manufacturing, with a share of approximately 96 and 87 per cent, respectively. Overall, value added and employment are more concentrated in Ireland than in the other OECD countries for which comparable estimates exist.[18]

[17] See also Jovanovic (1987), Cochrane (1994), Durlauf (1993) and Nirei (2006)

[18] The countries included are Austria, Belgium, Denmark, Finland, Hungary, Norway, Portugal, over the period 1996-2012. Figures reported are weighted averages across all countries and years. See Berlingieri et al (2017)

Box 1. Background to the OECD MultiProd Project[19]

In recent years, the policy and research communities' interest in harmonised cross-country microdata has increased significantly. This reflects the recognition of the need of microdata for understanding the growing complexity in the way economies work and the underlying heterogeneity in economic outcomes.

Significant obstacles remain, however, for transnational access to official microdata. As a result, cross-country studies based on the analysis of official microdata are rare; where they are performed, it is generally via the formation and coordination of networks of national researchers, with each team having access to their respective national microdata. Therefore, the comparability of the country level results needs to be ensured via the use of a commonly specified protocol for data collection and aggregation, and a commonly specified model for the econometric analysis. This method is called the distributed microdata approach. It is a method of collecting statistical moments of the distribution of firm characteristics (employment, productivity, wages, age, etc.) by a centrally written routine that is flexible and automated enough to run across different data sources in different countries.

The advantages of this novel data collection methodology are manifold: it puts a lower burden on individual researchers through the development of a common programme; in a related vein, the development of the programme allows for low-cost reproducibility; it also overcomes the confidentiality constraints of directly using national micro-level statistical databases; and finally, it allows for a high degree of cross-country harmonisation and comparability. It was pioneered in the beginning of the 2000s in a series of cross-country projects on firm demographics and productivity (Bartelsman, 2004; Bartelsman, et al., 2005; Bartelsman, Haltiwanger, et al., 2009). The OECD STI Directorate currently follows this approach in three ongoing projects: MultiProd, DynEmp, and MicroBeRD.

The data collected in MultiProd are computed by running a standardised STATA® routine on firm level data. The program produces a set of statistics based on micro-level longitudinal information on output, inputs (labour and capital), labour costs, economic sector, age, and ownership of the firm. The information is used to calculate firm level labour and multifactor productivity (MFP), the latter estimates using the Solow Residual and Wooldridge (2009) methods, which are then aggregated to the 2-digit sector level, separately for each year. Moreover, some statistics are further refined by age and size classes, ownership characteristics, quantiles of the productivity distribution, and quantiles of the size distribution (defined in terms of sales or employment).

[19] Based on Berlingieri et al (2017).

4. Market Concentration – the large contribution of a few large firms

4.1. The granular hypothesis

28. In large economies it is generally assumed that uncorrelated micro shocks, on average, cancel each other out. In an economy like Ireland, where a small group of large firms dominate certain sectors, this is unlikely to be the case, suggesting that aggregate (productivity) variation is likely to be the result of (large) firm level variation. Indeed, the so-called 'granular hypothesis' (Gabaix, 2011) suggests that aggregate (productivity) fluctuations are the result of microeconomic (firm level) shocks rather than economy-wide shocks.[20]

29. This section outlines the extent to which a small group of large firms contribute to aggregate outcomes, including productivity estimates. A number of measures of the concentration of the Irish economy are presented here, which help to contextualise the productivity estimates that follow in subsequent sections.

4.2. Concentration measures

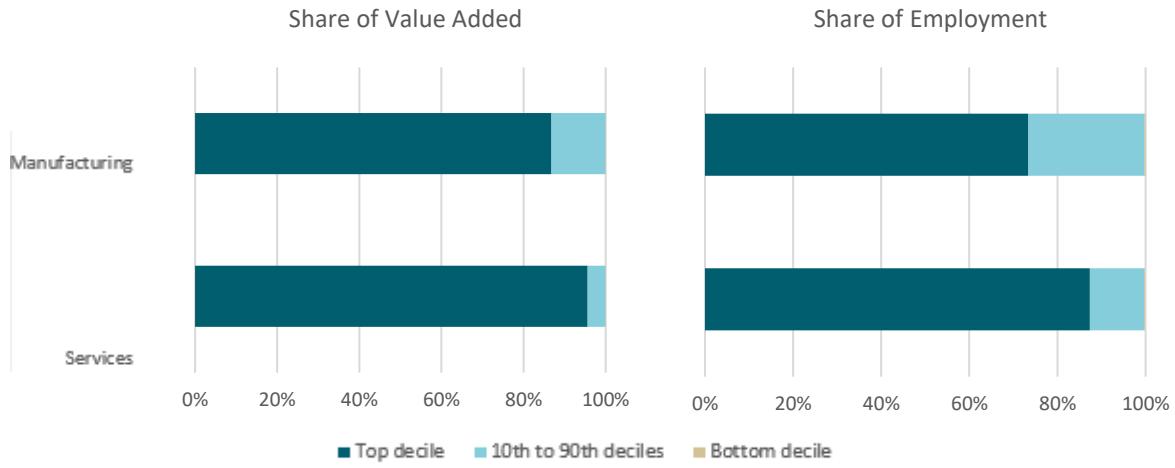
30. The first concentration measure MultiProd constructs is the market share (either in terms of value added or employment) that is accounted for by the top decile of firms as ranked by their sales (gross output). Figure 6 below contains three ranges in the sales distribution, namely the top 10 per cent of firms, the bottom 10 per cent, and the rest (i.e. the middle 80 per cent). For each range it provides the share of value added and total employment accounted for by these groups over the period 2006-2014.

31. The top 10 per cent of firms, by gross output, account for 87 per cent of value added and 73 per cent of employment in manufacturing. In services the contributions to value added and employment from the largest firms is higher than manufacturing, with a share of approximately 96 and 87 per cent, respectively. Overall, value added and employment are more concentrated in Ireland than in the other OECD countries for which comparable estimates exist.[21]

[20] See also Jovanovic (1987), Cochrane (1994), Durlauf (1993) and Nirei (2006)

[21] The countries included are Austria, Belgium, Denmark, Finland, Hungary, Norway, Portugal, over the period 1996-2012. Figures reported are weighted averages across all countries and years. See Berlingieri et al (2017)

Figure 6. Value Added and Employment Shares by Sales Quantile, 2006-2014



Source: MultiProd on the basis of CSO data

32. Another measure to assess the extent of market concentration is the Herfindahl-Hirschman Index (HHI).[22] The HHI, calculated as the sum of the squared market shares (by gross output) of all firms in a given industry, represents a single measure of market concentration.[23] It ranges from 0 to 1, with higher levels of concentration having a higher HHI score. Positive changes in a HHI score over time indicate increasing levels of concentration and market power.

33. Table 1 below presents the HHI in 2011 from Berlingieri et al. (2017) for a number of countries included in the MultiProd network, along with Ireland in 2008, 2011 and 2014.[24] Of the comparator countries, the economy with the most concentrated manufacturing sector in the comparator group is Australia, with a HHI of 0.155, a particularly large score relative to the next highest, Austria, which had a score of 0.063 that year. In services the comparator group generally report significantly lower HHI scores, relative to manufacturing, with Switzerland reporting the highest score of 0.044.

34. By comparison, the MultiProd results show that Ireland recorded a HHI of 0.158 in 2011 in manufacturing, only slightly above Australia, and 0.220 in services, by far the highest score in services that year, and more than twice that of Switzerland, the next highest. The results show that both sectors in Ireland became increasingly concentrated in the 3 years between 2008 and 2011, although remained somewhat stable in the following 3 years.

[22] This measure of concentration has been calculated by the authors outside the MultiProd framework on the basis of the same CIP and ASI data.

[23] $HHI_j = \sum_i \left(\frac{s_{ij}}{sj}\right)^2$

[24] The cross-country results have been revised from previous versions of this paper due to a change in methodology.

Table 1. Herfindahl-Hirschman Index of concentration, 2011

Country	Manufacturing	Services
Australia	0.155	0.036
Austria	0.063	0.016
Belgium	0.050	0.019
Canada	0.018	0.017
Chile	0.058	0.014
Denmark	0.041	0.027
Finland	0.057	0.013
France	0.007	0.005
Germany	0.014	0.011
Hungary	0.041	0.009
Italy	0.001	0.002
Japan	0.026	0.009
Netherlands	0.010	0.004
Norway	0.052	0.008
Portugal	0.016	0.008
Switzerland	0.041	0.044
Sweden	0.044	0.010
Ireland	**0.158**	**0.220**
Ireland (2008)	**0.145**	**0.166**
Ireland (2014)	***0.157***	***0.214***

Source: Berlingieri et al (2017) and Ireland's CIP and ASI.

35. As a final concentration measure, the share of GVA accounted for by the 50 largest firms by gross output was also calculated from the microdata.[25] Overall, the 50 largest firms accounted for 50 per cent of GVA in 2008 which grew to 56 per cent in 2014. Overall manufacturing (74 per cent on average) was more concentrated than services (44 per cent on average) over the period.

36. These findings from the microdata on the concentrated nature of the Irish economy are consistent with a range of other measures from publicly available sources:

- Companies that report to the CSO large cases unit, a unit that interacts with the [50-100] largest firms,[26] accounted for 80 per cent of turnover in 2015[27].

[25] Authors' calculations made outside the MultiProd framework on the basis of the CIP and ASI data.

[26] For confidentiality reasons, the CSO does not disclose the actual number of firms covered by its large cases unit.

[27] See CSO (2017a)

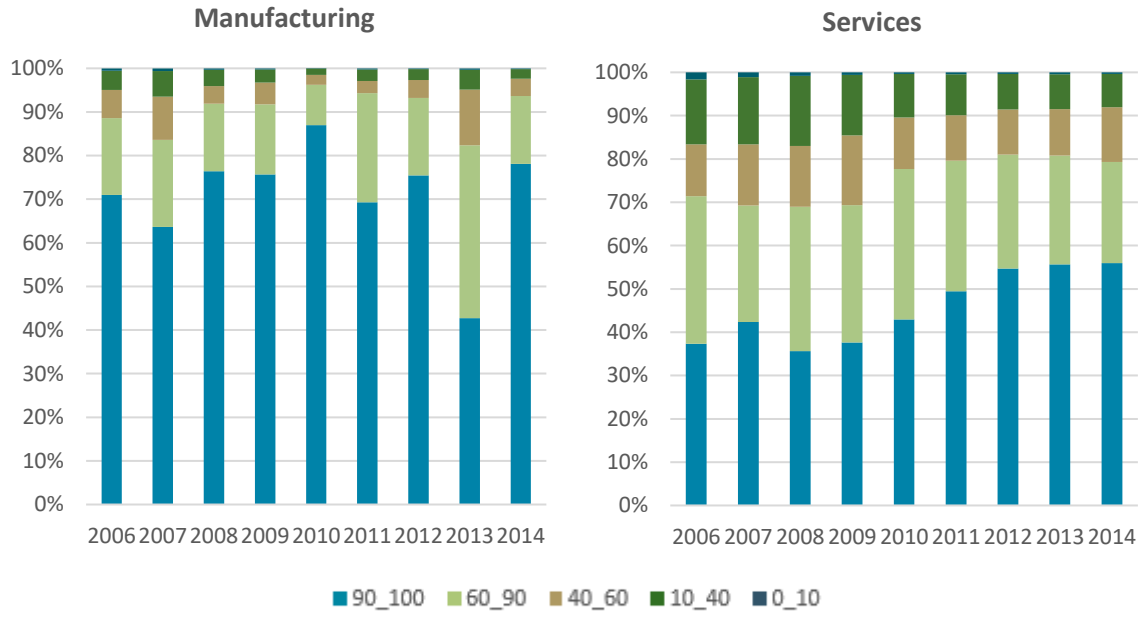
- A small number of sectors dominated by foreign owned multinationals accounted for 40 per cent of gross value added in the economy in 2016.[28]
- The Revenue Commissioners reported that the ten largest payers accounted for 40 per cent of net corporation tax receipts in recent years.[29]

37. Lastly, if a small group of large firms are also the most productive ones, then the impact on aggregate productivity is likely to be significant. Figure 6 below shows the contribution of the most productive firms to aggregate productivity in both manufacturing and services.

38. As illustrated in the Figure 7, the top performing firms in manufacturing (defined as those located between the 90th and 100th percentiles of the labour productivity distribution) account for 70 per cent (on average) of aggregate productivity over the period 2006-2014, and just under 80 percent in 2014.[30]

39. In services, however, the impact of the most productive firms on aggregate productivity is lower than in manufacturing. The top 10 per cent most productive firms account for 46 per cent (on average) of aggregate productivity over the period, showing a growing trend after the crisis from 37 per cent in 2008 to 56 per cent in 2014.

Figure 7. The Contribution of the Most Productive Firms to Aggregate Productivity



Note: 90_100 represents the top productivity decile, with 0_10 representing the bottom decile, 40-60 represents a median group, with the remainder split into 2 equal sized quantiles each covering 3 deciles above and below the median group
Source: MultiProd on the basis of CSO data.

[28] See CSO (2017b)

[29] See Revenue Commissioners (2017)

[30] The 2013 decline in aggregate manufacturing productivity was mainly driven by a drop in value added of a number of top performing pharmaceuticals and chemicals firms, a phenomenon known as the 'patent-cliff', see Enright and Dalton (2014).

40. Overall, the findings presented in this section illustrate the impact that a small number of firms are having on aggregate statistics including industry level output, value added, employment and ultimately productivity. Given the small number of these large firms, uncorrelated idiosyncratic shocks would not be expected to 'average out' over a large number of firms. In other words, firm level productivity shocks within these players are likely to impact on aggregate productivity estimates to a large extent. These findings should be borne in mind when considering the results to follow in subsequent sections.

5. Productivity Heterogeneity

5.1. Introduction

41. A recurring finding from firm level productivity analysis is the large and persistent dispersion in both labour and multifactor productivity between firms, even within narrowly defined industries. Furthermore, despite the recent global productivity slowdown, a small group of frontier firms have experienced consistent rates of productivity growth, while other firms have (on aggregate) experienced much lower productivity growth over the same period. Four key questions regarding productivity dispersion in Ireland emerge:

- How is productivity distributed across sectors and firms (section 4.2);
- How much dispersion exists between frontier (both domestic and global) and laggard firms (Section 4.3);
- How does productivity dispersion differ across sectors, countries, and over time (also section 4.3); and,
- How much of the dispersion in productivity is driven by differences in productivity within sectors as against differences between sectors (section 4.4)

42. The OECD, through the MultiProd project, has recently found empirical evidence of such firm level productivity heterogeneity across a number of countries,[31] and it is the purpose of this chapter to investigate and document the same for the case of Ireland.

5.2. Productivity distribution[32]

5.2.1. Distribution across firms

43. The distribution of productivity across firms in both manufacturing and services sectors in 2014 is presented in the figures below.[33] Figure 8 presents the productivity distribution for labour productivity. Both manufacturing (ind_a7=3) and services (ind_a7=6) sectors show a large right-hand tail in their distribution, especially in the case of manufacturing, which is reflective of the presence of extremely high-productivity firms.[34] The productivity distribution of manufacturing firms depicts a large number of "modal firms" (i.e. firms with very similar productivity levels) co-existing with a small

[31] Berlingieri et al (2017)

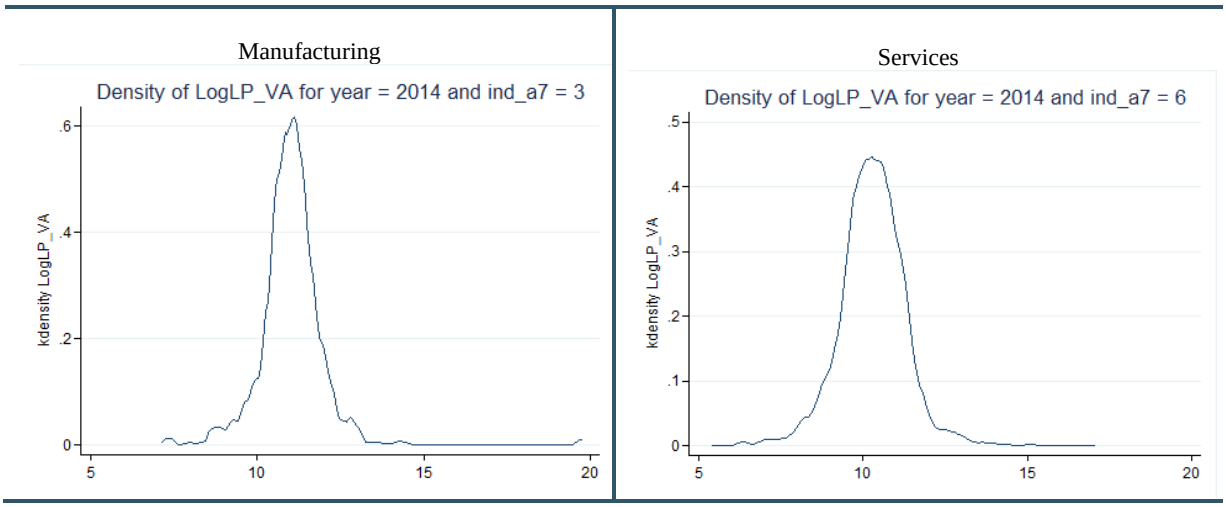
[32] MultiProd performs a number of data cleaning procedures, including removal of duplicates and implausible jumps as well as an outlier filtering on final computed variables. For details see Berlingieri et al (2017)

[33] Distributions measured as Kernel density values for the logged values of labour and multifactor productivity.

[34] Though not shown herein, both distributions are have longer tails than in previous years (i.e. 2006 and 2010) indicating an increasing presence of extremely high productivity firms.

number of super productive firms in the tail. Labour productivity across service firms, while equally heterogeneous, seems to be distributed across a broader range of values.

Figure 8. Labour productivity distributions for manufacturing and services, 2014

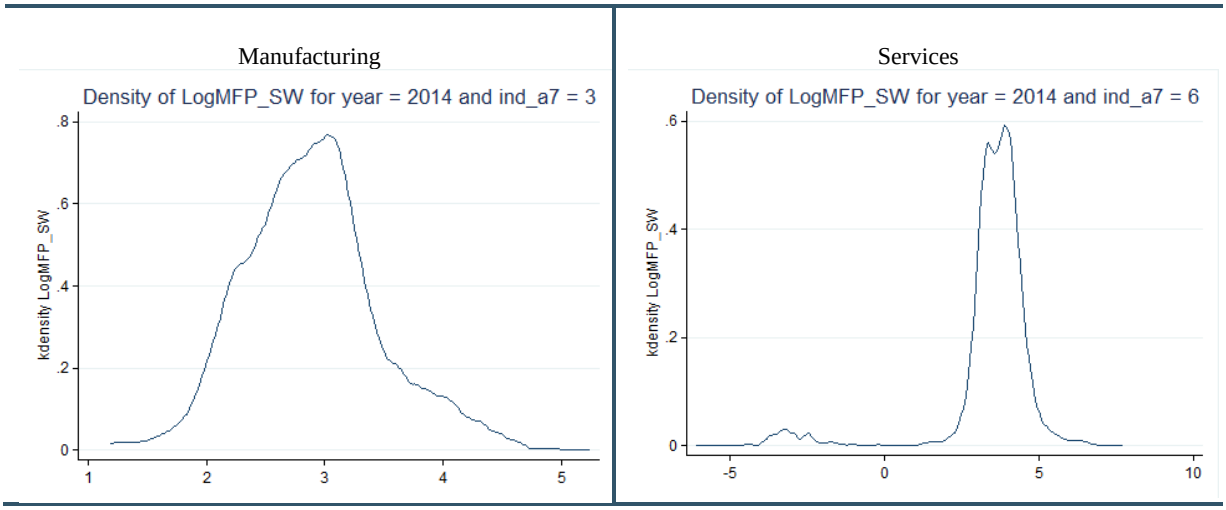


Source: MultiProd on the basis of CSO data.

44. In the case of manufacturing, the 'fat tails' seen on the right-hand side of the labour productivity distribution are less pronounced for the Solow MFP measure (Figure 9), which accounts for capital and intermediate inputs. In services, however, MFP seems to be more widely spread towards both ends of the distribution, with evidence of a long tail of low-productivity firms (some of them with negative values).

45. These findings highlight the co-existence of different firms featuring various levels of productivity in a given industry at a particular point of time.

Figure 9. Multifactor productivity (Solow) distributions for manufacturing and services

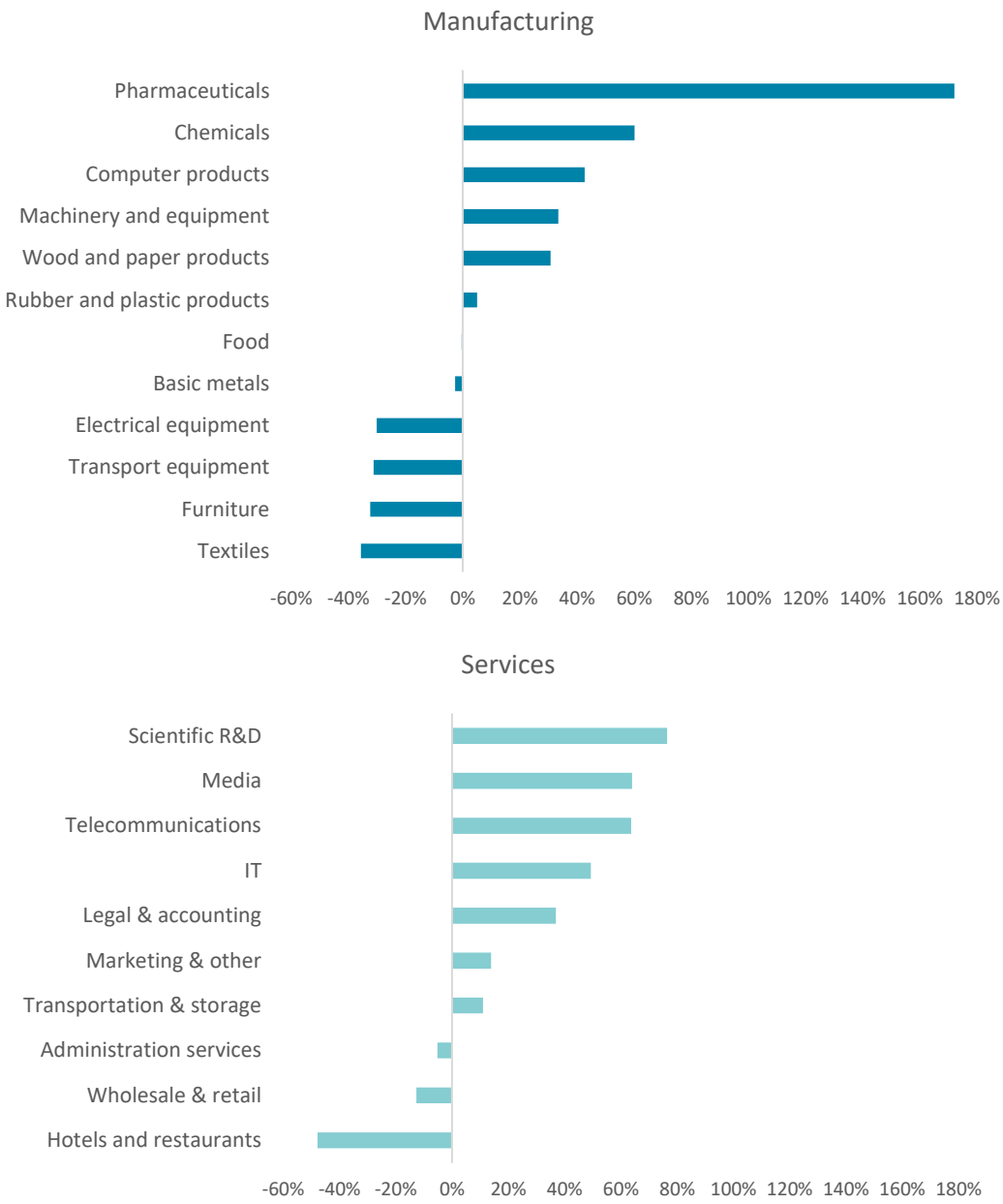


Source: MultiProd on the basis of CSO data.

5.2.2. Distribution across sectors

Figure 10 below reports the (unweighted) average of firm level labour productivity at 2-digit sectors, relative to the unweighted mean of the industry (i.e. manufacturing and services). As the ratios are expressed in logs, the value on the horizontal axis corresponds to the percentage difference between the productivity level of an individual sector, and the unweighted average across the industry that sector belongs to. A value higher (lower) than zero indicates that the sector is relatively more (less) productive than the average across the industry, with a value of zero indicating that the sector has the same productivity level as the industry average.

Figure 10. Relative productivity by 2-digit industries (2006-2014 average) – labour productivity



Source: MultiProd on the basis of CSO data.

46. For manufacturing, the Pharmaceutical sector is by far the most productive, with an average firm level labour productivity that is about 170 per cent larger than the manufacturing average. Chemicals and computer products are also well above the manufacturing industry average, being 60 per cent and 43 per cent more productive. These sectors also record the largest shares of VA in manufacturing, accounting for 55 percent of

manufacturing value added in aggregate.[35] In other words the most productive sectors, are also the largest, in value-add terms. The ranking of the top five sub-sectors in manufacturing is consistent with results reported for a benchmark group of countries, as part of the MultiProd project.[36] At the other end, the least productive sub-sectors in manufacturing are Textiles and the Furniture industries, falling 36 per cent and 32 per cent below the average, respectively.

47. In the case of services, the most productive sector relative to the industry average is Scientific R&D (76 per cent more productive). This is followed by the Publishing, audio-visual and broadcasting services (media) and Telecommunications sectors, which are about 64 per cent larger than the average productivity in the services industry. On the other hand, the Hotel and restaurant sub-sector is 48 per cent below the average, and in line with the benchmark group of countries is the least productive sector relative to the average in services.[37]

48. In terms of multifactor productivity, which takes into account capital and intermediate inputs, Machinery & Equipment and Furniture & Others,[38] turn out to be the most productive sectors (around 40 per cent higher) with respect to the manufacturing average (see Figure 11). Conversely, Food & beverages, Chemicals, Transport equipment, Metal products and Electrical equipment showed below average levels of multifactor productivity over the period 2006-2014.

49. In services, the most productive sectors are Scientific R&D (130 per cent above average) and IT (70 per cent above average) followed by Wholesale & retail trade and Legal & accounting, with multifactor productivity about 60 per cent higher than the average. The Telecommunications sector shows the lowest relative multifactor productivity over the period 2006-2014. Once again, these results are consistent with the OECD benchmark group of countries for the MultiProd project.[39]

[35] See Table 22 of CSO (2017c)

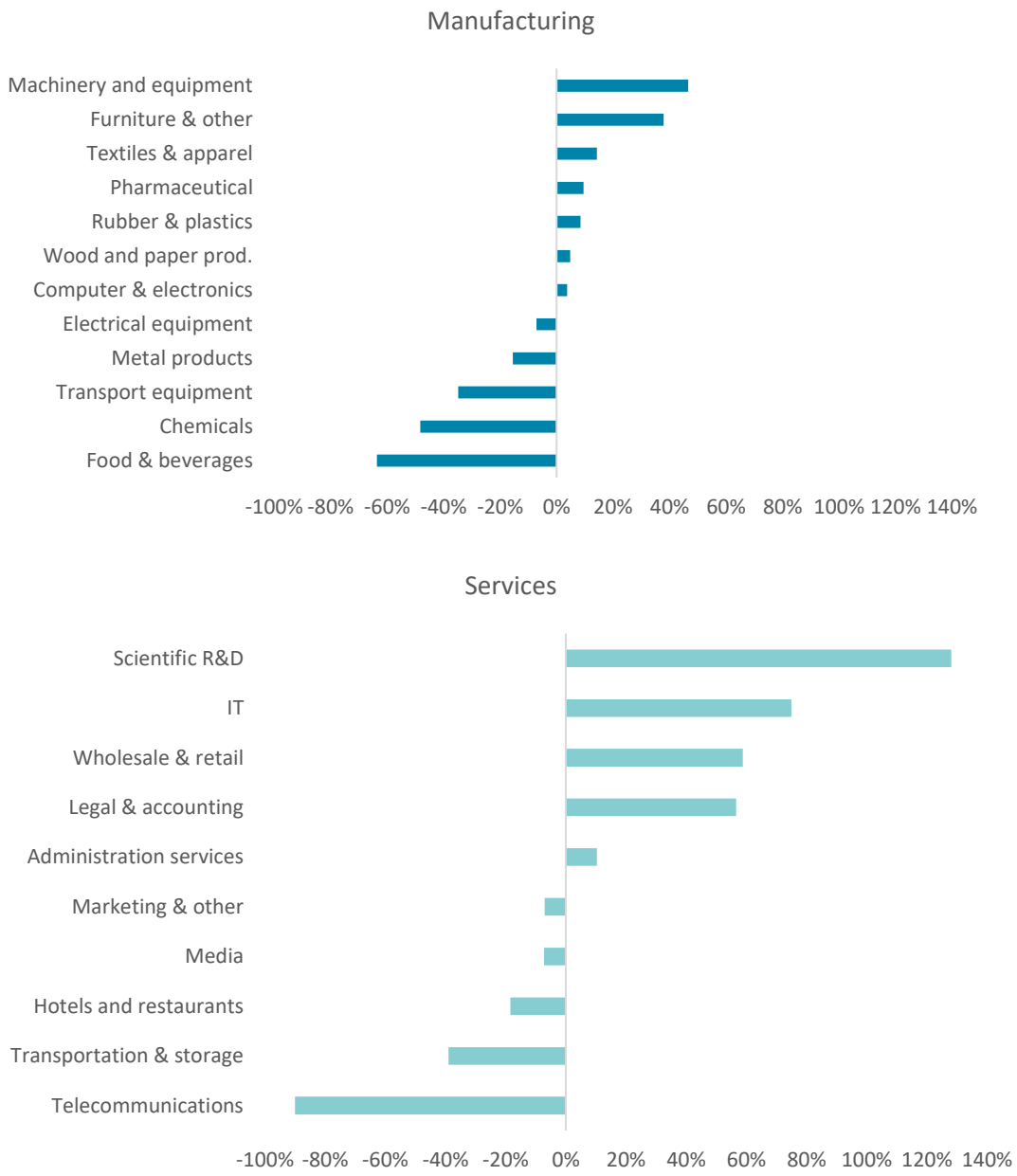
[36] See OECD (2017)

[37] Both manufacturing and services labour productivity at 2-digit industry level are broadly consistent with the CSO figures published in the CIP and ASI (full samples) as well as National Accounts (see Appendix A2)

[38] Others includes other manufacturing (e.g. jewellery as well as sport, medical and dental instruments) and repair and installation of machinery & equipment (e.g. electronic and optical equipment as well as ships and aircrafts)

[39] See OECD CIIE Country note for Italy (2017)

Figure 11. Relative productivity by 2-digit industries (2006-2014)– Log multifactor productivity

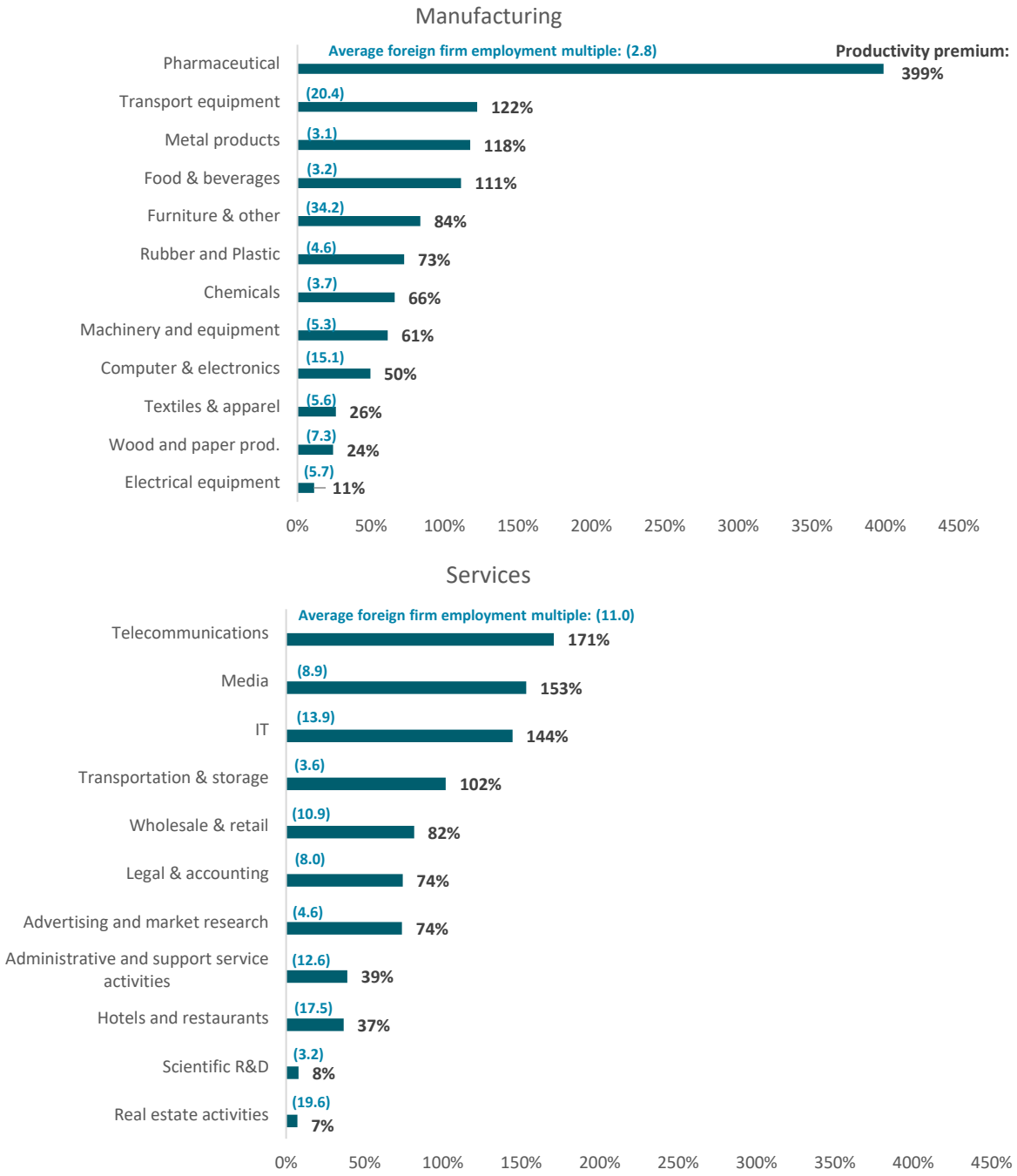


Source: MultiProd on the basis of CSO data.

50. As a final look at sectoral differences, Figure 12 below sets out the within sector foreign firm labour productivity premium, for manufacturing and services (the bars in the chart). The chart also notes the average foreign firm employment multiple, the numbers in brackets above the bars, as a measure of relative size. The results show that across all sectors, foreign firms are more productive and larger, as defined by the employment differential, than domestic firms. For instance, in the pharmaceuticals sector foreign firms have a 399 percent productivity premium over domestic firms, and on average have 2.8 times as many persons engaged as domestic firms. Though not reported in the charts, the

positive premium observed for labour productivity also exists for total factor productivity, with the exception of the textiles sector.

Figure 12. Within-sector foreign firm (log) labour productivity premium and employment differential (2014)



Note: The bars represent the foreign firm labour productivity premium and are read off the horizontal axis. The average foreign firm employment multiple reported in brackets.
Source: MultiProd on the basis of CSO data

5.3. Productivity dispersion

5.3.1. Frontier vs. laggard firms

51. In order to understand the performance of different groups of firms causing the above-described heterogeneity, Figure 13 and Figure 14 illustrate some selected percentiles of the labour productivity and MFP distributions over time, namely the 10th percentile (laggard firm), 50th percentile (median firm), and both 90th and 97th percentiles (frontier firm).[40] All percentiles have their (logged) productivity levels in 2006 normalised to 100, in order to see their relative paths in the following years.

52. For manufacturing firms, Figure 13 illustrates a decline in labour productivity across all deciles after 2007, coinciding with the onset of the crisis. Even though this pattern reverses from 2010, the recovery has been skewed towards the most productive firms (90th and 97th percentiles), with a clear widening in the productivity gap between frontier firms and the rest by the end of the period. While year-on-year growth rates are somewhat volatile,[41] overall top performers' are roughly 10 percentage points above their productivity level in 2014 compared with 2006, with the median firm productivity in 2014 is just above its pre-crisis level of 2006, and the bottom performing firms still lagging.[42] Overall this illustrates a widening in the productivity gap between the 'best' and the 'rest'.

53. In services, labour productivity levels declined post-2007 across all cohorts of firms, and still remained well below their 2006 level (between 15 and 40 per cent) at the end of the period. As with manufacturing, a widening in the labour productivity gap can be observed, although for slightly different reasons. While in the manufacturing sector frontier firms have seen a faster recovery in productivity growth after the crisis, in the services sector frontier firms have seen a slower decline in productivity growth as compared to laggards.[43]

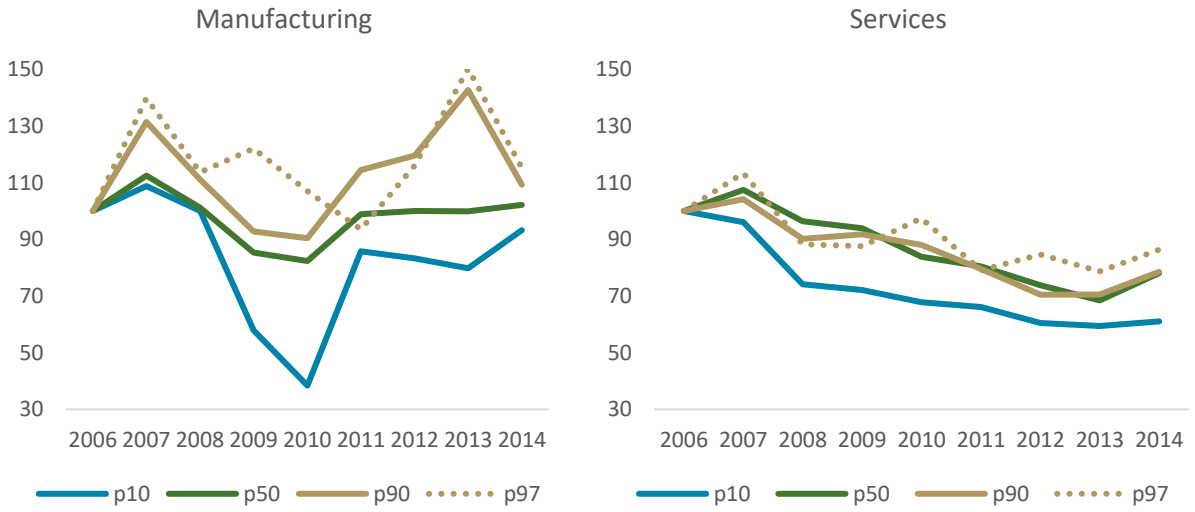
[40] Sensitivity analysis carried out by the authors indicate a reasonable degree of consistency in the overall path for different definitions of the frontier (i.e. top 10%, 5% and 3% percentiles of firms) in labour productivity measures. However, in MFP terms, there is evidence of a divergence between the 90th and the 95th percentiles of the distribution of firms, which is even greater in manufacturing, with the 97th percentile standing out. It should be noted that the results for the 97th percentile are close to those of the (weighted) average of firms in the top decile.

[41] Productivity growth in the bottom decile (p10) in 2010 is due to a lower number of surveyed enterprises in the CIP, featured by small and low-productivity firms. The spike observed in the 90th (p90) and 97th (p97) percentiles in 2013 is partly due to developments in the pharmaceutical sector, while the subsequent fall is partly due to developments in the food & beverage industries.

[42] An overall weighted average is also produced by MultiProd. For manufacturing firms this measure is much more stable around the 2006 initial productivity levels, suggesting that the firms at the very top of the productivity distribution recorded productivity growth during this period.

[43] Weighted measures of labour productivity in services show an even slower decline than the p97, suggesting that the largest firms have a much more stable, or possibly increasing level of labour productivity over time. Weighted measures in services are highly influenced by domestic non-traded sectors, such as wholesale, retail and accommodation.

Figure 13. Trends for top, median and bottom decile of (log) Labour productivity distribution



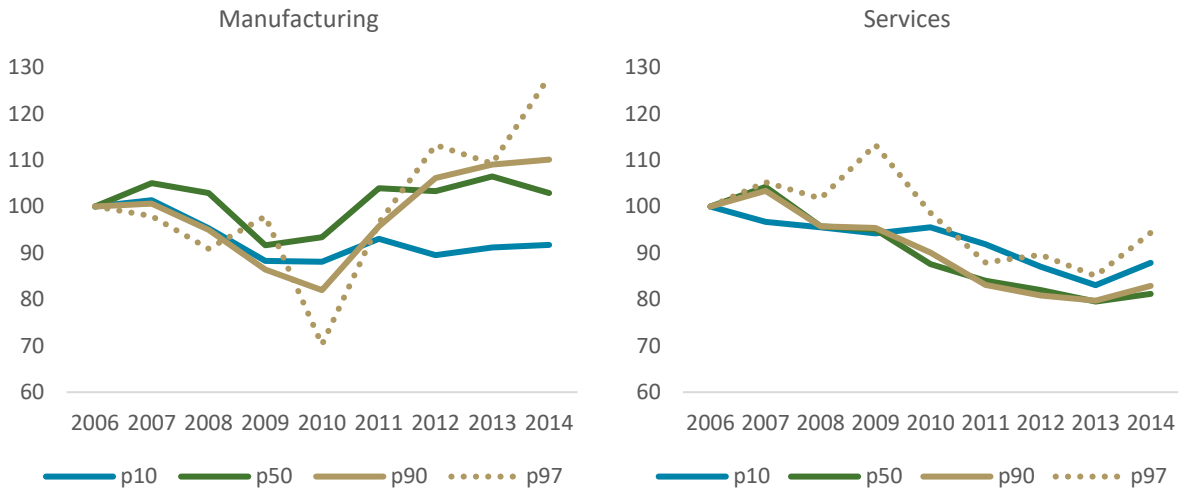
Source: MultiProd on the basis of CSO data

54. Transfer pricing could potentially have an impact on labour productivity statistics through the impact on output data. However, given that many of the foreign multinationals that engage in transfer pricing are likely to be extremely productive, located above even the 97th percentile, this is unlikely to affect the percentiles presented in Figure 13. Furthermore, the dispersion charts using the MFP measure of productivity shown in Figure 14, which also incorporate transfer pricing outflows by controlling for intermediate consumption thereby lessening the overall impact, show similar patterns over the period while also accounting for transfer pricing by containing the impact in both output and intermediate input variables.

55. In the case of MFP (Solow) for manufacturing, displayed in Figure 14, there is a similar trend observed to that of labour productivity with a fall post-2007 that is even across deciles, with the subsequent recovery more pronounced among frontier firms, in line with the labour productivity trends shown before. For example, the cumulated growth rate of manufacturing MFP in the 90th percentile in 2010 was nearly 20 per cent lower than in 2006, while at the end of the period, in 2014, it was about 5 per cent higher.

56. In services, there is again a trend downwards for all deciles from 2007 onwards, which levels off in recent years. Unlike manufacturing, the rate of decline observed in the top performers is faster than both the median and bottom performing firms. However the underlying reason behind the paths for the 10th and 90th percentiles differs, with the decline in the 90th percentile between 2006 and 2010 related to faster growth in capital relative to gross output, while in the 10th the fall in MFP is due to a slower decline in capital (and labour) relative to gross output over the same period. However, when frontier firms are measured as the top 3 per cent of firms (i.e. the 97th percentile), they declined the slowest and recovered the fastest as compared to the median and laggard firms.

Figure 14. Trends for top, median and bottom decile of the (log) MFP distribution



Source: MultiProd on the basis of CSO data.

57. Overall, Ireland's trends for the top, median and bottom deciles of labour productivity growth in manufacturing are relatively close to those observed in the cross-country analysis carried out by the OECD (Figure 1). However, in the case of Ireland, productivity growth declined much faster and the recovery was slower than other countries. This is not surprising given the relatively deeper recession experienced by the Irish economy during that period. In the case of services though, Irish labour and multifactor productivity, across all deciles, has not yet returned to pre-crisis levels, unlike the median OECD country, where recovery has occurred.

5.3.2. Productivity dispersion by country

58. To put these measures into perspective, the 90-10 ratio in Ireland can be compared against the group of countries in the MultiProd network. This is presented in Table 2 below for 2011,[44] along with a number of other dispersion ratios for Ireland.

59. Some important features are illustrated in Table 2. First, there is significant productivity dispersion between the frontier and laggard firms, across all countries. Second, dispersion is on average higher in services than manufacturing. Third, the labour productivity dispersion ratio of 6.6 in manufacturing for Ireland in 2011 implies that firms at the top of the distribution can produce more than six times as much value added per worker as firms in the bottom decile of the country's manufacturing sector,[45] and similarly nine times in services. This is in line with the average ratios across countries of 7.7 and 9.3 for manufacturing and services, respectively. Fourth, other measures of productivity dispersion for Ireland are also presented at the bottom of the table. As expected, when the most productive frontier firms are taken into account in the 95-10 and 97-10 ratios, which incorporate firms in the 95th and 97th percentiles respectively, productivity dispersion

[44] 2011 is the reference year used for cross country comparison by the MultiProd project as per Berlingieri et al (2017).

[45] This is calculated as the exponential of the log difference reported in the Table

widens, with respect to the same laggard firms. As might be expected, productivity dispersion is lower when frontier firms are compared against the median firm (90-50 ratio) or when dispersion around the median firm (i.e. interquartile range 75-25) is taken into account.

Table 2. Labour Productivity dispersion by country, 2011

Country	(LP_VA) 90-10 ratio	
	Manufacturing	Services
Australia	6.5	7.8
Austria	7.1	11.2
Belgium	5.0	5.7
Chile	20.1	34.1
Denmark	4.3	7.1
Finland	3.2	4.0
France	3.9	6.1
Hungary	16.3	26.8
Indonesia	22.4	-
Italy	5.3	7.5
Japan	3.5	4.0
Netherlands	7.4	19.7
New Zealand	6.3	8.1
Norway	5.6	8.8
Portugal	6.6	14.2
Sweden	4.3	6.4
OECD average	**6.6**	**9.2**
Ireland	**7.9**	**9.3**
Ireland (95-10)	*9.8*	*14.1*
Ireland (97-10)	*13.2*	*18.4*
Ireland (90-50)	*2.9*	*2.9*
Ireland (75-25)	*2.4*	*3.0*

Note: Cross country comparators from Berlingieri et al (2017) .
Source: MultiProd on the basis of CSO data and MultiProd database.

5.3.3. Productivity dispersion by sector

60. The significant productivity dispersion shown in the previous section for both manufacturing and services was obtained as an average of the underlying "within sector" dispersion amongst firms within each sector in each of these broad industries. Table 3 below illustrates these underlying dispersions for Ireland by reporting the (unweighted) labour productivity differences between top (90th percentile) and bottom (10th percentile) performing firms at a more disaggregated sectoral level for both manufacturing and services over the period 2006-2014 (on average).

Table 3. Labour productivity 90-10 ratio at 2-digit sector level

Manufacturing	90-10 ratio
Basic pharmaceutical products and pharmaceutical preparations	129.3
Computer, electronic and optical products	10.1
Transport equipment	9.4
Chemicals and chemical products	8.5
Food products, beverages and tobacco	7.8
Rubber and plastic products, and other non-metallic mineral products	6.8
Furniture; other manufacturing; repair and installation of machinery and equipment	6.4
Electrical equipment	6.2
Textiles, wearing apparel, leather and related products	6.1
Wood and paper products, and printing	5.5
Basic metals and fabricated metal products	5.2
Machinery and equipment n.e.c.	4.7
Services	
Telecommunications	18.8
Publishing, audiovisual and broadcasting activities	15.9
Real estate activities	15.7
Scientific research and development	13.2
Wholesale and retail trade, repair of motor vehicles and motorcycles	8.6
Administration and support service activities	8.3
Legal and accounting activities, etc.	7.9
Advertising and market research, etc.	7.6
IT and other information services	7.5
Transportation and storage	6.8
Accommodation and food service activities	5.6

Source: MultiProd on the basis of CSO data and MultiProd database.

61. In manufacturing, the pharmaceutical industry shows the widest labour productivity gap, whereby top performers are about 130 times more productive than bottom performing firms. This is followed by computer products (10.1), transport equipment (9.4), chemical products (8.5) and food & beverage products (7.8), with machinery & equipment and wood products showing the lowest productivity dispersion, with the 90th percentile just under 5 times more productive than the 10th.

62. In services, labour productivity dispersion is the largest in telecommunications (19 times larger), followed by publishing, audio-visual and broadcasting services, and real estate activities (both are just under 16), while it is the lowest in accommodation and food service activities with a ratio of just over five times.

5.4. Productivity dispersion decomposition

63. The previous sections have reported the productivity dispersion within two digit sectors of the two broad industries, namely manufacturing and services. By focusing only on the dispersion within 2-digit sectors the results might not explain the overall dispersion in the industry. However this section shows that the within 2-digit sector dispersion is actually capturing most of the overall dispersion in the broader industries.

64. The overall dispersion in productivity in each broad industry can be decomposed into productivity variation within (2-digit) sectors, capturing how much a firm's individual productivity differs from the sector (labour-weighted) average, and variation between sectors, capturing how much sectors vary from each other.[46] This is presented in Table 4 below for manufacturing and services, for Ireland and the comparator countries, based on results reported in Berlingieri et al (2017).

65. The results for Ireland show that within-sector dispersion accounts for nearly 95 per cent of the overall labour productivity dispersion observed across firms in manufacturing, and 94 per cent in services. Therefore, the vast majority of the productivity dispersion comes from the variation in productivity between firms within the same two-digit sector, rather than differences in productivity between sectors, indicating that a large part of the productivity heterogeneity is firm- rather than sector-specific. As a result, the within sector dispersion in Ireland is amongst the largest across the group of MultiProd comparators, only below Australia in manufacturing, and Australia, Chile and Hungary in services.

[46] Total productivity variance (V_t) can be split into two components: a within-industry component (V_{Ft}) and a cross-industry component (V_{Xt}).$V_t = V_{Ft} + V_{Xt}$. Within-industry variance is the average over all sectors *j* of the square deviation of the firms' productivity to their sector (weighted) average labour productivity. $V_{Ft} = \sum_j \frac{L_{jt}}{L_t} \delta_{jt}^2$. The cross-industry component is the average of the squared deviation of sector *j*'s average productivity ($\bar{P}_{jt}$) to the economy-wide productivity ($\bar{P}_t$). $V_{Xt} = \sum_j \frac{L_{it}}{L_t} \left(\bar{P}_{jt} - \bar{P}_t\right)^2$

Table 4. Share of labour productivity dispersion accounted for by within sector variation, 2011

Country Year 2011	Manufacturing	Services
Australia	98%	99%
Austria	86%	90%
Belgium	76%	88%
Chile	90%	97%
Denmark	84%	63%
Finland	65%	76%
France	63%	85%
Hungary	79%	99%
Indonesia	79%	-
Italy	82%	65%
Japan	75%	89%
Netherlands	80%	71%
Norway	83%	73%
Portugal	62%	76%
Sweden	53%	74%
Ireland	**94%**	**94%**
Ireland (2014)	**98%**	**97%**

Note: Cross country results from Berlingieri et al (2017)
Source: MultiProd on the basis of CSO data

66. Table 5 below reports the top three sectoral contributors to labour productivity variance in 2011 for manufacturing and services. Results are presented for Ireland and Australia, as both are countries that possess similarly high levels of within sector variation. Some sectors, such as pharmaceutical products and food & beverages in manufacturing, as well as transportation & storage and legal & accounting activities in services, appear in the top three industries ranked by level of productivity dispersion in both countries. This suggests there may be sectoral features of the within sector distribution of firms that might affect the distribution of productivity at a more aggregated level in Ireland and other countries alike.

Table 5. Top three sectors in share of within sector Labour Productivity dispersion, 2011

Country Year 2011	Manufacturing	% variation share	Services	% variation share
Ireland	Basic pharmaceutical products and pharmaceutical preparations [CF]	98%	Legal and accounting activities, etc. [MA]	20%
	Chemicals and chemical products [CE]	18%	Transportation and storage [H]	20%
	Food products, beverages and tobacco [CA]	1%	Media/Publishing	18%
Australia	Food products, beverages and tobacco [CA]	35%	Transportation and storage [H]	26%
	Machinery and equipment n.e.c. [CK]	28%	Legal and accounting activities, etc. [MA]	25%
	Basic pharmaceutical products and pharmaceutical preparations [CF]	13%	Wholesale and retail trade, repair of motor vehicles and motorcycles [G]	21%

Source: MultiProd on the basis of CSO data and Berlingieri et al (2017)

6. Efficiency of Resource Allocation

6.1. Introduction

67. There is a growing body of productivity research dedicated to looking at how the allocation of resources across firms can impact aggregate productivity, as well as the impacts of reallocation on aggregate productivity growth. In addition to the contribution to productivity growth of innovation at the frontier, or the diffusion of innovation from the frontier to the rest of the economy, the allocation of resources across firms can have a positive effect on aggregate productivity when there is a flow of inputs (capital and/or labour) from low- to high-productivity firms. Conversely, if factors are largely allocated to, or flowing towards inefficient firms, aggregate productivity will be adversely affected.

68. A constant churn, or reallocation, of resources between firms in the same industry has been found in previous empirical research (Foster et al., 2002) where in addition to the entry of new firms and the exit of shrinking firms, it has been driven by continuous upscaling and downscaling of incumbent firms. This churning can contribute to aggregate productivity growth, the extent to which depends on how effectively resources are reallocated across firms and sectors. Allocative efficiency has been found to vary considerably across countries (Bartelsman et al., 2004), as well as sectors (Arnold et al., 2011). Bartelsman et al. (2009) also showed considerable variation exists in the dynamic case, finding estimates ranging from highly positive to highly negative. Overall, results show that countries differ significantly in their ability to allocate resources effectively, with important consequences for productivity growth.

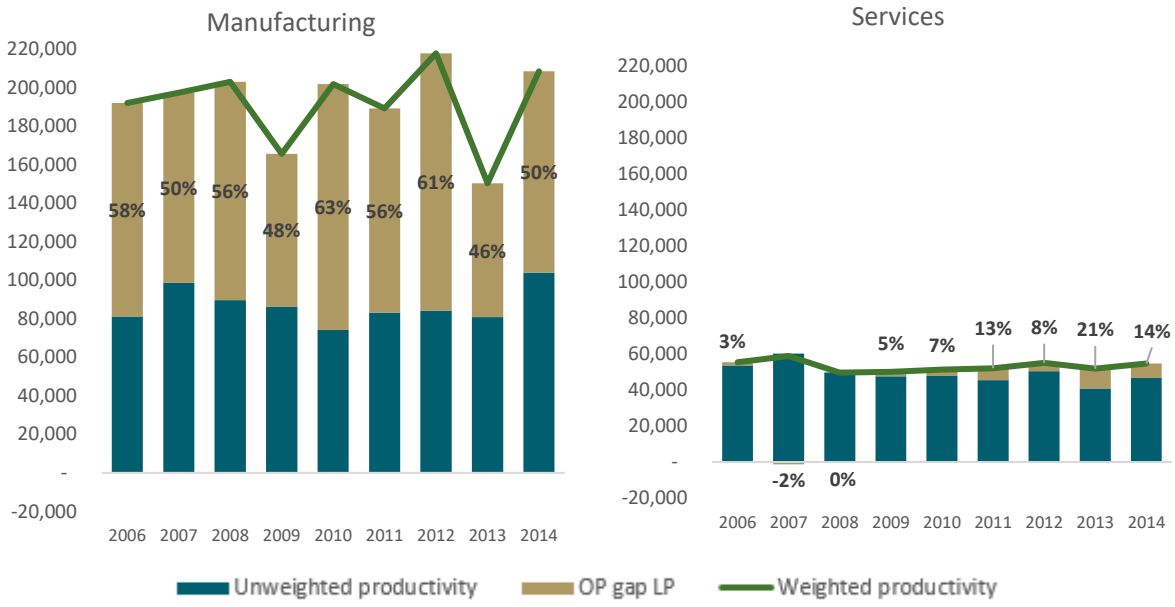
69. While the previous section looked at Ireland's productivity differences between frontier firms and the rest, this section looks at how resources (such as labour and capital) are allocated across firms of different productivity levels, and the extent to which factors are reallocated from low to high productivity firms, thereby enabling highly productive firms, whether large or small, to grow. In particular, this section looks at the Olley-Pakes

(1996) resource allocation measure to examine the relationship between productivity and firm size at a given point in time. A dynamic version of the OP gap, developed by Melitz and Polanec (2015), is then used to examine contributions from various forces such as resource reallocation and within-firm productivity growth as well as entry and exit effects to aggregate productivity growth.

6.2. Static Productivity Decomposition

70. Contributions to (weighted) aggregate productivity can be decomposed using the Olley-Pakes (1996) method into the contributions from (unweighted) within firm productivity, and the efficiency or resource allocation (allocative efficiency), as measured by the covariance between firm size and productivity. The latter term (known as the OP gap) is a measure of allocative efficiency, since it increases if more productive firms capture a larger share of resources in the sector.[47] Figure 15 below plots the (weighted) aggregated productivity and its components, namely unweighted productivity and the OP gap for manufacturing and services.

Figure 15. Resource allocation: 'OP gap', weighted and unweighted productivity



Source: MultiProd on the basis of CSO data.

[47] $P_t = \frac{1}{N_t}\sum_i P_{i,t} + \sum_i (\theta_{i,t} - \bar{\theta}_t)(P_{i,t} - \bar{P}_t)$ where P_t is the weighted industry level productivity at time t, N represents the number of firms in a sector, $\theta_{i,t}$ is the share of a firm i at time t, and $\bar{P}_t$ and $\bar{\theta}_t$ are sectoral averages. In the case of the value added based measure of labour productivity, the weights used are simply labour shares. The first term on the right hand side of the equation represents unweighted productivity while the second term represents the OP gap.

71. In the manufacturing sector, more than a half (54 per cent on average) of aggregate labour productivity is accounted for by the allocative efficiency term (OP gap) over the whole 2006-2014 period. The remaining part of aggregate productivity in manufacturing is accounted for by within-firm productivity. The most significant increase in allocative efficiency took place in 2010, when the contribution to aggregate productivity from the OP gap went up to 63 per cent, while the sharpest decline occurred in 2013 when this term decreased to 46 per cent (from 61 per cent the previous year). The 2013 decline in weighted productivity was mainly driven by a drop in value added of large chemical and pharmaceutical enterprises, coinciding with the 'patent cliff' in those sectors.[48]

72. On the whole, Ireland's OP gap in the manufacturing sector is relatively large and stable over time, indicating a fair degree of allocative efficiency as a high share of resources are already allocated to the most productive firms. However, as referred to earlier in the discussions on market concentration and productivity dispersion, large variations exist in firm productivity even within narrowly defined sectors. While the OP gap for Ireland indicates that resource allocation is relatively efficient in the manufacturing sector as a whole, these results are likely driven by particularly efficient sub-sectors like pharmaceuticals, chemicals and computer products.[49]

73. In services (Figure 15), most of the aggregate productivity is accounted for by within-firm (unweighted) productivity over the period 2006-2014, with the overall allocation of resources (the OP gap term) playing a very small role. In fact, the OP gap was even negative during the crisis indicating an inefficient resource allocation during that period, indicative of an increase in market share by (and flow of resources towards) less productive firms.[50] After the crisis the OP gap started to grow, accounting for about 14 per cent of aggregate productivity in 2014.[51]

74. Ireland's resource allocation term in manufacturing is large when benchmarked against other OECD countries[52], with only Hungary and Chile reporting OP gaps of 50 per cent or more in 2011. This outcome is likely to be driven by the impact of a small number of very large firms, in certain foreign dominated sectors, a view supported by the positive productivity and size premium that foreign firms have over domestic firms, as illustrated in Section 4. With this in mind, Figure 16 below presents the OP gap for manufacturing with a small number of sectors dominated by foreign multinationals excluded from the analysis.[53]

75. Relative to the full manufacturing sample, the exclusion of foreign dominated sectors results in a much lower OP gap of 33 per cent in 2014 (compared to 50 per cent in

[48] See Enright and Dalton (2014)

[49] In fact, the OP gap has been found to be negative in a few manufacturing sub-sectors such as wood and paper products etc. (CC), basic metals and fabricated metal products (CG) and electrical equipment (CH).

[50] In fact, the OP gap has been found to be negative in a numbers of services sub-sectors such as Administrative and support service activities (NACE sector N), Real estate activities (L), and Accommodation and food service activities (I). The low value of the OP gap in services may reflect the lower correlation between productivity and size in the service sector, as recently showed by Berlingieri et al. (2018).

[51] Resource allocation analysis for services with foreign dominated sectors excluded are not presented here as the removal of foreign dominated sectors does not materially change the results.

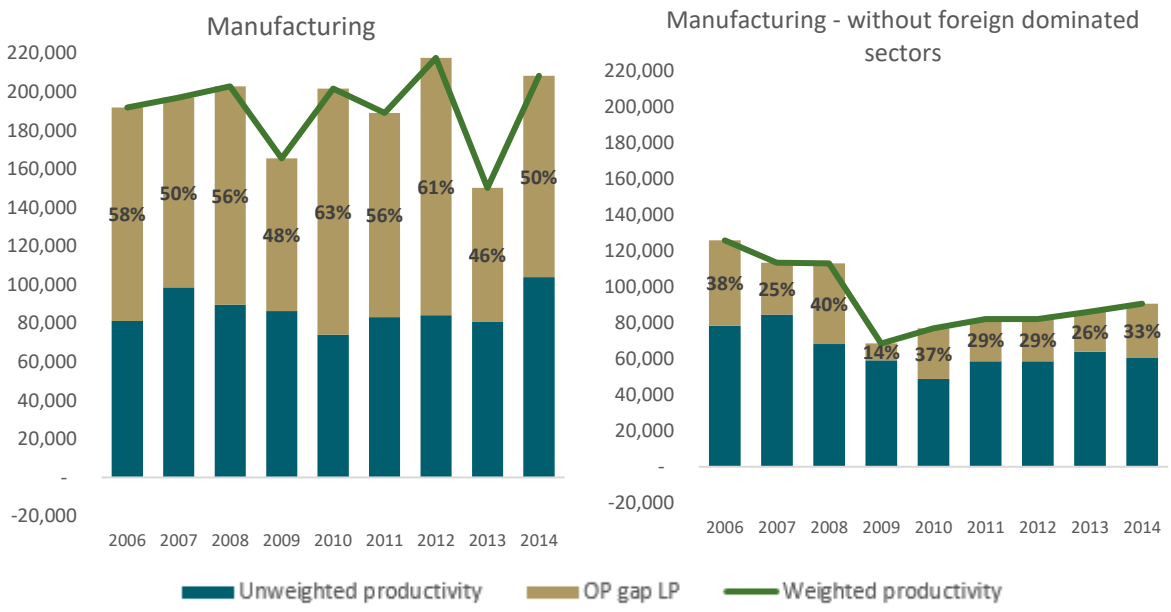
[52] See Berlingieri et al (2017)

[53] See CSO (2017b), and footnote 6 herein, for a list of foreign MNE dominated sectors.

Figure 15) rising from a low of 14 per cent in 2009 (compared to 48 per cent in Figure 15), and gradually returning towards the pre-crisis levels (Figure 16). These results suggest that a substantial part of aggregate labour productivity (in manufacturing) is indeed driven by efficient allocation of resources within a small group of foreign dominated sectors.

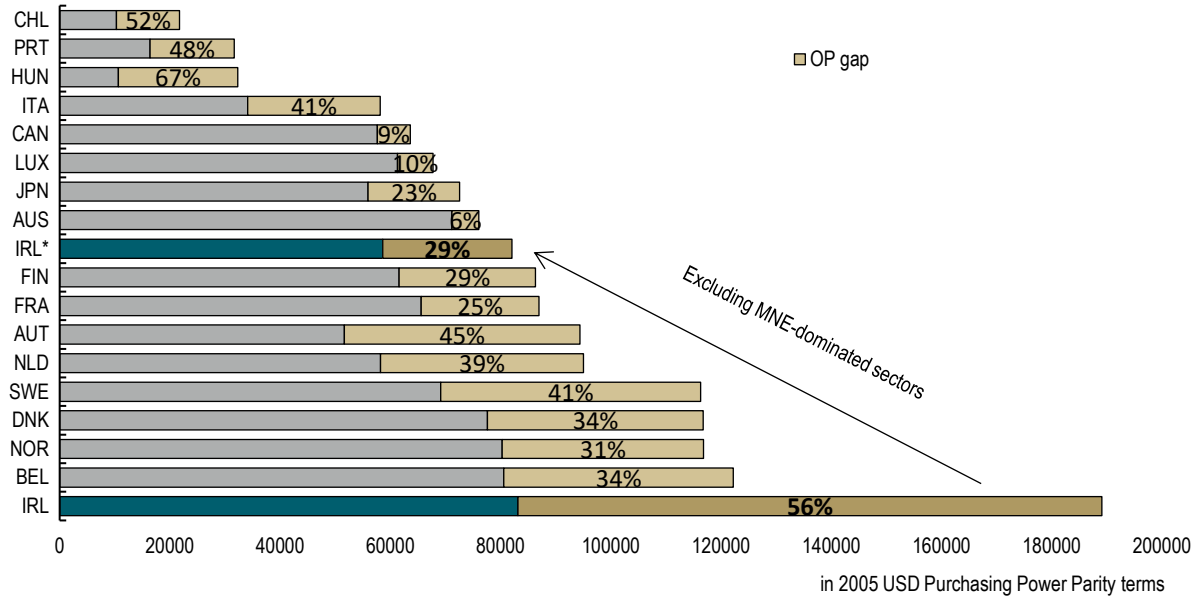
76. Both these results are compared to the OP gap in other countries manufacturing sectors in Figure 17, which shows once these highly productive foreign dominated sectors are removed Ireland is much more in line with the average level of resource allocation efficiency and aggregate productivity. The results for manufacturing without foreign dominated sectors also removes the influence of firms who have located intellectual property in Ireland, which would inflate their productivity statistics, as intellectual property can give rise to scalability. The results suggest that the allocation of resources is less efficient in the non-foreign dominated sectors of the economy. This is particularly important as it is the allocation of resources amongst the non-foreign dominated sectors which would have a greater impact on living standards in Ireland.

Figure 16. Resource allocation: 'OP gap', weighted and unweighted productivity in manufacturing (excluding foreign dominated sectors)



Source: *MultiProd on the basis of CSO data*

Figure 17. Resource allocation: OP gap for manufacturing across countries - 2011



Source: MultiProd on the basis of CSO data; Berlingieri et al (2017).

6.3. Dynamic Productivity Decomposition

77. A dynamic version of the OP gap, as developed by Melitz and Polanec (2015), is presented below, firstly for manufacturing and then for services.[54] This approach decomposes the contributions to the growth in (log) labour productivity into four elements; within-firm productivity growth by incumbents (analogous to the unweighted productivity term in the static Olley-Pakes framework), resource reallocation (the change in the Olley-Pakes gap), as well as the impact of entrants and exitors. The last two terms can positively contribute to aggregate productivity by more productive entrants joining the market, and less productive firms exiting the market.

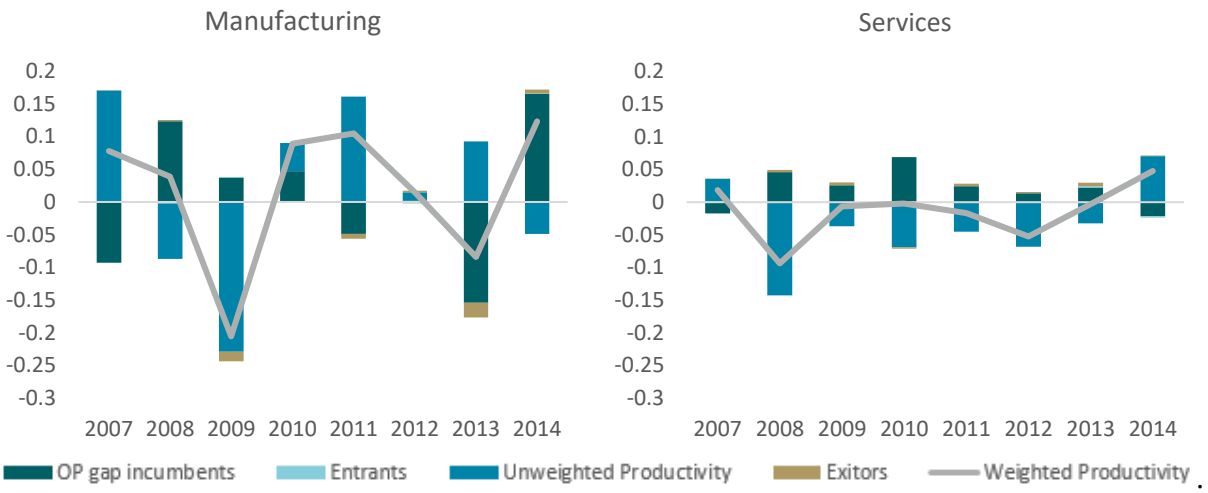
78. Overall the main contributors to the annual changes in labour productivity growth in manufacturing came from within-firm productivity changes by incumbents, and reallocation, with both effects being negatively correlated (see Figure 18), with the reallocation term having the biggest impact over the full sample period (2006-2014).[55] The negative correlation between the within and reallocation terms is may be related to the structure of the Irish economy, with a large number of small (low-productivity) firms and a very small number of large and highly productive firms. This leads to a situation whereby growth in productivity amongst small and less productive firms will increase the

[54] $\Delta p_t = \frac{1}{N^C}\sum_{i\in C}(p_{it} - p_{it-1}) + \Delta cov_{i\in C}(\theta_{it}, p_{it}) + (\sum_{i\in E}\theta_{it}).(p_t^E - p_t^C) + (\sum_{i\in X}\theta_{it-1}).(p_{t-1}^C - p_{t-1}^X)$ where p_t^E, p_t^C and p_{t-1}^X are the weighted productivity averages of respectively entrants, incumbents and exitors in the relevant time period with weights that sum up to one within each group.

[55] Of the 8 percent growth in (weighted) labour productivity in manufacturing between 2006 and 2014, approximately 16 percentage points were contributed by reallocation of resources, with other factors all contributing negatively. In services the main driver of the fall in weighted productivity was a negative contribution from within firm productivity changes, with the reallocation term generally contributing positively.

unweighted (within firm) term, but reduce the reallocation term (the OP gap), and vice versa.

Figure 18. Resource Allocation: Contributions to aggregate productivity growth



Note: Data reported as annual growth rates and contributions in logs.
Source: MultiProd on the basis of CSO data.

79. For instance (weighted) productivity growth in manufacturing in 2010 and 2014 was mostly driven by reallocation of resources amongst incumbents. However, the reasons behind the negative productivity growth in 2009 and 2013 were different. In 2009, (weighted) productivity growth in manufacturing fell largely as a result of decreases in within-firm productivity, primarily amongst small firms. In 2013, instead, (weighted) productivity growth fell due to a drop in the value added of large firms in the chemical and pharmaceutical sectors, which was partially offset by increases in within-firm productivity of small companies.[56]

80. Of note is the negligible impact that entry has had on aggregate productivity growth, and the generally negative impact of exit. The negative impact of exitors is likely to be driven by a merger & acquisitions (M&A) effect, whereby firms that are more productive than average are being acquired and exiting the sample. The negligible impact of entry can be related to the fact that the analysis focuses on year on year changes, while the contribution of new entrants takes time to materialise since new firms do not immediately enter at their efficient scale and their productivity tend to increase over time (conditional on surviving).

81. On the services side, the main forces are once again within firm effects and reallocation, with no impact from entry, and a generally negative exit effect. It is worth noting that the within firm contribution to growth has generally been negative, while allocative efficiency has made a positive contribution to aggregate productivity growth for nearly all years. However as shown in Figure 16, in terms of the level of productivity, the OP gap contribution is small compared to the within-firm term.

[56] A levels (i.e. non-logged) specification is used in the previous section on static productivity decomposition. Hence there are some differences in weighted labour productivity between Figure 14 and Figure 16, particularly in 2013.

7. Conclusions

82. This paper has followed the approach of recent influential cross-country studies by the OECD, to attempt to understand the dynamics driving Ireland's recent productivity trends. Some of the patterns seen in the paper are similar to those observed in the cross country results from the MultiProd project, and other firm level global productivity studies by the OECD, particularly in manufacturing, though less so in services. Indeed the productivity patterns displayed in services perhaps warrant a study of their own. The findings on firm level productivity variation, which point to within sector differences as the main driver of overall variation, rather than differences between sectors, are also highly insightful.

83. Also of interest are the findings on the efficiency of resource allocation with and without foreign dominated sectors, painting an interesting picture of the contribution of foreign multinationals in a sub-set of sectors to aggregate productivity. Initially, the allocation of resources in Irish manufacturing appears extremely high, and therefore aggregate productivity, especially when compared to a number of OECD countries. However, the removal of these sectors shows that Ireland's resources amongst domestic sectors and firms are much less efficiently allocated, and appears to be about average compared to other countries. It is productivity growth in these firms and sectors that will be important for growth in future living standards in Ireland.

84. The MultiProd model allows for a number of productivity decompositions, in terms of firm age, firm size and ownership, providing avenues for future research, while it also facilitates analysis of the nexus between productivity and wages. The cross-country aspect to the MultiProd project also offers the potential for rich insights as to how Ireland's drivers of productivity growth compare to global trends.

85. In the meantime it is hoped that the findings herein can inform policy. In particular, the diverging productivity trend between the best and the rest in manufacturing, the declines across all percentiles in services, and the way in which resources are allocated in sectors without a large foreign firm presence.

86. The globalised nature of Ireland's economy and its influence on economic statistics mean that health warnings related to issues such as transfer pricing and relocations of intellectual property are pertinent and considered in this analysis. However, the use of MFP measures that account for some of the impacts of transfer pricing, and the analysis of the efficiency of resource allocation without foreign-dominated sectors, mean that suitable conclusions can be drawn on Ireland's domestic productivity.

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Annex A.

A.1 Data coverage

Table A.1. Data Representativeness

Number of Firms

Year	Manufacturing (CIP)		Services (ASI)		Business Register	
	Full Sample	RMF	Full Sample	RMF	Total Population	RMF Representativ.
		(1)		(2)	(3)	[(1)+(2)]/(3)
2006	4,620	3,563	91,292	8,461	-	-
2007	5,812	4,301	-	8,867	-	-
2008	15,955	2,670	175,188	10,679	244,195	5.5%
2009	16,285	2,249	179,965	8,583	244,428	4.4%
2010	16,050	2,521	182,787	7,205	242,692	4.0%
2011	16,132	1,917	183,863	6,750	240,880	3.6%
2012	16,385	1,838	188,364	6,870	244,394	3.6%
2013	16,540	1,679	188,475	6,551	243,571	3.4%
2014	16,497	1,661	185,531	6,546	238,249	3.4%

Number of Employees

Year	Manufacturing (CIP)		Services (ASI)		Business Register	
	Full Sample	RMF	Full Sample	RMF	Total Population	RMF Representativ.
		(1)		(2)	(3)	[(1)+(2)]/(3)
2006	233,298	163,356	823,900	331,488	1,242,765	39.8%
2007	243,204	171,737	-	392,927	1,332,136	42.4%
2008	240,946	152,567	1,041,980	432,050	1,511,920	38.7%
2009	218,279	141,537	960,348	420,560	1,345,461	41.8%
2010	202,301	137,997	926,542	391,906	1,270,475	41.7%
2011	201,695	140,520	925,658	366,207	1,259,326	40.2%
2012	199,193	136,661	939,243	361,649	1,264,769	39.4%
2013	200,991	134,771	961,338	353,833	1,288,017	37.9%
2014	210,545	132,451	989,230	327,660	1,334,291	34.5%

Source: CIP, ASI and BR.

A.2 Robustness Check

1. Figure A.1and Figure A.2 below show that for both manufacturing and services, with the exception of a handful of sectors, the production surveys used in MultiProd (micro measure) generate consistent results with the national accounts (macro measure) . This is in part due to a coherency project that was recently carried out by the CSO, to ensure consistency between estimates from Production Surveys and those in the National Accounts.

2. The exceptions include water supply (35) and electricity/gas supply (36), where measurement issues arise, and real estate (68) and renting and leasing activities (77), due to the inclusion of imputed rents and aircraft leasing in the national accounts measures.

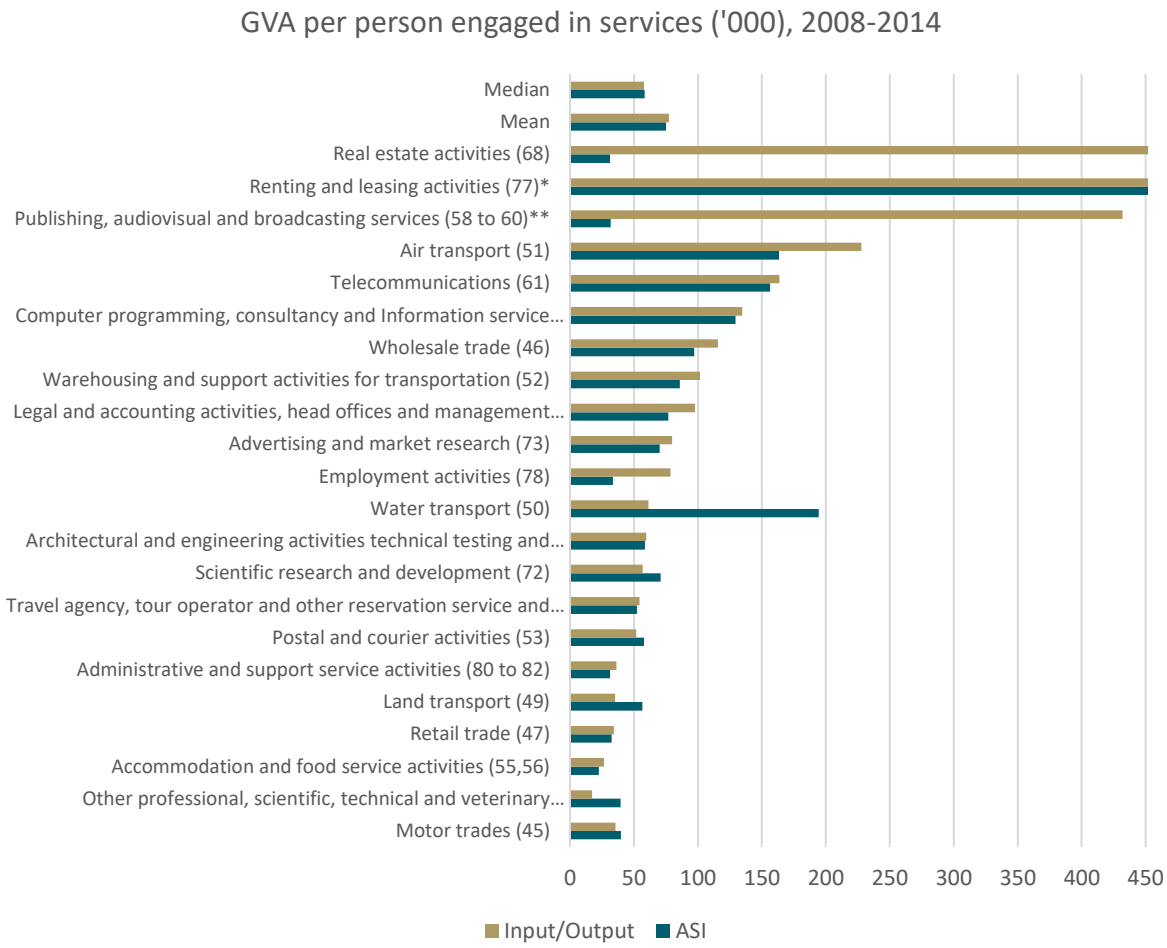
3. Productivity is also extremely high in publishing (58 to 60) due to a handful of foreign dominated firms, highlighting the greater heterogeneity in services.

Figure A.1. Labour productivity – Micro vs. Macro measure



Note: Persons engaged for Input/Output sectors drawn from EHECS/QNHS (macro measure) Persons engaged for CIP drawn from CIP survey responses (micro measure)
*Sub-sector 19 is removed from the CIP due to confidentiality
Source: CIP and Input/Output tables from National Accounts (CSO).

Figure A.2. Labour productivity – Micro vs. Macro measure



Note: Persons engaged for Input/Output sectors drawn from EHECS/QNHS (macro measure) Persons engaged for ASI drawn from ASI survey responses (micro measure)
*The differences observed between source data for renting and leasing are due to the differential treatment of aircraft leasing activities, which has been completely removed from the MultiProd database
**Sub-sectors 58 and 60 are removed from the ASI due to confidentiality
Source: ASI and Input/Output tables from National Accounts (CSO).

A.3 Transformations to the primary data

4. Substantial transformation of the micro data were made by the authors in order to ensure comparability with MultiProd requirements, including:

- *Harmonisation of the pre- and post-2008 methodologies in the production surveys*. To ensure consistency with the national accounts, the CSO revised the structural business statistics series (e.g. CIP and ASI) back to 2008. A key methodological change was the capitalisation of R&D, which post-2008 positively contributes to investment and hence GVA, and prior to 2008 was treated as intermediate consumption, thus negatively contributing to GVA. The pre-2008 data in the longitudinal panel have therefore been transformed to ensure consistency. This

involved netting out the impact of R&D (as reported in the production surveys) and only leaving in R&D figures stemming from the Business Expenditure on Research & Development survey (BERD).

- It was necessary to drop sector 7735 (aircraft leasing) from the ASI panels, to avoid distortions between the treatment of aircraft pre- and post-2008, following the incorporation of the 'change in economic ownership' treatment under SNA 2008 in the ASI from 2008 onwards.
- The Mining and Quarrying sector was also dropped from the CIP dataset as it contained less than the minimum number of observations MultiProd requires to run.
- Year of birth records on the BR were provided from various sources. Birth years can differ across sources for the same firm and there could be a level of replication of records for the same firm. Therefore, the earliest year on record for any firm regardless of source was taken as its birth year.

5. An additional run of MultiProd was carried out with foreign dominated sectors excluded, with the aim of providing a clearer picture of productivity of the domestic economy and firms. Foreign owned Multinational Enterprise (MNE) dominated sectors occur where MNE turnover on average exceeds 85 percent of the sector total.[57]

A.4 Capital Stock Estimation

6. For MFP estimation, firm level capital stocks are calculated based on the perpetual inventory method (PIM) using annual firm level investment. The PIM relies on an opening capital value for each firm, annual investment and depreciation.

7. While the main MultiProd run begins in 2006 (the first year the Business Register is available), in order to generate an initial capital value for each firm, the closing value of a parallel run is used. The parallel run begins for each firm in the year of their first ever observation in either the CIP or ASI, which commenced in 1991 and 1999 respectively, and ends in the year 2006. For firms that join the production survey after 2006 their opening capital stock values are calculated as the average of two proxies, namely:

- Average firm investment in all years divided by the depreciation rate, as provided by the OECD STAN tables;
- Country-industry-year specific capital-labour ratio (K/L) from the same STAN tables, which is then multiplied by firm level employment (L)[58].

[57] See CSO (2017b)

[58] See Berlingieri et al (2017)

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