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Scale, Market Power and Competition in a Digital World: Is Bigger Better?

Michael McMahon[*], Sara Calligaris[**], Eleanor Doyle[†] and Stephen Kinsella[§]

Rising concentration across many developed economies has seen issues of competition and market power take centre stage. This report contributes to that debate by examining the role of technology in altering the balance of competition between large and small firms. It focuses on digitalisation as a potential driver of enhanced benefits to scale, by examining the evolution of mark-ups and multifactor productivity (MFP) across firms of different sizes. It finds that size is positively related to mark-ups and that this relationship has strengthened over time. This trend has been accompanied by an increase in the relative productivity advantage of larger firms and both changes are more pronounced in digital-intensive sectors, suggesting that digitalisation may be an underlying driver. The differential impact of digital technologies on larger and smaller firms suggests that current trends towards greater concentration, falling business dynamism, higher mark-ups and greater divergence in productivity may continue, requiring policy makers to consider appropriate responses.

Keywords: Scale; Mark-ups; Market Power; Multifactor Productivity; Digitalisation; Intangible Assets.

JEL Codes: D2; D24; L1; L2; O33.

[*] Michael McMahon worked in the Directorate for Science, Technology and Innovation for the duration of the report, and is currently pursuing a PhD at the University of Limerick.
[**] Sara Calligaris is an Economist in the Directorate for Science, Technology and Innovation.
[†] Eleanor Doyle is Professor of Economics and Vice-Dean for Internationalisation and External Engagement at Cork University Business School.
[§] Stephen Kinsella is Associate Professor of Economics at the University of Limerick and Senior Fellow at the Melbourne School of Government.

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Executive Summary

There are a number of features of digital technologies – and intangible assets more generally – that could bestow greater advantages on bigger firms. For instance, they are typically characterised by large fixed costs, but low marginal costs, making them highly scalable. They are also reliant on complementary human capital and other intangible assets, more of which may be found in larger firms.

The report examines if digital technologies are providing greater advantages to larger firms by first splitting the firms in our data into four 'size groups': those with less than 50 employees; with 50 – 499; with 500 – 4,999 and with 5,000+. It then assesses how levels of market power may be changing between the size groups by examining changes in mark-ups and MFP over time. It also evaluates how levels of industry digitalisation may be impacting these dynamics by splitting the industries into '*digital intensive*' and '*less digital intensive*' sectors. It comes to the following six conclusions.

1. **Larger firms have, on average, higher mark-ups and MFP**. The empirical analysis provides evidence of a significant size premium for both mark-ups and MFP, particularly for the two largest size groups.
2. **The differences are becoming greater over time**. Both mark-up and MFP premiums have tended to increase from the first period of the study (2001 – 2007) to the second (2008 – 2014), with the largest groups seeing the largest increases.
3. **Many of the mark-up and MFP patterns hold across both digital intensive and less digital intensive industries, though the increases in the gaps are more pronounced in digital intensive industries.** The empirical analysis shows that many of the patterns above hold across both more and less-digitally intensive industries. The two larger size groups have substantial mark-up and MFP gaps relative to the smaller groups. The gaps in mark-ups and MFP also tend to increase from the period 2001 – 2007 to the period 2008 – 2014, though the increase is more pronounced in digital intensive industries.
4. **The trends are broadly consistent across manufacturing and services, with mark-ups in digital intensive services being an exception.** There are more digitally intensive industries in services than manufacturing, so it is important to establish that the trends identified do not simply reflect service-manufacturing distinctions. The empirical analysis shows that many of the patterns are indeed consistent across manufacturing and services: in both sectors there is evidence of a clear step-up with size for both mark-ups and MFP. The only exception is mark-ups in digital intensive services: the mark-up and productivity gaps between the size groups are lower in this category than elsewhere. They do tend to increase significantly in the second period, however.
5. **It appears that there has been a shift in market power towards large firms.** Large firms tended to have higher rates of sales growth throughout the sample period. They were more profitable, and the gap widened by the end of the period. They also tended to have the highest mark-ups, regardless of the country or time period considered, whether the data was split by digital intensity, or whether the sector was services manufacturing.
6. **There is evidence that technological factors are playing a role.** If the mark-up trends are mirrored by similar trends in MFP, then we can be more confident that

technological factors play a role. A clear step-up in MFP with size has been identified, confirming findings in many previous studies (Berlingieri, Calligaris and Criscuolo, 2018, for example). In addition, gaps between larger and smaller firms have tended to widen over time. Moving into larger size groups is also associated with progressively larger increases in mark-ups and it is notable that these effects are stronger in digital intensive industries.

As digital technologies evolve and robotics and artificial intelligence become more commonly used, there is potential for some of the trends noted above to continue, if not accelerate. Complex technologies requiring large amounts of data and highly specialised skills may be easier for large firms to develops. If these technologies are combined with other complementary and scalable intangible assets, this could further enhance their competitive position. If that proves the case, then current trends of greater concentration, falling business dynamism, higher mark-ups and greater divergence in productivity may continue. This would clearly present further threats to competition and ultimately consumer welfare, and would require policy makers to consider appropriate responses.

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Section 1. Introduction

Increasing market concentration has become a feature of many developed economies, bringing debates about competition and market power to the fore. Digital technologies add a new dimension to this debate, as they fundamentally change how products and services are produced and consumed. They may also alter competitive dynamics between larger and smaller firms, though the direction of impact is uncertain. Some characteristics of digital technologies may be more beneficial to smaller firms, such as reduced search costs and access to a wider range of customers and suppliers. Others, such as the high fixed cost and low marginal cost nature of many digital technologies, may favour larger firms. Investigating changes in competition and market power therefore requires an analysis of the role and impact of digital technologies.

Mark-ups are a key – although imperfect – indicator of market power, and if digital technologies have a heterogeneous impact across firms of different sizes, then differences in mark-ups by firm size may reveal changing competitive dynamics. If those changes are consistent with patterns of productivity between firms of different sizes, it may point to an explanatory role for digital technologies. In that context, this study examines how firm size and digitalisation are related to mark-ups and productivity in order to see if larger firms gain greater advantages in a digital world.

1.1. Report Overview

The literature to date suggests that mark-ups are increasing (De Loecker, Eeckhout and Unger, 2019; Crouzet and Eberly, 2018; Hall, 2018) and are positively related to digitalisation (Calligaris, Criscuolo and Marcolin, 2019). They also appear to be positively related to size, though the findings are not consistent . What we do not know is whether technological factors are influencing the relative mark-ups between small and large firms, and if these relationships are changing over time.

In addition, the literature has demonstrated a strong positive relationship between size and MFP with regard to manufacturing, and to a lesser extent services (Berlingieri, Calligaris and Criscuolo, 2018). We also know that digital adoption at the industry level is associated with productivity gains at the firm level, and that gains are stronger in routine-intensive activities and for more productive firms (Gal et al., 2019; Bajgar et al., 2019).

Intangible assets play a key role with regard to questions of productivity, scale and digital technology. Obtaining the benefits from digital investments is contingent on other intangible assets such as complementary management skills (Bresnahan, Brynjolfsson and Hitt, 2002; Brynjolfsson et al. 2008; Bloom et al, 2012), and there may also be a link between the efficacy of intangible assets and size due to the specific properties of intangible assets (Haskel and Westlake, 2018; Bajgar et al., 2019). Lastly, we know that business dynamism is declining (particularly for digital intensive industries), and this is consistent with theories of industry lifecycles where competitive benefits associated with scale increase over time (Calvino and Criscuolo, 2019; Klepper, 1996). What we do not know is the role technology is playing in the changing productivity dynamics between smaller and larger firms.

This paper seeks to build on the literature above, looking at how trends in mark-ups and productivity can be used to assess how technology is impacting the competitive balance between large and small firms. If digital technologies favour larger companies then we should see:

- higher mark-ups at larger firms, all else equal;
- increasing gaps in mark-ups between larger and smaller firms over time as digital technologies mature; and
- similar trends in MFP to those observed for mark-ups, relative to size and over time.

Assessing the impact of industry digitalisation on mark-ups and MFP should provide further insights. We therefore pose the following six questions.

Do Larger Firms Have Higher Mark-ups and MFP?

We split the firms into 4 'size groups': those with less than 50 employees; with 50 – 499; with 500 – 4,999 and with 5,000+. The size dummies provide evidence of a significant size premium for both mark-ups and MFP, particularly for the two largest size groups. Industry-specific factors play an important role, though the premium remains even when controlling for them. A firm entering a new size group is also positively related to both mark-ups and MFP.

How Are These Mark-up and MFP Trends Changing Over Time?

The data was split into two economic cycles (2001 – 2007 and 2008 – 2014). Both mark-up and MFP premiums have tended to increase from the first cycle to the second, with the largest groups seeing the largest increases.

Do Patterns Vary According to the Digital Intensity of an Industry?

The firm-level size dummies were then interacted with digital dummies that categorise industries by their digital maturity, employing the industry taxonomy created by Calvino et al. (2018). Those industries in the top two quartiles of digitalisation comprise the 'digital intensive' sector, with those below making up the 'less digital intensive' sector.

We found that many of the patterns hold across both sectors. The two larger size groups have substantial mark-up and MFP gaps relative to the smaller groups. The gaps in mark-ups and MFP also tend to increase from Cycle 1 to 2, though the increase is more pronounced in the digital intensive sector.

We then split the digital dummy out into those industries in the third and fourth quartiles of digitalisation. We find that the most-digitally intensive sector (Quartile 4) is an exception to the general rule of a clear step-up pattern for size and mark-ups. The largest size group actually exhibits lower mark-ups than the smallest, though the gap narrows in the second cycle, particularly when MFP is used as a control.

There are a number of potential explanations. It may be that smaller firms can achieve 'scale without mass' in these industries, enhancing their ability to compete with larger firms and reducing or even reversing mark-up gaps. Unobserved factors such as skill intensity and the degree of routinisation may also play a role. Another interesting candidate is the level of industry maturity, per Klepper (1996). Significant disruption caused by the development of the Internet in the late-1990s may have diminished the competitive position of larger firms. We do see evidence that larger firms in this segment may be re-establishing their advantages over time, however.

A final aspect worth noting is that moving into a new size group is positively related to changes in mark-ups, particularly in the digital intensive sector. The impact is particularly large for Size Groups 3 and 4 in Digital Quartile 4 industries (increases in mark-ups of 18 - 23% and 23 – 29% depending on the period and controls used). Changes in size group

therefore have a particularly large impact on mark-ups within the most-digitally intensive sector.

Are the Trends Consistent Across Manufacturing and Services?

There are more digital intensive industries in services than manufacturing, so it is important to establish that the trends identified do not simply reflect service-manufacturing distinctions. Splitting the data gives us four categories: less digital intensive manufacturing; digital intensive manufacturing; less digital intensive services; and digital intensive services. Broadly speaking, we see that many of the patterns are indeed consistent across manufacturing and services. There is evidence of a clear step-up with size for both mark-ups and MFP. The only exception is mark-ups in digital intensive services. The productivity gaps between the size groups are also the lowest of the four sectors, though they increase significantly in the second cycle.

These findings appear consistent with the patterns of business dynamism observed by Calvino and Criscuolo (2019), who found that, while levels of dynamism were highest in digital intensive services, they also exhibited the largest declines. It may be that larger firms in these industries are gaining in market power as they become more established.

Given the Above, Has There Been a Shift in Market Power Between Large and Small Firms?

A large amount of evidence supports a shift in the competitive balance, with large firms gaining market power relative to smaller firms. Large firms tended to have higher rates of sales growth throughout the sample period. They were more profitable, and the gap widened by the end of the period. They also tended to have the highest mark-ups, regardless of what type of fixed effects were used, whether the data was split by digital intensity, or whether the sector was services or manufacturing.

Differences in mark-ups between the largest two size groups and the smaller groups also increased over time. While industry-specific factors play a role, regressions with industry fixed effects show that this remains true even when controlling for these factors.

As noted above, the only exception to the general pattern regarding mark-ups is the most-digital sector. This raises interesting questions regarding 'scale without mass' (Brynjolfsson et al. 2008), and could also point to higher levels of skill intensity and lower levels of routinisation in these industries which may reduce the benefits of scale. Cycles of industry maturity could also be a factor. Unfortunately, without better firm-level data and a longer time span than is currently available in Orbis, we cannot be definitive.

Finally, it is also notable that regressions with firm fixed effects show that moving up size groups has a positive impact on mark-ups, and this effect increases systematically with size.

If So, Are Technological Factors Playing a Role?

We have already noted the substantial mark-up gaps between larger and smaller firms, and that these gaps are increasing. Importantly, the average increase in the mark-up gap has been greater in the digital intensive sector, albeit from lower initial levels.

If the mark-up trends are mirrored by similar trends in MFP then we can be more confident that technological factors play a role. We do indeed identify a clear step-up in MFP with size, confirming findings in many studies (Berlingieri, Calligaris and Criscuolo, 2018, for example). We also see that gaps have tended to widen over time. While the gaps are narrower for the digital intensive sector, the increase has been greater, driven by increasing productivity gaps in the most digitally intensive industries. We have also seen that moving

into larger size groups is associated with progressively larger increases in mark-ups. It is notable that these effects are stronger in the digital intensive industries.

While the associations identified from the estimations do not 'prove' that the increased use of digital technologies lies behind increased market power of the largest firms, they are suggestive of such a relationship. The topic does appear to warrant further research, though more granular firm level data on digital investments and other intangible assets would be required to be more confident of causation. Ideally, we would be able to parse the impact of a firm's digital and intangible investments, how they vary with size, and in turn impact competition between large and small firms. Unfortunately, this is not possible in the data. If these omitted variables are positively correlated with mark-ups, MFP and size (as would seem plausible), then large and significant size dummies may reflect their impact.

In any case, as digital technologies evolve and robotics and artificial intelligence become more commonly used, there is potential for some of the trends here to continue, if not accelerate. Complex technologies requiring large amounts of data and highly specialised skills may be easier to develop for large firms. If these technologies are combined with other complementary and scalable intangible assets, this could further enhance their competitive position. If that proves the case, then current trends of greater concentration, falling business dynamism, higher mark-ups and greater divergence in productivity may continue. This would clearly present further threats to competition and ultimately consumer welfare, and would require policy makers to consider appropriate responses.

1.2. Report Structure

The report is structured as follows. Section 2. provides a brief overview of relevant research, while Section 3. sets out the estimation framework. Section 4. outlines the data set and some of the key variables. Section 5. provides an overview of the results and how mark-ups and MFP have trended over time, while Section 6. looks at how revenues and costs change with scale at a very coarse-grained level. Section 7. to Section 12. then address the six questions set out in Section 1.1, and Section 13. concludes.

Section 2. Previous Research

2.1. The Mark-ups Literature

Looking at the evidence to date, most studies on mark-ups have concluded that they have increased substantially in recent years. De Loecker et al. (2018) concluded that average mark-ups in the US increased from 18% above marginal cost in 1980 to 61% today. Crouzet and Eberly (2018) found that average mark-ups in the US increased from about 20% to 40% over marginal cost. They also found strong links between investment in intangible assets and both mark-ups and productivity (depending on the sector). Meanwhile Hall (2018) found that US mark-ups have increased to about 30% over marginal cost. He found no evidence that 'mega-firm'-intensive sectors have higher mark-ups, but some evidence that mark-ups grew in sectors with rising mega-firm intensity (a mega-firm having more than 10,000 employees).

Traina (2018) offers a dissenting position, finding average increases of 8 – 10% from 1980 – 2016. However, De Loecker and Eeckhout (2018) show that differences are due to a different estimation method which more closely matches the operating profit rate than their measure of mark-ups.

Looking at the global picture, Díez et al. (2019) found mark-ups in advanced economies have been rising steadily since the 1980s, and at an accelerated pace since the mid-2000s. Corporate level data suggest that these trends have been driven by a relatively small number of "superstar" firms.

The weight of evidence therefore suggests that mark-ups have increased substantially, though the increase is concentrated in a subset of firms. The question then turns to the factors which lie behind the increases.

Size and Mark-ups

De Loecker et al. (2018) found that mark-ups are positively related to size within narrowly defined industries. As noted above, Hall found 'moderately strong evidence' that mark-ups grew in sectors with rising mega-firm intensity. In addition, Raval (2020) found a positive relationship between mark-ups and size, as well as exports and profit shares. Finally, Díez et al (2019) found a non-monotonic relationship between mark-ups and size, with mark-ups initially decreasing, but then rising for firms beyond the 95th percentile of size.

Digitisation and Mark-ups

As outlined in Calligaris et al. (2019), there is no a priori expectation for the impact of digital technologies on mark-ups and market power. On the one hand, digital technologies can provide for greater market access, reduced search costs, easier information sharing and access to a wider range of both customers and suppliers. This has the potential to reduce entry costs, and all else equal, lower mark-ups. However, there are also a number of reasons to believe that digital technologies favour some firms more than others, potentially granting those firms greater market power.

Technological investments impact firms in a heterogeneous manner, and many of these factors are dependent on the size of firms.

- Reaping the benefits from digital investments is contingent on other intangible assets such as complementary organisational methods and management skills

(Bresnahan, Brynjolfsson and Hitt, 2002; Brynjolfsson, Hitt and Yang, 2002; Brynjolfsson et al. 2008; Bloom et al. 2012; Bajgar et al, 2019). The range and depth of skills necessary are more likely to be found in larger firms.

- Another defining characteristic of digital investments (and intangible assets in general), is that they tend to be highly scalable, which can provide advantages for larger firms (Haskel and Westlake, 2018). For example, Bajgar et al. (2019) found that the impact of additional intangible investments (proxied by patent growth) is significantly stronger for larger companies. They found that the increase in market share associated with additional intangible investments is 10 times higher for the top 8 firms in an industry than for the other 92 in the top 100.
- Technological investments typically have a large fixed cost component with low marginal costs. As well as promoting scalability, this, favours larger firms who often face fewer financial constraints and can spread the costs over a greater range of output.
- Digital technologies may be protected by intellectual property rights, limiting diffusion and providing for higher mark-ups (Calligaris et al. 2019). As patents tend to be highly concentrated in large multinational firms[1], this may help create a relationship between size and mark-ups.
- Technological investments can help cut through complexity by improving coordination between operating units and within supply chains. These issues are typically more acute for larger firms, meaning that they could stand to gain more from these investments.
- Large firms can gain benefits from technological investments over a larger range of output versus smaller firms, but with relatively less cost because of low marginal costs.
- As Calligaris et al. (2019) outline, digital industries are often characterised by direct and indirect network effects, economies of scope in data collection, and high and increasing levels of product differentiation due to data analytics. Again, many of these impacts (particularly substantial network effects) generate winner-take-all dynamics, causing activity to concentrate in few large companies.

Calligaris et al. (2019) find that firms in digital intensive industries have considerably higher mark-ups, and what is more, this difference has increased over time. The gap stood at 13 – 14% (depending on the specification) in the 2001 – 2003 period and 16 – 21% in 2013 – 2014. The equivalent figures for firms in the top quartile of digital industries were 30 – 33%, and 55 – 61%.

The Productivity Literature

Size and productivity

The literature has shown a consistently strong relationship between size and productivity. Berlingieri, Calligaris and Criscuolo (2018a, 2018b) provide perhaps the most comprehensive review in recent years using OECD MultiProd data. They find a very strong and positive relationship between size and productivity in the manufacturing sector, in common with a number of other studies such as van Ark and Monnikhof (1996) and Bartelsman, Haltiwanger and Scarpetta (2013).

The more novel findings however concern the service sector, where they find that the productivity-size relationship is not as strong. They do not find a significant step-up with

size for labour productivity, though it is evident for MFP (albeit not to the same extent as manufacturing). They do, however, find a very strong link between wages and productivity in the services sector.

The authors perform a number of robustness checks on their estimates by controlling for various factors. Interestingly, controlling for skill intensity at the industry level eliminates the productivity differential between large manufacturing and service firms. It also increases the productivity differential of smaller services firms relative to smaller manufacturers. This could indicate that large services firms tend to be less skill intensive and / or smaller services firms tend to be more skill intensive. The authors note that caution is required due to the use of a sector level control for skill, and a more precise measure is required to clarify these relationships.

Berlingieri, Calligaris and Criscuolo also look at how relationships between size and productivity change over time. Adding a dummy for the post 2007 period, they find that the interaction term with the size groups are mostly negative in the case of MFP, implying a weakening of the size-productivity relationship over time. As the authors note however, it is difficult to disentangle the changes due to the financial crisis from any structural changes in the relationship between size and productivity

Digitalisation and Productivity

Turning to the relationship between digitalisation and productivity, we can say that after a famously slow start, a strong and positive relationship has now been established. In 1996 Brynjolfsson and Hitt concluded that the 'productivity paradox' noted by Robert Solow had disappeared. They found that information system spending made a substantial and statistically significant contribution to firm output in their sample of firms from 1987 - 1991, with a gross marginal product of 81%. They stated that the reasons for positive findings versus previous studies were due to more comprehensive and firm level data, as well as a later time period.

The fact that it took time for the positive impacts on productivity to appear in the aggregate statistics is perhaps no surprise. As Brynjolfsson & Hitt note, the investment in computer capital in the 1970s and early 1980s was so low that even if it had doubled the productivity of other forms of capital its impact would hardly register with conventional estimation procedures.

Furthermore, process may not have had enough time to adapt to maximise the value of those IT investments. As Perez (2010) points out, the introduction of a radical new technology tends to follow a logistic pattern. The efficacy (and revenues associated with the technology) tend to rise slowly at first as producers, suppliers, distributors and customers engage in a feedback and learning process. It therefore takes time for the full productivity benefits to emerge.

More recently, Gal et al. (2019) found robust evidence that digital adoption at the industry level is associated with productivity gains at the firm level. The effects are stronger in manufacturing and routine-intensive activities. They are also stronger for more productive firms, but weaker in the presence of skill shortages, which point to complementarities between digital technologies, human capital and other forms of intangible capital. Bajgar et al. (2019) report similar findings looking at the manufacturing sector. They found that digital adoption is correlated with productivity on average, but the impacts are concentrated on productive firms with complementary digital and management skills.

The connection with complementary skills is an important one. IT investments can have a significant bearing on productivity, but are particularly effective when combined with certain organisational and management practices, reflecting the synergies often found

between different intangible assets (Haskel and Westlake, 2018). For example, Bresnahan, Brynjolfsson and Hitt (2002) and Brynjolfsson, Hitt and Yang (2002) looked at how firms' investments in IT and complementary organisational practices reinforced eachother, producing higher market valuations and greater demand for skilled labour.

Furthermore, Bloom et al (2012) find that US multinational affiliates gain more productivity from their IT capital and use IT more extensively. These US owned firms have higher scores on their authors' 'people management' practices which are based on policies for promotions, rewards, hiring and firing. These practices account for most of the higher IT based output elasticity. Indeed, the combination of heterogeneous technological and managerial capabilities is so important that Van Reenen (2018) states that they can account for a large part of the substantial, and increasing, productivity differences across firms.

A final aspect of digitalisation worth mentioning here is its role in facilitating 'scale without mass'. While examining labour share and market concentration trends in the US, Autor et al. (2017a, 2017b) note that concentration is typically greater when measured in sales terms rather than employment terms. Many high revenue firms are therefore generating these sales with relatively few employees. They refer to this as the ability to achieve scale without mass, following Brynjolfsson et al. (2008). That earlier paper had outlined how IT investments enable firms to replicate successful business practices, potentially building competitive advantage by boosting productivity and lowering marginal costs. They linked this to greater market turbulence and higher concentration, particularly in IT intensive industries.

In conclusion, while we know that digitalisation has a positive impact on productivity, particularly in conjunction with other complementary skills, its role in altering the competitive balance between firms of different sizes is less clear. Many of the same conflicting factors mentioned above for mark-ups apply here. On the one hand greater levels of digitalisation could make it easier for smaller firms to expand, enter new markets and compete on a more even footing with larger firms. On the other hand, many of the complementary skills that are so vital to achieving the full benefits of digital investments are more likely to be found in larger firms. Larger firms should also find it easier to leverage their IT and other intangible investments given their inherent scalability, thereby boosting their efficiency relative to smaller firms.

Dynamism, Industry Lifecycles and Productivity

Calvino and Criscuolo (2019) look at trends in business dynamism (rates of firm entry / exit and job reallocation) across 15 countries and examine the extent to which digitalisation has influenced these trends. Two stylised facts emerge. Firstly, levels of dynamism are higher in digitally intensive industries, and particularly so in services which has considerably higher entry rates. Secondly, these levels of dynamism have been declining in both digitally intensive and less digital intensive industries since the turn of the century. Interestingly, the decline has been steeper in digitally intensive industries. These findings are consistent with trends seen in the US, as documented by Decker et al. (2014, 2016, 2017) and others.

Calvino and Criscuolo state that these patterns are consistent with industry life cycles as set out by Klepper (1996). In the early stages of an industry life cycle entry is high, the number of producers grows, and market shares change rapidly as firms innovate and new versions of the industry product appear. Over time this dynamism declines as product variety decreases, industry leadership stabilises, and the number of new entrants falls. Firms shift focus somewhat from product innovation to process innovation and achieving minimum efficient scale in the dominant design. The ability to gain returns from process

innovation "depends centrally" (ibid, p. 580) on the size of the firm, and so the benefits of scale increase over time as these larger firms become more productive and profitable.

2.2. The Research Questions

The core aim of this report is to examine if digital technologies are changing the balance of competition between large and small firms. For the purposes of the report, the competitive balance essentially refers to the relative ability of large and small firms to compete, grow and earn returns in the market. Mark-ups are used as the key indicator of market power, but changes in sales and profitability are also examined.[2]

Changes in productivity brought about by digital investments should have a profound impact on a firm's competitiveness. Since there are reasons to believe that digital technologies impact large and small firms in heterogeneous manners, the relationships between digitalisation, scale and productivity are of great interest. The interplay between productivity and mark-ups should also shed light on their role in generating market power.

While Calligaris et al. (2019) demonstrated a positive relationship between digitalisation and mark-ups, we do not know how those dynamics interact with size, and if and how they have changed over time. The issue is further complicated by industry maturity / product lifecycle dynamics. Finally, it will be the case that some firms in less digital intensive industries have very high levels of digital expertise, while others in digital intensive industries may have relatively underdeveloped digital capabilities. While the nature of the data available in Orbis makes it impossible to accurately gauge the impact of digital investments at the firm level (see Section 4 for further details), there are a number of hypotheses we can put forward to assess their impact on competitive balance at a more aggregate level.

If digital technologies alter the competitive balance in favour of larger companies then we should see:

- higher mark-ups at larger firms, all else equal;
- increasing gaps in mark-ups between larger and smaller firms over time as digital technologies mature; and
- similar trends in MFP to those observed for mark-ups, relative to size and over time.

Assessing the impact of industry digitalisation on mark-ups and MFP should provide further insights. For example, what are the differences in mark-up and MFP gaps in more and less digitally intensive industries, and how are they changing over time? We therefore proceed by looking for evidence of the above trends in the overall sample, but also assessing the impact of splitting the data according to other factors such as digital intensity and whether the firms belong to the manufacturing or services sectors. This leads to us pose the following six questions:

1. Do larger firms have higher mark-ups and MFP?
2. How are these mark-up and MFP trends changing over time?
3. Do patterns vary according to the digital intensity of an industry?
4. Are the trends consistent across manufacturing and services?
5. Given the above, has there been a shift in market power between large and small firms?
6. If so, are technological factors playing a role?

Section 3. Estimation Framework

3.1. Mark-ups

The mark-up for a given firm is defined as the ratio of price to marginal cost (P/MC). In a world of perfect competition, the firm faces a perfectly elastic residual demand curve, and cannot influence price. Price is equal to marginal cost, and the firm has no market power. In circumstances where the firm faces a downward sloping demand curve it has some influence over price. The steeper the residual demand curve, the greater the influence. This will create a wedge between price and marginal cost, with the extent of that wedge dictated by the firm's influence / market power.

Despite their theoretical significance, mark-ups are not a perfect measure of market power. Accurately measuring marginal costs is difficult. The methodology employed in the study requires us to estimate production functions, which are subject to bias from unobserved productivity. In addition, mark-ups may reflect more than pure market power. For example, they may reflect returns to overhead or fixed costs, such as brand or intellectual property investments. Nevertheless, measuring changes in aggregate mark-ups should give an indication of how market power is evolving.[3]

Firm level mark-ups are estimated according to the method developed by Hall (1988) and De Loecker and Warzynski (2012). A key assumption in the De Loecker and Warzynski method is that there is at least one variable input that can be adjusted in each period, but there are frictions associated with the capital inputs and any fixed costs. Each firm is assumed to minimise costs with respect to the variable inputs, and the cost minimising condition is given by:

$$\frac{\partial Lit}{\partial Vit} = P_{it}^{V} - \lambda \frac{\partial Q(.)}{\partial Vit} = 0, \qquad (1)$$

where L stands for labour, V is the variable input, Q is quantity and P is price for firm i in time t. Each term is then multiplied by Vit/Qit and rearranged to give the input elasticity of the variable input free of adjustment cost:

$$\theta_{it}^{v} \equiv \frac{\partial Q(.)}{\partial Vit} \frac{Vit}{Qit} = \frac{1}{\lambda} \frac{P_{it}^{V} Qit}{Qit}. \qquad (2)$$

The Lagrange multiplier gives us a measure of marginal cost, and defining the mark-up as $\mu = P/\lambda$, we can substitute the marginal cost to price ratio in (2) to give:

$$\mu_{it} = \theta_{it}^{v} \frac{PitQit}{P_{it}^{V} Vit}.$$

The higher the value of μ, the greater the wedge between price and marginal cost, and the greater the market power, all else equal. All that is needed for an estimate of mark-ups is therefore the output elasticity with respect to a variable input, and that input's share in total revenue. In keeping with Calligaris et al. (2019), we use materials as the variable input, as labour market rigidities in some countries within the sample means that materials flexibility represents a safer assumption.

The output elasticity is estimated using a Cobb Douglas production function. As is common in the literature, a 2-stage estimation approach is used to account for unobserved productivity based on an approach developed by Ackerberg, Caves and Frazer (2015); henceforth referred to as the ACF approach. The approach accounts for the influence of unobserved productivity under the assumption that it is monotonically increasing in

materials usage. Given that the variable input responds to productivity shocks while fixed inputs do not, we can purge the data of the influence of productivity and estimate the coefficients in the second stage. The coefficient values from the first stage OLS regressions are used as the starting points for the second stage regressions.

3.2. Multifactor Productivity

Multifactor productivity (MFP) is estimated using the Wooldridge method with value add rather than gross output, as per a number of OECD studies (for example Gal 2013; Berlingieri et al., 2017; Berlingieri, Calligaris and Criscuolo, 2018). The Wooldridge (2009) method also addresses the identification issues outlined above, but does so with a one-step procedure which estimates variable inputs with a polynomial of lagged inputs and a polynomial of intermediates.

The mark-up estimation procedure also produces estimates of MFP, though these will have a strong relationship with mark-ups simply due to the fact that they emerge from the same process. Using value add as the output measure and the Wooldridge method in the production function estimation has an added advantage in this context in that is lessens concerns around endogeneity between the mark-up and MFP estimates.

The data was split into two economic cycles (2001 – 2007 and 2008 – 2014) when estimating both mark-ups and productivity, with individual production technologies estimated for each cycle at the NACE 2-digit level (52 industries). This allows for any changes in production technology between the two cycles to be assessed and accounted for, while keeping a reasonable span of time to analyse changes in MFP with a common production technology. A second set of regressions were estimated with a single production technology over the whole period. As well as providing for a single time span to analyse MFP, it also affords sufficient data to estimate the production functions at the NACE 3-digit level (220 industries).

The core results presented below are those with individual production technologies for each cycle, with summary results for the single production function presented in the appendix (Table A.15 contains the mark-up results with the MFP results in Table A.16). Given ongoing technical progress it would seem reasonable to provide for at least one change in production technology in each cycle. The well documented fall in the aggregate labour share over the past 40 years would appear to reinforce this. In any case, the results are generally quite similar regardless of which technique is used. The correlation between the two sets of mark-up results is 0.99 while the correlation between the MFP results is 0.67.

Section 4. Data for the Study

The data used for the study is identical to the dataset used by Calligaris et al. (2019) in their study of the impact of digital technologies on mark-ups, and further details can be obtained from that report. The firm-level data is obtained from the Orbis® database, which is owned by Bureau Van Dyke (BVD). Given that it contains data from 26 countries[4], all data is deflated with appropriate industry level purchasing power parity (PPP) deflators.

It has also been through a range of cleaning steps, including the elimination of negative values and the removal of the 1% tails for the key variables (gross output, value added, labour and intermediates). The Orbis database has relatively fewer smaller and younger firms, particularly in the services sectors. In addition, only firms with 20 or more employees were kept to ensure comparability across countries, since there are a number of countries in Orbis for which little or no data exists for firms under this threshold.[5]

In common with many studies on productivity and mark-ups, the industries covered are limited to the manufacturing and non-financial market service sectors. Utilities, construction and real estate are also removed. A full list of industries is provided in Table A.1.

As per Calligaris et al. (2019), mark-up observations of less than 0.95 were removed and observations between 0.95 and 1 were set to 1 (a mark-up of less than one would imply that the firm is setting prices below marginal cost). The top and bottom 3% of the mark-up distribution in each 3-digit industry were also dropped. This was done in order to ensure that estimates were not overly impacted by outliers. The total share of observations dropped during the cleaning process varied by specification but was in the region of 10%. Summary statistics for variables used as inputs in the production functions are provided below. The period of the study is from 2001 – 2014, and all variables were converted to 2005 industry level PPP US dollars.

Table 4.1. Summary Statistics for Input Variables

Variable	Mean	Median	SD	Observations
Gross Output	51,000	11,800	401,000	2,285,584
Value Add	13,300	2,994	136,000	2,285,584
Materials	27,200	5,548	187,000	2,285,584
Labour (number of employees)	177	50	1,295	2,285,584
Capital Stock	21,500	1,937	374,000	2,285,584

Source: authors' estimates based on Orbis® data.

4.1. Digital Intensity

In their 2018 report, Calvino et al. created a taxonomy of digital intensity that ranked industries across 7 dimensions of digital maturity. The rankings correspond to the start of the sample period (2001 – 2003) and the end (2013 – 2014). The indicators used were:

- share of ICT tangible investment;
- share of ICT intangible investment (i.e. software);
- share of purchases of intermediate ICT goods;

- share of purchases of intermediate ICT services;
- stock of robots per hundred employees;
- share of ICT specialists in total employment; and
- the share of turnover from online sales.

The result of these rankings across the seven dimensions were distilled into one overall digital intensity ranking per industry which is outlined in Table A.1 (the full set of rankings for each dimension and industry are also provided in Table A.2.). A digital dummy was then created with those industries lying above the digital median assigned a value of 1. Note that while some industries change quartile from the beginning of the period to the end, no industry goes above or below the median, so the digital dummy remains constant. Consistent with the terminology in this study, we refer to industries above the digital median as being 'digital intensive', with those below making up the 'less digital intensive' sector.

While this measure of digitalisation should pick up differences across industries, it will not capture differences across firms. Orbis does not report data in sufficient detail to provide for between firm comparisons of digital or other intangible assets. While a number of studies (e.g. Peters and Taylor, 2017; Crouzet and Eberly, 2018) have used data on sales, general and administrative costs to estimate intangible assets at the firm level, this information is not available in Orbis.

It is certainly the case that levels of digitalisation will not be uniform within industries, and some firms may be relatively digitally mature within an industry classification of 'less digital intensive'. This makes the analysis of productivity all the more important. If changes in productivity trends are consistent with changes in mark-up trends, it is more likely that digitalisation is an underlying driver.

Section 5. Results Overview and Trends

Table 5.1 splits the input variables, mark-up results and MFP results by the level of digital intensity at the beginning and end of the sample. Firms in the digital intensive sector tend to be larger on average, though the relative share of inputs is similar with the exception of a lower physical capital intensity (capital stock / gross output) in the digital intensive sector.

We see that mean mark-ups in the digital intensive sector are slightly higher in the first period, with the gap increasing in the second period. Mark-ups in the digital intensive sector are also notably more dispersed.

Table 5.1. Summary of Key Input and Output Variables (Beginning and End of Sample)

	2001 - 2003 Less Digital Intensive				2001 - 2003 Digital Intensive					
Variable	Mean	SD	Median	Obvs.	Mean	SD	Median	Obvs.	t_stat	p_value
Gross Output	32,248,498	250,065,088	10,700,000	144,169	51,963,960	405,135,360	11,300,000	234,190	-16.6	0.00
Value Add	9,199,709	98,823,072	2,768,203	144,169	13,264,309	147,268,640	2,820,533	234,190	-9.3	0.00
Materials	23,048,790	157,639,648	7,272,596	144,169	38,699,652	278,384,000	7,807,783	234,190	-19.5	0.00
Labour (employees)	134	1,475	48	144,169	190	1,366	48	234,190	-11.7	0.00
L. productivity log(VA/L)	10.87	0.63	10.92	144,169	10.91	0.67	10.93	234,190	-15.1	0.00
Capital Stock	13,469,031	166,213,216	1,798,143	144,169	17,284,528	470,219,296	1,652,644	234,190	-3.0	0.00
Markup	1.30	0.34	1.19	122,391	1.35	0.65	1.18	207,772	-23.7	0.00
Log Markup	0.24	0.20	0.18	127,667	0.24	0.29	0.17	213,315	-1.6	0.12
Log MFP	12.17	0.77	12.07	86,361	12.07	0.77	12.05	158,304	31.2	0.00

	2013 - 2014 Less Digital Intensive				2013 - 2014 Digital Intensive					
Variable	Mean	SD	Median	Obvs.	Mean	SD	Median	Obvs.	t_stat	p_value
Gross Output	44,593,360	536,778,080	11,000,000	131,069	69,748,592	530,707,936	12,700,000	217,299	-13.5	0.00
Value Add	11,823,395	201,893,248	2,972,028	131,069	17,853,994	169,298,416	3,254,051	217,299	-9.5	0.00
Materials	32,769,964	355,613,888	7,087,301	131,069	51,894,596	394,317,888	8,270,481	217,299	-14.4	0.00
Labour (employees)	152	1,464	52	131,069	218	1,449	54	217,299	-13.0	0.00
L. productivity log(VA/L)	10.71	0.86	10.89	144,169	10.91	0.88	10.94	217,299	-67.4	0.00
Capital Stock	26,697,532	566,677,696	2,131,244	131,069	30,977,542	484,821,312	1,938,048	213,315	-2.4	0.02
Markup	1.36	0.46	1.22	114,819	1.45	0.81	1.21	189,593	-32.6	0.00
Log Markup	0.27	0.25	0.20	112,255	0.29	0.35	0.19	190,043	-5.9	0.00
Log MFP	11.64	0.85	11.71	119,397	11.89	0.90	11.79	166,864	-73.2	0.00

Source: authors' estimates based on Orbis® data.

This dispersion is such that median mark-ups in the digital intensive sector are actually lower than the less digital intensive sector. It should be noted however that this result is entirely driven by the wholesale and retail industry, which accounts for about 25% of sample firms. This industry is in the third decile of digital intensity, and as such is classified as 'digital intensive'. It is also typically a high volume, low margin business, with relatively low mark-ups. In fact, the average mark-ups in this industry are far below almost all other digital industries (see Table A.3 for a breakdown at ISIC 2-digit level). If retail is excluded, the median figures for the log mark-ups in the digital intensive sector is 0.25 in the first period and 0.30 in the second, far above those of the less digital intensive sector.

Turning to MFP, we can see that the mean values for more and less digitally intensive sectors are closer than is the case for mark-ups. Mean MFP is slightly higher for the less digital intensive sector in the first period, with this situation being reversed in the second period. Another notable factor is how much less skewed the MFP results are, with observed median values much closer to mean values than for mark-ups.

5.1. Trends by Size Group

If digital technologies are changing the balance of competition between large and small firms, then we should see some evidence of this from trends in mark-ups, sales and profitability. Four 'size groups' were created for firms with less than 50 employees (in practice 20 – 49 for the Orbis data), 50 – 499 employees, 500 – 4,999 employees and 5,000+ employees. The resulting distribution of observations by size group, as well as the mean and median mark-ups are as follows.

Table 5.2. Data by Size Group

Size Group	Employees	Frequency	Percent	Mean Markup	Median Markup	Mean Log MFP	Median Log MFP
1	20 - 49	1,126,855	49.3	1.33	1.19	11.68	11.64
2	49 - 499	1,049,177	45.9	1.40	1.20	12.08	12.07
3	500 - 4,999	101,942	4.5	1.53	1.24	12.65	12.65
4	5,000 +	7,610	0.3	1.40	1.20	13.19	13.25
		2,285,584	**100**				

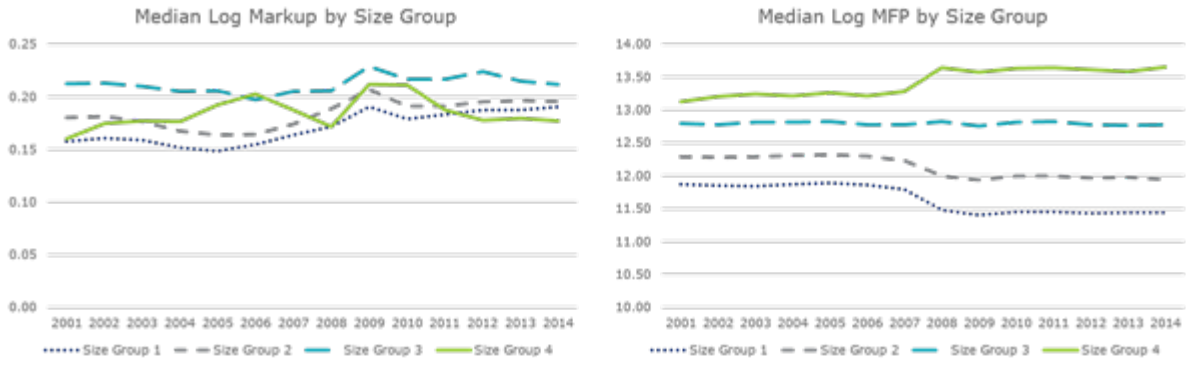
Source: authors' estimates based on Orbis® data.

Table 5.2 shows a non-linear pattern between size and mark-ups, with mean (and to a lesser extent median) mark-ups increasing initially up to Size Group 3, and then decreasing for the largest group. The MFP values are much less skewed, with the means and medians for each group being very close. Here we see a clear step-up with each size group, in line with the literature.

Figure 5.1 shows how mark-ups and MFP have evolved over time. We see that the unweighted median mark-up for each group has increased over time, but that the gaps between the size groups have remained relatively constant with the exception of Size Group 4. (Additional volatility is perhaps to be expected given the lower number of firms.)

In contrast, the gaps in log MFP between the larger size groups (Size Groups 3 and 4) and the smaller size groups have grown over time, with median MFP for Size Group 3 staying relatively flat in the face of the financial crisis and Size Group 4 actually increasing. This stands in sharp contrast to the two smaller groups which declined significantly.

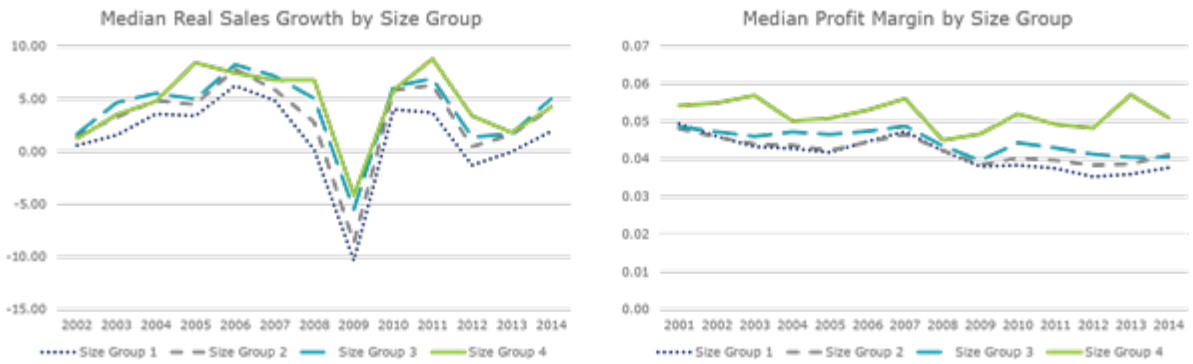
Figure 5.1. Median Mark-ups and MFP by Size Group



Source: authors' estimates based on Orbis® data.

Turning to sales and profitability, we can see that growth in real sales has also been tiered by size group, with the largest firms consistently achieving higher rates of growth. Median profit margins[6] also exhibit this pattern, though the gap between the largest size group and the others is noticeably bigger. The gap has also increased over time, having been relatively minor around the time of the financial crisis.

Figure 5.2. Median Sales Growth and Profit by Size Group



Source: authors' estimates based on Orbis® data.

Section 6. Basic Scaling Relationships

Before considering the impact of scale on mark-ups and MFP, it is instructive to look at some basic scaling relationships between revenues and costs, following Daepp et al. (2015) and West (2017). The approach is simply to use logs to examine the rate at which real revenues and costs scale. If costs scale at a lower rate than revenues on average, then we would have evidence of economies of scale. While the approach lacks the rigour of estimating production functions, it has the advantage of being independent of decisions regarding functional form and estimation techniques. It would be instructive to see if the patterns which emerge from this analysis match those of the mark-up / MFP analysis.

All firms in the sample were divided up according to size as measured by the number of employees in log intervals. The data below is based on a $\log_3$ scale (< 27 employees, 27 – 80, 81 – 242, etc.), but the exercise was also repeated for $\log_2$ and $\log_{10}$ to examine if the patterns persisted at greater and lower degrees of granularity.

We took averages of the log of both revenues and costs[7] for each size category to see how both scaled with firm size. Given that the minimum number of employees in the sample is 20, and the maximum is c. 375,000, the procedure produces 5 data points using $\log_{10}$, 10 data points for $\log_3$ (see the table below), and 14 data points for $\log_2$. While the slopes of the resulting lines of best fit vary slightly according to the granularity, the pattern of scaling for both revenues and costs is consistent. Cost tends to scale at a marginally lower rate than revenue, producing higher average profit margins at larger firms.

The average $\log_3$ values for revenues and costs across all sizes are 14.897 and 14.842, which is a gap of 0.055, and corresponds to a profit margin (before interest or tax) of c. 5.9%. However, there is a considerable amount of variation across the size categories, as outlined in the table below.

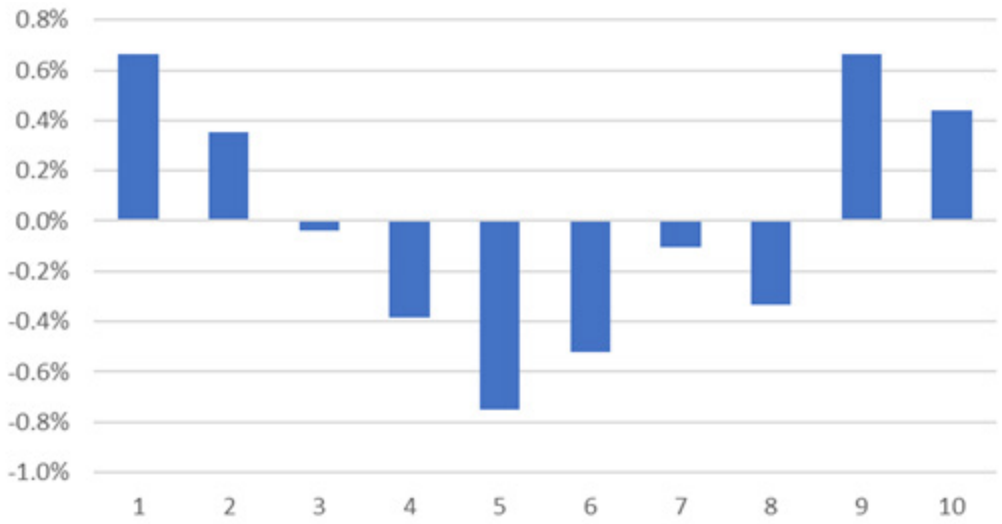
Table 6.1. Scaling Relationships

Scaling Relationships (Base 3)										
Size Category	1	2	3	4	5	6	7	8	9	10
Max Firm Size	26	80	242	728	2,186	6,560	19,682	59,048	177,146	-
Number of Observations	345,475	1,325,156	549,346	191,615	55,594	14,999	4,729	1,067	186	13
Margin	5.9%	5.9%	5.8%	5.8%	5.8%	6.3%	7.1%	7.1%	8.5%	8.6%
Predicted Margin	5.2%	5.5%	5.9%	6.2%	6.5%	6.8%	7.2%	7.5%	7.8%	8.1%
Difference	0.7%	0.4%	0.0%	-0.4%	-0.8%	-0.5%	-0.1%	-0.3%	0.7%	0.4%

Source: authors' estimates based on Orbis® data.

It is interesting to note the difference in the predicted margin versus the actuals. Firms at either end of the size spectrum have higher than expected profitability, indicating a degree of non-linearity in the data.

Figure 6.1. Difference in Margin, Actual versus Predicted



Source: authors' estimates based on Orbis® data.

It is also worth noting that the character of this non-linearity changes over time. Table 6.2 splits the average margins for each size group out by economic cycle (2001 – 2007 and 2008 – 2014). We can see that the pattern in the second period is for an almost continuous increase by size group (with the exception of the largest group which consists of only two companies and three observations during the second cycle). This means that the 'outperformance' of the smaller size categories vanishes and only the largest firms outperform (their already higher) expected margins.

Table 6.2. Scaling Relationships by Cycle

Average Margin for Each Size Group by Economic Cycle										
Size Category	1	2	3	4	5	6	7	8	9	10
Max Firm Size	26	80	242	728	2,186	6,560	19,682	59,048	177,146	-
Av. Margin for Cycle 1	6.3%	6.1%	6.0%	6.0%	5.9%	6.3%	6.9%	6.6%	9.5%	7.9%
Av. Margin for Cycle 2	5.2%	5.5%	5.5%	5.5%	5.5%	6.0%	6.9%	7.3%	8.1%	4.9%
Diff. vs. predicited Cycle 1	*0.8%*	*0.3%*	*0.0%*	*-0.4%*	*-0.8%*	*-0.6%*	*-0.3%*	*-0.8%*	*1.8%*	*-0.1%*
Diff. vs. predicited Cycle 2	*0.0%*	*0.1%*	*-0.1%*	*-0.3%*	*-0.5%*	*-0.1%*	*0.6%*	*0.9%*	*1.4%*	*-1.9%*

Source: authors' estimates based on Orbis® data.

The analysis is repeated using $\log_{10}$ and $\log_2$, and similar trends were evident at these levels of granularity (see Table A.4). Larger firms tend to earn larger profit margins on average, and the relative outperformance has increased somewhat over time.

These findings are consistent with the trends outlined in the previous section, and suggest that firms gain a profitability advantage as they grow due to the fact that costs tend to scale at a marginally lower rate than revenues.

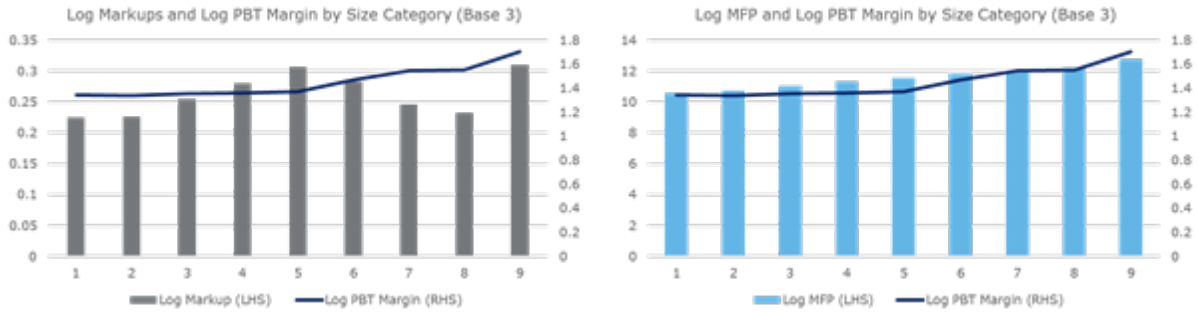
6.1. The Relationships Between Size and Mark-ups / MFP

As noted in the previous section, the largest size group has lower mark-ups on average than Size Group 3. The first graph below shows the mark-up progression at a finer level of granularity, noting that the largest size group is equivalent to category 6 and above. We can see that categories 6 – 8 (corresponding to firms between circa 6,000 - 60,000 employees) all exhibit lower mark-ups on average than category 5. Interestingly, average mark-ups

increase again after this point, though it should be stressed that the last two groups contain a small number of very large firms, with approximately 200 observations in total (category 10, which has a mean value of 0.57, is not shown below as it has only 13 observations).

Interestingly, profit margins at the larger firms do not suffer from their lower average mark-ups (as demonstrated by the blue line in the graphs below). This may indicate that profitability at these larger firms is more dependent on volume and efficiency, as opposed to unit margins. The second graph below supports this view. It shows that the relationship between MFP and profit margin is considerably closer than that between mark-ups and profitability.

Figure 6.2. Profit Margins, Mark-ups and MFP by Size Category



Note: size categories described in Table 6.1 and Table 6.2.
Source: authors' estimates based on Orbis® data.

Section 7. Do Larger Firms Have Higher Mark-ups and MFP?

As we saw from the previous section, larger firms tend to have higher mark-ups on average, though the relationship is not linear. We now apply a number of controls to see if size retains a significant impact after accounting for these variables.

Three regressions were run with log mark-ups as the dependent variable, all of which included dummies for Size Groups 2, 3 and 4. If size has a positive impact (due, for example, to the scalability and complementarity of digital and other intangible assets), then we should see evidence of this in the size dummies. Two sets of control variables were used, one with the capital intensity ratio (log of capital stock / output) and the log of firm age, and a second set which added log MFP. Per Calligaris et al. (2019), controls were lagged to reduce endogeneity concerns.

The key differences in the three sets of regressions are the fixed effects used to control for various time invariant factors. All regressions include a set of dummies to control for differences for each country-year pair. Regression 2 contains a further set of dummies to control for industry-year pairs, which is important given the substantial differences in mark-ups across industries. Finally, the last regression replaces the industry-year dummies with individual firm dummies. Summary results for the key size variables are presented here, with the full set of results in Table A.5. Table A.15 provides corresponding results for regressions using a single production technology at the NACE 3-digit level (these are very similar).

Table 7.1. Mark-ups by Size Group

	1	2	3
Size Group 2	0.05***	0.02***	0.04***
Size Group 3	0.14***	0.04***	0.09***
Size Group 4	0.12***	0.05***	0.14***
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age
Fixed Effects	Country-year	Country-year, industry-year	Country-year, firm
Observations	1,694,732	1,694,694	1,641,317
R-squared	0.08	0.54	0.94

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

After controlling for the various factors in Regression 1, we still see evidence of substantial size premiums, particularly for the two largest size groups. It is notable that Size Group 4 displays a significant mark-up premium over the two smaller size groups, despite the fact that the unweighted average is similar. Interestingly, when controlling for industry year fixed effects as well as country / year fixed effects in regression 2, we see the level of difference decline substantially, suggesting that industry-specific factors play a substantial role in determining the level of mark-ups (we turn to some of these industry-specific factors in the next section). Nevertheless, a clear step-up pattern remains.

The third regression controls for firm fixed effects. This comes at a cost however, as only firms who change size category (about 20% of the sample) remain in the regression.

Interestingly however it also shifts the analysis to how mark-ups are related to changes in size group. This shows that moving into different size groups has a positive impact on mark-ups, with the effect increasing with size.

Lastly, it should be noted that the standard errors for the above regressions were clustered at the firm level. A robustness check was also conducted with standard errors clustered at the country / industry (NACE 3-digit) level. All terms remain significant at the 1% level. These results are shown in Table A.5 along with results clustered at firm level.

A second set of regressions were run which were identical to the first, apart from the inclusion of MFP as a control variable. The results are presented below in Table 7.2. While every effort was made to reduce endogeneity concerns as outlined in Section 3.2, they cannot be eliminated as individual firm-level pricing decisions could impact both mark-ups and measured levels of productivity. On the other hand, if productivity helps determine mark-ups, then leaving it out results in omitted variable bias. If MFP and size are correlated (as the literature suggests), then the bias could be significant.

Table 7.2. Mark-ups by Size Group with MFP as an Additional Control

	1	2	3
Size Group 2	0.11***	0.06***	0.04***
Size Group 3	0.27***	0.15***	0.10***
Size Group 4	0.27***	0.20***	0.15***
Controls	K intensity, Firm Age, MFP	K intensity, Firm Age, MFP	K intensity, Firm Age, MFP
Fixed Effects	Country-year	Country-year, industry-year	Country-year, firm
Observations	1,186,510	1,186,471	1,140,887
R-squared	0.14	0.58	0.95

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data

We can see that each of the coefficients is larger when including MFP as a control, as there is a negative relationship between MFP and mark-ups. As Syverson (2011) notes, productivity spreads between firms based on physical output tend to be higher than those based on revenue. This results from more productive firms tending to have lower unit prices, which reduces the productivity gap when it is measured in revenue terms. This could lead to a negative relationship between mark-ups and MFP, all else equal.

We can see that the magnitude of the increase is much smaller for Regression 3 which includes firm specific fixed effects. This would be expected given that firm level MFP is often quite persistent, and may not change significantly over relatively short periods of time.

7.1. The Impact of Scale on Multifactor Productivity

The table below shows the value of the size dummies for MFP, with regressions 1, 3 and 5 representing results with age and capital intensity as controls, and regressions 2, 4 and 6 also including Log Mark-up as a control.

We observe a substantial size premium, which increases with each size group. The coefficient for Size Group 4 in Regression 1 is large at 1.24, implying MFP at those firms is c. 245%[8] higher than Size Group 1. We do see sizeable coefficients in other studies,

however. For example, Berlingieri et al (2018a) found dummy values in excess of 1 for large manufacturing firms (250+ employees) in their data. It is interesting to note that the values from Regression 3 with industry-year fixed effects are more similar to those from Regression 1 than was the case for mark-ups. This suggests that industry-specific factors play less of a role with regard to productivity than with mark-ups. Regression 3 shows that changing size group also has a positive impact on productivity, similar in magnitude to the mark-ups equivalent.[9]

Table 7.3. MFP by Size Group

	1	2	3	4	5	6
Size Group 2	0.33***	0.38***	0.35***	0.39***	0.02***	0.03***
Size Group 3	0.74***	0.88***	0.83***	0.91***	0.09***	0.09***
Size Group 4	1.24***	1.34***	1.25***	1.36***	0.22***	0.23***
Controls	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year, industry-year	Country-year, industry-year	Country-year, firm	Country-year, firm
Observations	1,461,464	1,212,004	1,461,443	1,211,978	1,414,245	1,165,445
R-squared	0.29	0.34	0.67	0.70	0.92	0.92

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data

7.2. Do Larger Firms Have Higher Mark-ups and MFP?

Our mark-up results demonstrate a significant size premium, particularly for the largest two size groups. Industry-specific factors play an important role, though the premium remains even when controlling for them. MFP size dummies indicate a clear step-up pattern with successive size groups, with the largest group almost always exhibiting the largest MFP premium. Changes in size group are also positively related to both mark-ups and MFP.

Section 8. How Are These Mark-up and MFP Trends Changing Over Time?

8.1. Changes in Mark-ups by Economic Cycle

The table below splits out the changes out by economic cycle (outlined in Section 3.2). We see the impact of scale increases from the first cycle to the second, consistent with the scaling data presented earlier. As the coefficients also increase in Regression 2 (with industry-year fixed effects), we conclude this is not simply due to industry-specific factors. For the sake of brevity we show results without MFP as an additional control here, as the trends with MFP included are similar (see Table A.7).

We see that the impact of changing size group declines slightly from Cycle 1 (2001 – 2007) to Cycle 2 (2008 – 2014) for each of the size groups. The pattern of systematic increases of mark-ups with size group persists, however.

Table 8.1. Mark-ups by Size Group and Cycle

	1a	1b	2a	2b	3a	3b
Cycle	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 2	0.05***	0.06***	0.01***	0.02***	0.05***	0.03***
Size Group 3	0.13***	0.15***	0.04***	0.04***	0.10***	0.08***
Size Group 4	0.10***	0.13***	0.04***	0.06***	0.15***	0.12***
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age
Fixed Effects	Country-year	Country-year	Country-year, industry-year	Country-year, industry-year	Country-year, firm	Country-year, firm
Observations	703,689	991,043	703,666	991,028	653,839	940,601
R-squared	0.06	0.08	0.53	0.54	0.95	0.96

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

8.2. Changes in MFP by Economic Cycle

As with mark-ups, size appears to matter more during the second period than the first. The MFP size premium increases from the first cycle to the second for all size groups, though the increase is greater for the two largest groups. Somewhat surprisingly the change in MFP associated with moving size groups is marginally negative in the first cycle, though it becomes marginally positive in the second. Further results with mark-ups included as a control can be found Table A.8.

Table 8.2. MFP by Size Group and Cycle

	1a	1b	2a	2b	3a	3b
Cycle	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 2	0.30***	0.35***	0.34***	0.36***	-0.04***	0.02***
Size Group 3	0.57***	0.84***	0.78***	0.85***	-0.05**	0.04**
Size Group 4	0.96***	1.44***	1.28***	1.23***	-0.09	0.07**
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age
Fixed Effects	Country-year	Country-year	Country-year, industry-year	Country-year, industry-year	Country-year, firm	Country-year, firm
Observations	530,873	930,591	530,860	930,583	493,984	885,779
R-squared	0.16	0.31	0.65	0.66	0.96	0.96

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

To summarise then, size has a positive relationship with both mark-ups and MFP, and it tends to matter more in the second period.

Section 9. Do Patterns Vary According to the Digital Intensity of an Industry?

We now turn to the question of whether this positive size effect varies according to the digital intensity of an industry. Four regressions were run over two time periods to examine the relationships between mark-ups, size and industry digitalisation over time. The firm-level size dummies were interacted with the industry-level digital dummies for both Cycle 1 and Cycle 2.

These regressions show how the total size premiums from previous regressions are attributable to more and less digitally intensive sectors (bearing in mind our reference category is Size Group 1 less digital intensive). We see that the larger size groups have substantial mark-up gaps in both digital intensive and less digital intensive industries. The gap between the smaller and larger size groups also tends to increase from Cycle 1 to Cycle 2, and across both sectors. The average increase is larger in digital intensive industries, albeit from a lower initial level for Size Group 4 firms.

This points to an interesting aspect of the results - the reason for the slightly lower Size Group 4 term in Regression 1, Table 7.1, was due to firms in the digital intensive sector. This gap has closed over time however, and almost completely when MFP is used as a control. Mark-ups for digital intensive Size Group 2 and 3 firms are typically higher than their less digital intensive equivalents, and indeed mark-ups tend to be higher for digital intensive industries overall, consistent with Calligaris et. Al. (2019).[10]

Table 9.1. Mark-ups by Size Group and Digitalisation

	1a	1b	2a	2b
Cycle	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 2	0.01***	0.02***	0.08***	0.07***
Size Group 3	0.07***	0.10***	0.23***	0.24***
Size Group 4	0.15***	0.17***	0.45***	0.38***
S1*Digital Intensive	-0.02***	-0.01***	-0.05***	0.01***
S2*Digital Intensive	0.05***	0.07***	0.08***	0.13***
S3*Digital Intensive	0.14***	0.16***	0.23***	0.29***
S4*Digital Intensive	0.07***	0.11***	0.18***	0.28***
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age, MFP	K intensity, Firm Age, MFP
Fixed Effects	Country-year	Country-year	Country-year	Country-year
Observations	703,689	991,043	397,101	789,409
R-squared	0.06	0.09	0.15	0.14

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the firm level. Results with errors clustered at the industry-year level are provided in the appendix. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

In addition, a second set of regressions controlling for firm level fixed effects are outlined in Table A.9. All of the size and digital dummies are positive and significant, indicating that moving up size groups is associated with higher mark-ups across all industries, but to a greater extent in digital intensive industries. Moving into the largest size group is associated with an increase in mark-up of 6 - 8% for the less digital intensive sector

(depending on the period and controls used) and an increase of 14 – 18% for the digital intensive sector. The increases associated with moving into Size Group 2 are much smaller, at 2 - 4% for less digital intensive industries and 4 - 6% for digital intensive.

9.1. MFP Regressions with Size and Digital Dummies

Turning to MFP, we can see that the step-up with successive size groups holds true for both more and less digitally intensive sectors (though it is larger for the less digital intensive sector). We can also see that larger firms in both digital intensive and less digital intensive industries have tended to increase the productivity gaps from Cycle 1 to Cycle 2. The exception is Size Group 4 in the less digital intensive sector, albeit the reduction occurs from a very large initial gap.

The size premium for Size Groups 3 and 4 over Size Groups 1 and 2 has increased substantially in the case of the digital intensive sector. Therefore, while these size premiums are lower in the digital intensive sector in both periods, the gap has narrowed significantly over time.

Table 9.2. MFP by Size Group and Digitalisation

	1a	1b	2a	2b
Cycle	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 2	0.41***	0.42***	0.45***	0.46***
Size Group 3	0.87***	1.06***	1.06***	1.20***
Size Group 4	2.30***	1.68***	2.39***	1.96***
S1*Digital Intensive	-0.09***	0.17***	-0.08***	0.20***
S2*Digital Intensive	0.15***	0.47***	0.23***	0.55***
S3*Digital Intensive	0.40***	0.90***	0.54***	1.04***
S4*Digital Intensive	0.78***	1.52***	0.87***	1.62***
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age, Mark.	K intensity, Firm Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year	Country-year
Observations	530,873	930,591	397,155	814,849
R-squared	0.18	0.32	0.26	0.36

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the firm level. Results with errors clustered at the industry-year level are provided in the appendix. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

9.2. Regressions with Size and Digital Quartile 3 / 4 Dummies

The next set of regressions split the digital dummy into two separate dummies representing those industries in the third and fourth quartiles of digitalisation (the reference category remains Size Group 1 less digital intensive). We see very different patterns for the two quartiles. As outlined in Table A.11, the Quartile 4 digital dummy is very large and significant (0.23 - 0.27 depending on the cycle and whether MFP is used as a control). The result is that all size categories have higher mark-ups relative to the other quartiles.

The Quartile 4 size dummies are unique in that they do not display a marked step-up pattern by size group. The fact that all size groups have similar coefficients could indicate that smaller firms in the most-digital sector are able to achieve 'scale without mass' due to nature of these industries. Low levels of marginal costs associated with digital investments may enable successful firms to achieve high levels of sales relative to their employment

base. It may be that even smaller firms in the most-digital sector have relatively high levels of complementary skills or other intangible assets. It may also simply be that there are other industry-specific factors influencing the results that are not being controlled for.

Two pertinent candidates are skill intensity and the degree of routinisation. Berlingieri, Calligaris and Criscuolo (2018) note that including skill intensity as a control increases the impact of scale with regard to MFP in services in particular (most of the digital intensive industries are service industries). It may be digitalisation is more impactful where tasks are more routinised and less highly skilled (as suggest by Gal et al. 2019). This could help explain why scale has less of an impact in Quartile 4 industries.

Table 9.3. Mark-ups by Size Group and Digitalisation (Quartiles 3 and 4)

	1a	1b	2a	2b
Cycle	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 1*Q3	-0.09***	-0.09***	-0.13***	-0.10***
Size Group 2*Q3	-0.07***	-0.06***	-0.08***	-0.05***
Size Group 3*Q3	-0.02***	-0.01***	0.02***	0.02***
Size Group 4*Q3	-0.03***	-0.03***	0.08***	0.05***
Size Group 1*Q4	0.24***	0.26***	0.23***	0.27***
Size Group 2*Q4	0.29***	0.30***	0.32***	0.35***
Size Group 3*Q4	0.26***	0.28***	0.30***	0.36***
Size Group 4*Q4	0.11***	0.14***	0.15***	0.24***
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age, MFP	K intensity, Firm Age, MFP
Fixed Effects	Country-year	Country-year	Country-year	Country-year
Observations	703,689	991,043	397,101	789,409
R-squared	0.25	0.28	0.34	0.33

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. There are two digital dummies, the first equal to one if the firm is in an industry in the third quartile of digitalisation, and the second equal to one for industries in the fourth quartile. All controls at t-1. Errors clustered at the firm level. Results with errors clustered at the industry-year level are provided in the appendix. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

It is also notable that the size coefficients for the firms in Quartile 3 industries are negative, so they are not only smaller than those for Quartile 4, but also smaller than firms in the less digital intensive sector. The key driver here is the presence of the wholesale and retail industry in Quartile 3. The majority of wholesale and retail businesses are relatively high volume, low margin businesses, which leads to relatively low mark-ups and negative Quartile 3 dummies (-0.09 to -0.13 depending on the cycle and whether MFP is used as a control). The average mark-up for this industry is 1.11, compared to an unweighted average Quartile 3 mark-up (excluding retail) of 1.36. If retail is excluded from Quartile 3 the average unweighted mark-up is higher than less digital intensive industries (1.32).

As outlined in Table A.11, all Size Group 2, 3 and 4 terms are positive and significant in regressions which include firm fixed effects, which indicate that changes in size group are positively related to changes in mark-ups in both Digital Quartile 3 and 4 industries. The impact is particularly large for Size Group 3 and 4 in the Digital Quartile 4 industries (increases of 18 - 23% and 23 – 29% respectively depending on the period and controls used). Growth in size therefore has a particularly large impact in the most digitised of industries.

9.3. MFP Regressions with Size and Digital Quartile 3 / 4 Dummies

The MFP results by quartile are consistent with the previous MFP regressions in that there is evidence of the step-up pattern for both Quartile 3 and Quartile 4 firms. We also see that the size gaps in MFP have increased substantially in the case of the Quartile 4 firms, but not in the Quartile 3, indicating that the increase in Table 9.2 was due to firms in the most digitised industries.

Table 9.4. MFP by Size Group and Digitalisation (Quartiles 3 and 4)

	1a	1b	2a	2b
Cycle	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 1*Q3	0.04***	0.28***	0.02***	0.29***
Size Group 2*Q3	0.37***	0.64***	0.36***	0.67***
Size Group 3*Q3	0.69***	0.96***	0.70***	1.02***
Size Group 4*Q3	0.72***	0.92***	0.78***	0.93***
Size Group 1*Q4	-0.48***	-0.13***	-0.34***	-0.02***
Size Group 2*Q4	-0.18***	0.22***	-0.01***	0.35***
Size Group 3*Q4	0.27***	0.86***	0.43***	0.98***
Size Group 4*Q4	0.77***	1.57***	0.85***	1.65***
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age, Mark.	K intensity, Firm Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year	Country-year
Observations	530,873	930,591	397,155	814,849
R-squared	0.24	0.35	0.28	0.37

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. There are two digital dummies, the first equal to one if the firm is in an industry in the third quartile of digitalisation, and the second equal to one for industries in the fourth quartile. All controls at t-1. Errors clustered at the firm level. Results with errors clustered at the industry-year level are provided in the appendix. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

9.4. Do Patterns Vary by Digital Intensity?

To sum up, many of the patterns evident in Section 7. are consistent across both more and less digitally intensive industries. Larger size groups exhibit substantial mark-up and MFP gaps in both sectors. The gaps in mark-ups and MFP also tend to increase from Cycle 1 to 2, though the increase is more pronounced in the digital intensive sector.

In terms of mark-ups, an exception to the general step-up pattern with size occurs for the most-digital industries (Quartile 4). As indicated above, it may be related to unobserved factors such as skill intensity and the degree of routinisation. On the other hand, it may be that smaller firms can achieve 'scale without mass' in these industries, enhancing their ability to compete with larger firms and reducing or even reversing mark-up gaps.

Another interesting candidate is the level of industry maturity, per Klepper (1996). If the growth of the internet in the late 1990s led to significant disruption, growth in new entrants and a wave of innovation, the benefits of being a larger firm would likely have diminished. Over time, as product variety declines and the importance of process innovation grows, we would see industry leadership stabilise, the number of new entrants fall, and growth in the productivity and profitability of the larger firms.

As Calvino and Criscuolo (2018) outlined, levels of dynamism are higher in digitally intensive industries, and particularly so in services. However, these levels of dynamism

have been declining in both digitally intensive and less digitally intensive industries since the turn of the century, and more so in digital intensive industries. This would be consistent with a number of the patterns above. Initially, size premiums in the most-digital industries are low or even negative, consistent with a high level of competition in the early stages of digital maturity. However, these size premiums have increased over time, at the same time as the level of dynamism has declined. In addition, larger firms have increased the productivity gaps over smaller firms as these industries have matured.

Section 10. Are the Trends Consistent Across Manufacturing and Services?

As we can see from the taxonomy in Table A.1, there are more digital intensive industries in services than manufacturing. It is, therefore, important to establish that the trends identified previously do not simply reflect service / manufacturing distinctions. It is also instructive to determine if the lower mark-ups for Size Group 4 in the most-digital industries are a feature or manufacturing, services, or both.

10.1. Mark-up Regressions Split by Manufacturing and Services

Splitting the data generates four categories: less digital intensive manufacturing; digital intensive manufacturing; less digital intensive services; and digital intensive services. Manufacturing less digital intensive was designated as the base category. Dummies were then created for the other three categories, and interacted with the size group dummies.

Table 10.1. Mark-ups by Size Group, Digitalisation and Manufacturing / Services

	Dummy Values Less-Digital Manufacturing				Dummy Values More-Digital Manufacturing			
Cycle	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 1	-	-	-	-	0.00	0.01	-0.06	0.06
Size Group 2	0.00	0.01	0.07	0.06	0.02	0.03	0.02	0.11
Size Group 3	0.06	0.06	0.24	0.20	0.07	0.05	0.14	0.15
Size Group 4	0.16	0.11	0.47	0.28	0.07	0.07	0.30	0.30
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Age, MFP	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Age, MFP
Fixed Effects	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year
Observations	703,689	991,043	397,101	789,409	703,689	991,043	397,101	789,409
R-squared	0.11	0.12	0.16	0.15	0.11	0.12	0.16	0.15

	Dummy Values Less-Digital Services				Dummy Values More-Digital Services			
Cycle	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 1	0.13	0.10	0.08	0.09	0.04	0.03	0.00	0.03
Size Group 2	0.18	0.17	0.16	0.18	0.14	0.14	0.13	0.17
Size Group 3	0.24	0.26	0.29	0.34	0.22	0.23	0.27	0.32
Size Group 4	0.24	0.28	0.45	0.51	0.13	0.15	0.21	0.31
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Age, MFP	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Age, MFP
Fixed Effects	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year
Observations	703,689	991,043	397,101	789,409	703,689	991,043	397,101	789,409
R-squared	0.11	0.12	0.16	0.15	0.11	0.12	0.16	0.15

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is split by manufacturing and services, with less digital intensive manufacturing designated as the base category. All controls at t-1. Errors clustered at the firm level. Results with errors clustered at the industry-year level are provided in the appendix. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

In three of the four sectors we see that mark-ups increase with successive size groups, whether MFP is used as a control or not. The exception is digital intensive services, though Size Group 4 mark-ups do increase relative to the other groups in the second period, particularly when MFP is used a control. Overall, the gaps between the size groups narrow in manufacturing and widen in services (for both more and less digitally intensive). We

also see that service firms tend to earn higher mark-ups than manufacturing firms, though the differences often disappear when MFP is used as a control.

The regression including firm fixed effects (Table A.13) displays similar patterns, in that the transition to the largest size group has the biggest impact on mark-ups. The largest impacts occur in the services sector (and digital intensive services in particular). The coefficients on the interaction terms for the manufacturing sector are generally positive, though often relatively small in magnitude aside from Size Group 4.

10.2. MFP Regressions Split by Manufacturing and Services

Table 10.2. MFP by Size Group, Digitalisation and Manufacturing / Services

	Dummy Values Less-Digital Manufacturing				Dummy Values More-Digital Manufacturing			
Cycle	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 1	-	-	-	-	-0.60	0.41	-0.54	0.46
Size Group 2	0.45	0.48	0.48	0.51	-0.22	0.77	-0.13	0.84
Size Group 3	1.03	1.34	1.17	1.42	0.42	0.68	0.54	0.77
Size Group 4	1.60	1.80	1.83	2.05	0.84	1.23	1.06	1.33
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year
Observations	530,873	930,591	397,155	814,849	530,873	930,591	397,155	814,849
R-squared	0.27	0.34	0.32	0.37	0.27	0.34	0.32	0.37

	Dummy Values Less-Digital Services				Dummy Values More-Digital Services			
Cycle	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 1	-0.69	-0.21	-0.53	-0.13	-0.43	0.03	-0.32	0.10
Size Group 2	-0.42	0.09	-0.21	0.21	-0.20	0.33	-0.03	0.45
Size Group 3	-0.02	0.58	0.27	0.79	0.01	0.81	0.23	0.97
Size Group 4	2.46	1.44	2.72	1.80	0.40	1.44	0.58	1.56
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year
Observations	530,873	930,591	397,155	814,849	530,873	930,591	397,155	814,849
R-squared	0.27	0.34	0.32	0.37	0.27	0.34	0.32	0.37

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is split by manufacturing and services, with less digital intensive manufacturing designated as the base category. All controls at t-1. Errors clustered at the firm level. Results with errors clustered at the industry-year level are provided in the appendix. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Berlingieri, Calligaris and Criscuolo (2018) found that the step-up in MFP by size was larger in manufacturing industries than services, using the MultiProd database. This pattern was also evident in the Orbis data (results available upon request). Further splitting out manufacturing and services by more and less digitally intensive industries reveals a number of interesting features, however.

The pattern of successive increases with size group remains for MFP in both manufacturing and service sectors. The productivity gaps tend to be larger in less digital intensive industries however, with the gaps being lowest for digital intensive services. It is therefore the digital intensive service industries that appear to be responsible for lower step-ups by size in the service sector overall. It is notable however that these gaps increase significantly in the second cycle.

Recall that Berlingieri, Calligaris and Criscuolo found that controlling for skill intensity eliminates the productivity differential between large manufacturing and service firms. They stated that this could indicate that large service firms tend to be less skill intensive and / or smaller service firms tend to be more skill intensive. It may well be that the smaller firms in digital intensive industries are indeed more skill intensive. As noted above, it may also be that smaller firms in the digital intensive sectors (and digital intensive services in particular) can achieve 'scale without mass'.

10.3. Are the Trends Consistent Across Manufacturing and Services?

Broadly speaking, many of the patterns outlined in previous sections are consistent across manufacturing and services. We see evidence of a clear step-up with size for both mark-ups and MFP across almost every sector. The exception to the rule is mark-ups in digital intensive services. The productivity gaps between the size groups are also the lowest of the four sectors, though they increase significantly in the second cycle.

These findings appear consistent with the patterns of business dynamism observed by Calvino and Criscuolo (2019). They found that while levels of dynamism were highest in digital services, they also exhibited the largest declines. It may be that larger firms in these industries are gaining in market power as they become more established.

Section 11. Has There Been a Shift in Market Power Between Large and Small Firms?

There is a large amount of evidence to support the view that the competitive balance is shifting, with large firms gaining market power relative to smaller firms. Large firms tended to have higher rates of sales growth throughout the sample period. They were also more profitable, and the gap widened by the end of the sample period (particularly the largest firms). The data shows that the largest firms tended to have the highest mark-ups, regardless of what type of fixed effects were used, whether the data was split by more or less digital intensive, or whether the sector was services or manufacturing.

Differences in mark-ups between the largest two size groups and the smaller groups also increase over time. While industry-specific factors play a role, regressions with industry fixed effects show that this remains true even when controlling for these factors. When we look at the trends by industry, we see that larger size groups have substantial mark-up and MFP gaps in both more and less digitally intensive industries. The gap in mark-ups also tends to increase from Cycle 1 to 2, and this is matched by an increase in the MFP gap in the digital intensive sector.

Interestingly, the only exception to the general pattern is the most-digital sector (Quartile 4, which is made up of industries such Machinery and Equipment, IT and Telecoms - see Appendix A1). This raises interesting questions regarding 'scale without mass', and could also point to higher levels of skill intensity and lower levels of routinisation in these industries which may reduce the benefits of scale. Cycles of industry maturity could also be playing a role, and it is notable that mark-ups at the larger firms in the most digitised industries increase relative to the smaller firms in the second period (with their productivity premium also increasing). Unfortunately, without better firm-level data and a longer time span than is available in Orbis we cannot be definitive.

Finally, it is also notable that regressions with firm fixed effects show that moving up size groups has a positive impact on mark-ups, with the effect increasing systematically with size. Therefore, there is substantial evidence to show that increased size is associated with greater market power, and that this effect is increasing over time.

Section 12. Are Technological Factors Playing a Role?

The first aspect to note is that mark-ups are higher in the digital intensive sector, and so digitalisation is associated with greater market power at a broad industry level. We have also outlined substantial mark-up gaps between larger and smaller firms, and noted that these gaps are increasing. Importantly, the increases in the mark-up gaps have been greater in the digital intensive sector, albeit from lower initial levels. This is particularly noticeable when MFP is included as a control.

If mark-up trends are mirrored by similar trends in MFP then we can be more confident that technological factors play a role. We do indeed see a clear step-up in MFP with size, as has been found in many studies. We also see that these gaps have tended to widen over time. While the gaps are narrower for digital intensive industries, the increase has been greater, driven by increasing productivity gaps at the most-digital industries. We do note however that these results are based on regressions with separate production technologies for each cycle. Results with a single production technology show increasing gaps between the larger and smaller size groups when we look at the simple averages over the two cycles. However, the gaps between the larger and smaller MFP size dummies tend to decline slightly when the various regression controls are applied (see Appendix 16 for these results).

We have also seen that moving into larger size groups is associated with progressively larger increases in mark-ups. It is notable that these effects are stronger in the digital intensive sector, and strongest of all in the most-digital sector. Depending on the period and controls used, moving into the largest size group is associated with an increase in mark-up of 6 - 8% for less digital intensive industries, compared to 14 - 18% for digital intensive industries. The equivalent figures for Size Group 2 are increases of 2 - 4% for less digital intensive industries and 4 - 6% for digital intensive. The effect is magnified for the most digitised industries, with increases of 18 - 23% for Size Group 3 and 23 – 29% for Size Group 4

Another relationship that may be instructive is the relative importance of mark-ups and MFP in determining profits, and how this varies according to digital intensity. We estimate regressions linking firm profits (using the same definition as previously) with both mark-ups and MFP for Cycle 1 and Cycle 2. We incorporate the usual controls and all variables are standardised so we can directly compare the impacts (even though they are in log form the distributions vary). We also add a digital interaction term to the mark-up and MFP variables in order to see if the marginal impacts on profitability differ between more and less digitally intensive industries. Country-year and industry-year fixed effects were applied given the substantial variation across individual industries.

Table 12.1. Relationships Between Profits, Mark-ups and MFP by Sector

	1	2	3	4
Dependent Variable	Profit Margin	Profit Margin	Profit Margin	Profit Margin
Cycle	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Standardized values of Log Mark-up	0.136***	0.165***	0.136***	0.165***
	(0.005)	(0.005)	(0.030)	(0.025)
Log Mark-up x Dig. Dummy	-0.020***	-0.055***	-0.020	-0.055*
	(0.006)	(0.005)	(0.039)	(0.031)
Standardized values of Log MFP	0.451***	0.481***	0.451***	0.481***
	(0.005)	(0.004)	(0.017)	(0.019)
Log MFP x Dig. Dummy	0.073***	-0.009*	0.073***	-0.009
	(0.006)	(0.005)	(0.025)	(0.024)
Observations	497,869	778,140	497,869	778,140
R-squared	0.24	0.22	0.24	0.22
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age
Fixed Effects	Country-year, industry-year	Country-year, industry-year	Country-year, industry-year	Country-year, industry-year
Cluster	id	id	country-ind	country-ind

Note: The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the firm level for regressions 1 and 2, and clustered at the industry-year level for 3 and 4. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

We can see that MFP is the key determinant of profitability in both periods. In addition, the relative importance of MFP is greater in digital intensive industries. The digital interaction term on MFP is positive in the first period, and while it is marginally negative in the second period, the digital interaction term on mark-ups is negative and significant in both periods.

The fact that MFP is the largest determinant of profitability (with the influence increasing in the second period) shows that the MFP advantage of the larger firms is having a significant impact. It would appear then that the growing productivity differentials are a key factor in their increased profitability relative to the smaller size groups.

Section 13. Conclusions

This report has outlined several trends regarding size, mark-ups and MFP which would indicate that technology may be helping larger firms achieve higher levels of mark-ups and market power, thereby altering the balance of competition relative to smaller firms. We see evidence of a significant size premium with regard to both mark-ups and MFP. Industry-specific factors play an important role, though the premium remains even when controlling for them. The importance of size tends to increase over time for both mark-ups and MFP.

These patterns tend to be consistent across both more and less digitally intensive industries. Larger size groups have substantial mark-up and MFP gaps in both sectors. The gap in mark-ups between the smaller and larger size groups also tends to increase from Cycle 1 to 2, and this is matched by an increase in the MFP gap in the digital intensive sector. When we further divide the sectors by manufacturing and services, the broad patterns also tend to hold true. A notable exception regarding the typical mark-up pattern comes from the most digitised industries (those in Quartile 4). Here we see the typical size premium disappear, though larger firms do see greater mark-up increases in the second period.

The trends raise interesting questions regarding 'scale without mass', and could also point to higher levels of skill intensity and lower levels of routinisation in Quartile 4 industries which may reduce the benefits of scale. Cycles of industry maturity could also be a factor. Unfortunately, without better firm-level data and a longer time span than is available in Orbis we cannot be definitive.

Given the fact that larger firms are growing faster, are more profitable, earn higher mark-ups and are more productive, we can conclude that they have greater levels of market power. The fact that their profitability and mark-up advantages have grown would indicate that this power is increasing. There are a number of reasons to believe that technology may be contributing to these trends. The increase in mark-up gaps between larger and smaller firms is greater in the digital intensive sector. Furthermore, these increasing gaps in mark-ups are matched by increasing gaps in MFP. The impact of moving up size groups is also higher in digital intensive industries, and in the most digitally intensive in particular.

The associations above do not 'prove' that the increased use of digital technologies is a key factor behind the increased market power of the largest firms, though they are suggestive of this. More granular firm level data on digital investments and competencies (ideally with data on other intangible assets such as complementary management skills) would be required to be more confident of causation.

Ideally, we would be able to parse the impact of a firm's digital and intangible investments, how they vary with size, and in turn impact competition between large and small firms. Unfortunately, this is not possible in the data. If both omitted variables are positively correlated with mark-ups, MFP and size (as would seem plausible), then large and significant size dummies may reflect their impact. This interplay between digital and other intangible assets, and their impact on competition, is an important topic for future research.

In any case, assessing productivity and profitability trends over longer time periods may also shed further light on whether cycles of industry maturity could explain some of the dynamics we are seeing in digital intensive service industries. Controlling for skill intensity and degrees of routinisation could also provide greater clarity on how mark-ups and MFP vary by size across different industries.

It should also be noted that as digital technologies evolve and robotics and artificial intelligence become more commonly used, there is potential for some of the trends seen here to continue or even accelerate. Complex technologies requiring large amounts of data and highly specialised skills may be easier to develop for large firms. If these technologies are combined with other complementary and scalable intangible assets, this could further enhance their competitive position.

If data really is the 'new oil', there is no doubt that larger firms have greater access to it by virtue of their larger production and customer networks. They are also more likely to be able to attract and retain the highly specialised skills required to develop these technologies. Finally, the highly scalable nature of many digital technologies means that their benefits may be magnified over a wider range of output. Bigger may be better now, be it may be even more so in the future.

If that does prove to be the case then current trends of greater concentration, falling business dynamism, higher mark-ups and greater divergence in productivity may continue. This would clearly present further threats to competition and ultimately consumer welfare, and would require policy makers to consider appropriate responses.

[1] For example, a recent OECD report found that the top 2,000 corporate R&D investors own almost two thirds of patents filed at the largest 5 IP offices worldwide. http://www.oecd.org/sti/world-corporate-top-rd-investors-shaping-future-of-technology-and-of-ai.pdf

[2] While mark-ups are a commonly used indicator of market power, many others have been used in the literature such as market concentration, profitability, return on investment, dividends and market capitalisation (see Calligaris et al. (2019) for more details). Given the inherit difficulties in measuring mark-ups outlined in Section 3, examining other indicators of market power is prudent

[3] High mark-ups may also be due to high levels of fixed costs, and increases in mark-ups can reflect growing fixed costs. The impact of increases in fixed costs would also be reflected in profitability however, and this is another reason why we look at trends in profitability as well as mark-ups when assessing changes in market power.

[4] Australia, Austria, Belgium, Bulgaria, Denmark, Estonia, France, Finland, Hungary, Germany, Indonesia, India, Ireland, Italy, Japan, Republic of Korea, Luxembourg, the Netherlands, Portugal, Romania, Slovenia, Spain, Sweden, Turkey, the United Kingdom, and the United States.

[5] Coverage by size class does vary somewhat by country, but given that the focus of the paper is on differences between the size classes rather than differences across countries, this is not considered to be a significant drawback.

[6] Where costs were calculated as revenue minus EBITDA, plus a capital cost of 0.1 multiplied by total capital stock. All variables in real terms.

[7] Costs as per profit margin.

[8] As the dependent variables is in log form the percentages are calculated as exp(dummy value) – 1.

[9] Appendix 15 provides the corresponding results using a single production technology. The patterns are quite similar, though the gaps between the size groups are a little smaller in the case of Regression 1 (excluding mark-ups as a control), with dummy values of 0.24, 0.40 and 0.54 respectively.

[10] As demonstrated with a regression using the controls above and a single dummy representing digital intensive industries. Results available on request. We can see that Size Group 1 is also exception to the general rule of higher mark-ups in digital intensive sectors. It may be that these firms suffer greater competitive pressure from larger firms, or that digital intensive industries face lower entry barriers. However, some caution is needed in interpreting results for Size Group 1. As we noted in Section 4 , firms with less than 20 employees are excluded for comparability across countries, while firms with negative value add are also omitted. Potential therefore exists for selection bias.

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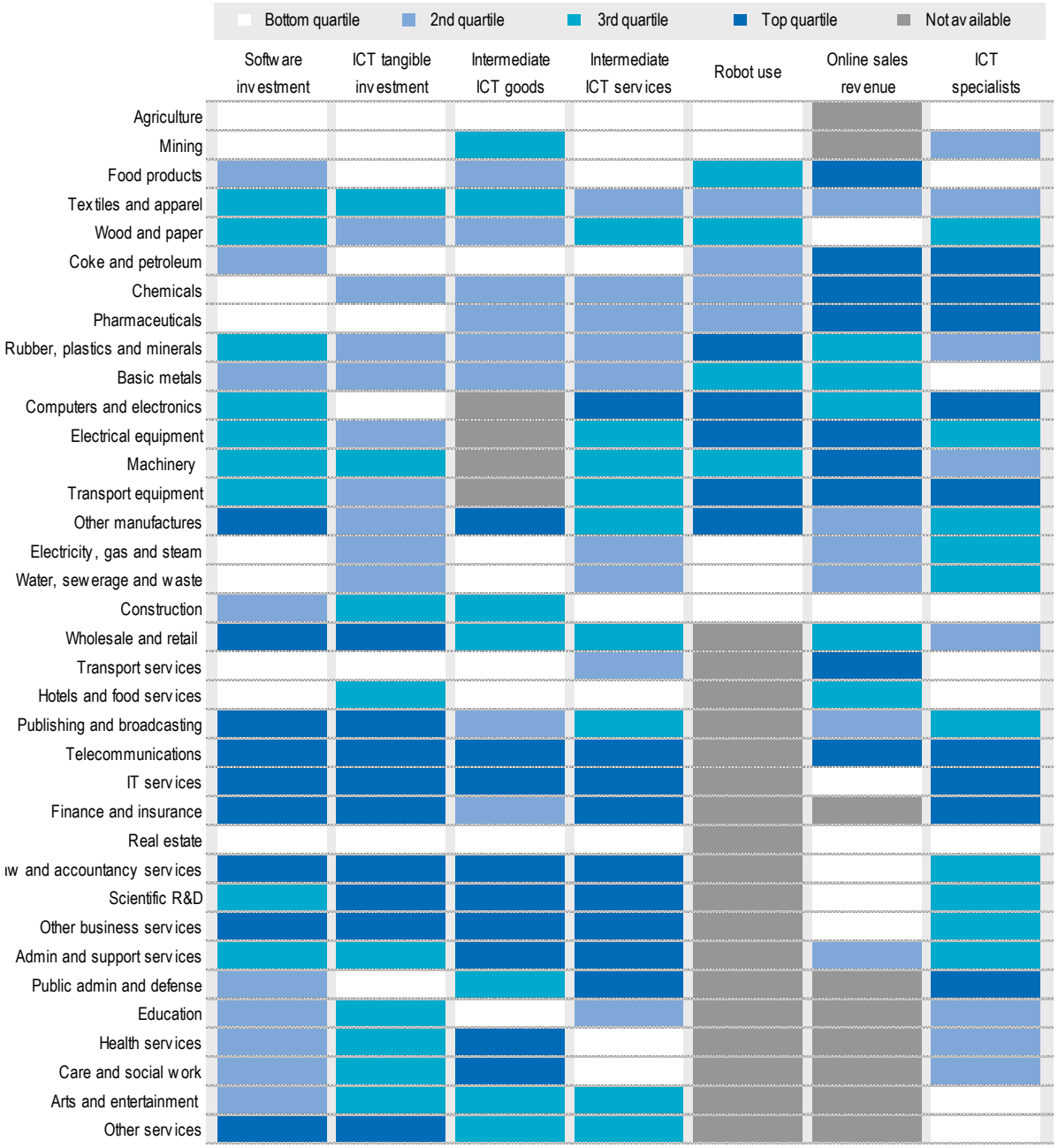
Appendix

Table A.1. Industry Classification and Digital Taxonomy

Industry Classification and Digital Intensity Taxonomy			
ISIC rev.4 code	**Description**	**Digital Quartile 2001 - 2003**	**Digital Quartile 2013 - 2015**
D10T12	Food products, beverages and tobacco [CA]	Low	Low
D13T15	Textiles, wearing apparel, leather and related products [CB]	Medium-Low	Medium-Low
D16T18	Wood and paper products, and printing [CC]	Medium-High	Medium-High
D20	Chemicals and chemical products [CE]	Medium-Low	Medium-Low
D21	Basic pharmaceutical products and pharmaceutical preparations [CF]	Medium-Low	Medium-Low
D22T23	Rubber and plastics, and other non-metallic mineral products [CG]	Medium-Low	Medium-Low
D24T25	Basic and fabricated metals, except machinery and equipment [CH]	Medium-Low	Medium-Low
D26	Computer, electronic and optical products [CI]	High	High
D27	Electrical equipment [CJ]	Medium-High	Medium-High
D28	Machinery and equipment n.e.c. [CK]	High	High
D29T30	Transport equipment [CL]	High	High
D31T33	Furniture, other manufacturing, repair of machinery and equipment [CM]	Medium-High	Medium-High
D45T47	Wholesale and retail trade, repair of motor vehicles and motorcycles [G]	Medium-High	Medium-High
D49T53	Transportation and storage [H]	Low	Low
D55T56	Accommodation and food service activities [I]	Low	Low
D58T60	Publishing, audiovisual and broadcasting activities [JA]	Medium-High	Medium-High
D61	Telecommunications [JB]	High	High
D62T63	IT and other information services [JC]	High	High
D69T71	Legal and accounting, activities of head offices, management consultancy, architecture and engineering, technical testing and analysis	High	High
D72	Scientific research and development [MB]	Medium-High	Medium-High
D73T75	Advertising and market research, other professional, scientific and technical activities, veterinary activities [MC]	High	High
D77T82	Administrative and support service activities [N]	High	High

Source: Calvino et al. (2018).

Table A.2. Digital Taxonomy by Indicator



Source: Calvino et al. (2018)

Table A.3. Mark-ups by Industry (ISIC Rev. 4 2 Digit Level)

ISIC Industry	2 Digit Code	Digital Dummy	Mean Mark-up
Food, beverages and tobacco	10	0	1.18
Textiles, wearing apparel, leather	13	0	1.54
Wood and paper products, and printing	16	1	1.22
Chemicals and chemical products	20	0	1.16
Basic pharmaceutical products	21	0	1.30
Rubber and plastics products	22	0	1.20
Basic and fabricated metals	24	0	1.24
Computer, electronic and optical products	26	1	1.24
Electrical equipment	27	1	1.20
Machinery and equipment	28	1	1.24
Transport equipment	29	1	1.16
Furniture, other manufacturing, repair	31	1	1.28
Wholesale and retail trade	45	1	1.11
Transportation and storage	49	0	1.46
Accommodation and food service activities	55	0	1.50
Publishing, audio-visual and broadcasting	58	1	1.39
Telecommunications	61	1	1.40
IT and other information services	62	1	1.74
Legal, accounting, consultancy, etc.	69	1	1.60
Scientific research and development	72	1	1.70
Advertising, market research and other prof.	73	1	1.57
Administrative and support service activities	77	1	2.46

Source: authors' estimates based on Orbis® data

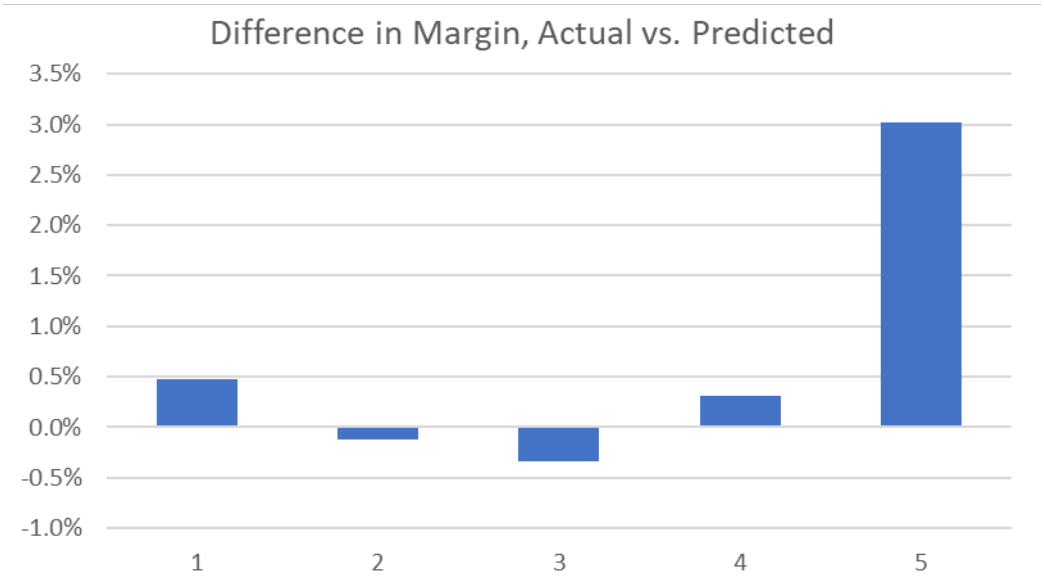
Table A.4. Scaling Relationships

Base 10

Scaling Relationships (Base 10)					
Size Category	1	2	3	4	5
Max Firm Size	99	999	9,999	99,999	-
Number of Observations	1,819,923	615,755	49,041	3,408	53
Margin	5.9%	5.8%	6.0%	7.0%	10.0%
Predicted Margin	5.4%	5.9%	6.4%	6.7%	7.0%
Difference	0.5%	-0.1%	-0.3%	0.3%	3.0%

Average Margin for Each Size Group by Economic Cycle					
Size Category	1	2	3	4	5
Av. Margin for Cycle 1	6.2%	6.0%	6.1%	6.9%	9.1%
Av. Margin for Cycle 2	5.5%	5.5%	5.7%	6.8%	10.8%
Diff. vs. predicited Cycle 1	*0.7%*	*0.2%*	*-0.1%*	*0.5%*	*2.5%*
Diff. vs. predicited Cycle 2	*0.1%*	*-0.5%*	*-0.7%*	*0.0%*	*3.7%*

Source: authors' estimates based on Orbis® data



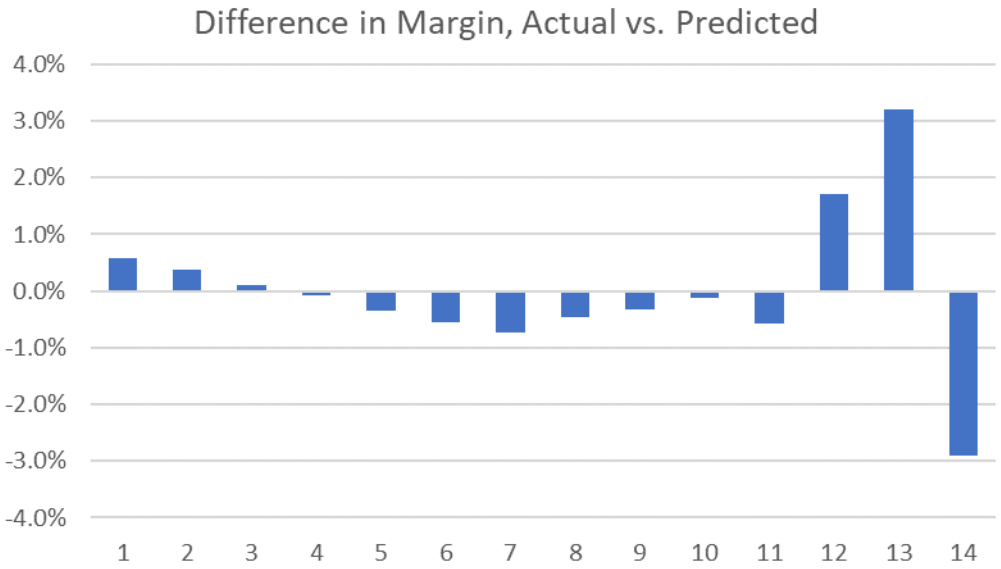
Source: authors' estimates based on Orbis® data

Base 2

Scaling Relationships (Base 2)														
Size Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Max Firm Size	63	127	255	511	1,023	2,047	4,095	8,191	16,383	32767	65,535	131,071	262,143	-
Number of Observations	599,657	874,499	487,559	273,677	137,031	64,830	28,199	12,392	5,780	4,086	355	124	38	3
Margin	5.9%	5.9%	5.8%	5.9%	5.8%	5.8%	5.8%	6.3%	6.6%	7.0%	6.7%	9.3%	10.9%	5.0%
Predicted Margin	5.3%	5.5%	5.7%	5.9%	6.1%	6.3%	6.5%	6.7%	6.9%	7.1%	7.3%	7.5%	7.7%	7.9%
Difference	0.6%	0.4%	0.1%	-0.1%	-0.3%	-0.6%	-0.7%	-0.5%	-0.3%	-0.1%	-0.6%	1.7%	3.2%	-2.9%

Average Margin for Each Size Group by Economic Cycle														
Size Category	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Av. Margin for Cycle 1	6.3%	6.1%	6.1%	6.1%	5.9%	5.9%	5.9%	6.4%	6.4%	6.8%	6.3%	12.0%	8.7%	8.4%
Av. Margin for Cycle 2	5.3%	5.5%	5.5%	5.5%	5.5%	5.5%	5.5%	5.9%	6.4%	6.8%	7.1%	8.4%	11.5%	-
Diff. vs. predicited Cycle 1	*1.0%*	*0.6%*	*0.3%*	*0.0%*	*-0.4%*	*-0.6%*	*-1.0%*	*-0.7%*	*-1.0%*	*-0.8%*	*-1.5%*	*3.9%*	*0.3%*	*-0.2%*
Diff. vs. predicited Cycle 2	*1.0%*	*0.8%*	*0.4%*	*0.1%*	*-0.3%*	*-0.7%*	*-1.0%*	*-0.9%*	*-0.9%*	*-0.7%*	*-0.9%*	*0.1%*	*2.9%*	-

Source: authors' estimates based on Orbis® data.



Note: Size category 14 consists of only 3 observations for 2 firms.
Source: authors' estimates based on Orbis® data.

Table A.5. Regression of Log Mark-up on Size Groups and Digital Dummies

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup
Log capital intensity (t-1)	0.003***	-0.002***	0.020***	0.016***	0.015***	0.014***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Log age (t-1)	-0.052***	-0.047***	-0.012***	-0.007***	-0.007***	-0.005***
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)
Log MFP (t-1)		-0.105***		-0.101***		-0.010***
		(0.001)		(0.001)		(0.001)
Size Group 2 Dummy (50 - 499 employees)	0.052***	0.106***	0.015***	0.060***	0.037***	0.040***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Size Group 3 Dummy (500 - 4,999 employees)	0.143***	0.270***	0.041***	0.148***	0.088***	0.099***
	(0.004)	(0.005)	(0.002)	(0.003)	(0.002)	(0.003)
Size Group 4 Dummy (5,000+ employees)	0.118***	0.269***	0.051***	0.200***	0.135***	0.145***
	(0.010)	(0.013)	(0.008)	(0.011)	(0.009)	(0.009)
Observations	1,694,732	1,186,510	1,694,694	1,186,471	1,641,317	1,140,887
R-squared	0.078	0.136	0.535	0.583	0.937	0.946
Country-Year FE	YES	YES	YES	YES	YES	YES
Industry-Year FE	NO	NO	YES	YES	NO	NO
Firm FE	NO	NO	NO	NO	YES	YES
Cluster	id	id	id	id	id	id

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Regressions with Errors Clustered at the Industry-Year Level

	(7)	(8)	(9)	(10)	(11)	(12)
Dependent Variable	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup
Log capital intensity (t-1)	0.003	-0.002	0.020***	0.016***	0.015***	0.014***
	(0.005)	(0.005)	(0.002)	(0.002)	(0.001)	(0.001)
Log age (t-1)	-0.052***	-0.047***	-0.012***	-0.007***	-0.007***	-0.005***
	(0.004)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
Log MFP (t-1)		-0.105***		-0.101***		-0.010***
		(0.014)		(0.006)		(0.002)
Size Group 2 Dummy (50 - 499 employees)	0.052***	0.106***	0.015***	0.060***	0.037***	0.040***
	(0.007)	(0.011)	(0.003)	(0.004)	(0.002)	(0.003)
Size Group 3 Dummy (500 - 4,999 employees)	0.143***	0.270***	0.041***	0.148***	0.088***	0.099***
	(0.017)	(0.027)	(0.007)	(0.012)	(0.007)	(0.008)
Size Group 4 Dummy (5,000+ employees)	0.118***	0.269***	0.051***	0.200***	0.135***	0.145***
	(0.023)	(0.032)	(0.011)	(0.017)	(0.012)	(0.013)
Observations	1,694,732	1,186,510	1,694,694	1,186,471	1,641,317	1,140,887
R-squared	0.078	0.136	0.535	0.583	0.937	0.946
Country-Year FE	YES	YES	YES	YES	YES	YES
Industry-Year FE	NO	NO	YES	YES	NO	NO
Firm FE	NO	NO	NO	NO	YES	YES
Cluster	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the industry-year level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Table A.6. Regression of Log MFP on Size Groups and Digital Dummies

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP
Log capital intensity (t-1)	-0.043***	-0.038***	-0.034***	-0.010***	-0.017***	-0.012***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log age (t-1)	0.107***	0.076***	0.043***	0.031***	0.108***	0.110***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)	(0.003)
Log Markup (t-1)		-0.595***		-0.565***		-0.121***
		(0.006)		(0.005)		(0.006)
Size Group 2 Dummy (50 - 499 employees)	0.334***	0.382***	0.353***	0.385***	0.024***	0.025***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Size Group 3 Dummy (500 - 4,999 employees)	0.743***	0.875***	0.829***	0.913***	0.088***	0.093***
	(0.008)	(0.009)	(0.006)	(0.006)	(0.007)	(0.007)
Size Group 4 Dummy (5,000+ employees)	1.235***	1.339***	1.253***	1.361***	0.222***	0.228***
	(0.027)	(0.030)	(0.022)	(0.023)	(0.032)	(0.037)
Observations	1,461,464	1,212,004	1,461,443	1,211,978	1,414,245	1,165,445
R-squared	0.291	0.344	0.665	0.700	0.916	0.922
Country-Year FE	YES	YES	YES	YES	YES	YES
Industry-Year FE	NO	NO	YES	YES	NO	NO
Firm FE	NO	NO	NO	NO	YES	YES
Cluster	id	id	id	id	id	id

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Regressions with Errors Clustered at the Industry-Year Level

	(7)	(8)	(9)	(10)	(11)	(12)
Dependent Variable	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP
Log capital intensity (t-1)	-0.043***	-0.038***	-0.034***	-0.010***	-0.017***	-0.012***
	(0.011)	(0.011)	(0.003)	(0.004)	(0.002)	(0.002)
Log age (t-1)	0.107***	0.076***	0.043***	0.031***	0.108***	0.110***
	(0.010)	(0.009)	(0.004)	(0.003)	(0.009)	(0.010)
Log Markup (t-1)		-0.595***		-0.565***		-0.121***
		(0.081)		(0.029)		(0.021)
Size Group 2 Dummy (50 - 499 employees)	0.334***	0.382***	0.353***	0.385***	0.024***	0.025***
	(0.016)	(0.013)	(0.009)	(0.008)	(0.006)	(0.006)
Size Group 3 Dummy (500 - 4,999 employees)	0.743***	0.875***	0.829***	0.913***	0.088***	0.093***
	(0.049)	(0.039)	(0.019)	(0.020)	(0.012)	(0.011)
Size Group 4 Dummy (5,000+ employees)	1.235***	1.339***	1.253***	1.361***	0.222***	0.228***
	(0.103)	(0.103)	(0.036)	(0.036)	(0.030)	(0.035)
Observations	1,461,464	1,212,004	1,461,443	1,211,978	1,414,245	1,165,445
R-squared	0.291	0.344	0.665	0.700	0.916	0.922
Country-Year FE	YES	YES	YES	YES	YES	YES
Industry-Year FE	NO	NO	YES	YES	NO	NO
Firm FE	NO	NO	NO	NO	YES	YES
Cluster	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the industry-year level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Table A.7. Regression of Log Mark-up on Size Groups Split by Cycle

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dependent Variable	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup
Cycle	1	2	1	2	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	0.008***	0.001*	0.003***	-0.005***	0.022***	0.019***	0.018***	0.015***	0.012***	0.010***	0.010***	0.009***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
Log age (t-1)	-0.045***	-0.057***	-0.040***	-0.050***	-0.009***	-0.014***	-0.005***	-0.008***	-0.005***	-0.005***	-0.004***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Log MFP (t-1)			-0.124***	-0.096***			-0.102***	-0.101***			-0.025***	-0.013***
			(0.001)	(0.001)			(0.001)	(0.001)			(0.001)	(0.001)
Size Group 2 Dummy (50 - 499 employees)	0.046***	0.056***	0.112***	0.103***	0.012***	0.017***	0.059***	0.061***	0.046***	0.034***	0.050***	0.036***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Size Group 3 Dummy (500 - 4,999 employees)	0.130***	0.151***	0.262***	0.272***	0.037***	0.044***	0.137***	0.154***	0.102***	0.078***	0.115***	0.087***
	(0.004)	(0.004)	(0.006)	(0.005)	(0.003)	(0.003)	(0.005)	(0.004)	(0.004)	(0.003)	(0.006)	(0.004)
Size Group 4 Dummy (5,000+ employees)	0.100***	0.129***	0.238***	0.291***	0.040***	0.058***	0.181***	0.212***	0.147***	0.115***	0.158***	0.120***
	(0.013)	(0.012)	(0.018)	(0.016)	(0.010)	(0.010)	(0.013)	(0.014)	(0.012)	(0.013)	(0.014)	(0.011)
Observations	703,689	991,043	397,101	789,409	703,666	991,028	397,083	789,388	653,839	940,601	363,288	743,364
R-squared	0.060	0.084	0.149	0.130	0.528	0.537	0.592	0.577	0.951	0.957	0.963	0.961
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Industry-Year FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Firm FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	id	id	id	id	id	id	id	id	id	id	id	id

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. Cycle 1 runs from 2001 – 2007, and Cycle 2 runs from 2008 – 2014. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Regressions with Errors Clustered at the Industry-Year Level

	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Dependent Variable	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup
Cycle	1	2	1	2	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	0.008	0.001	0.003	-0.005	0.022***	0.019***	0.018***	0.015***	0.012***	0.010***	0.010***	0.009***
	(0.008)	(0.006)	(0.010)	(0.007)	(0.002)	(0.002)	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Log age (t-1)	-0.045***	-0.057***	-0.040***	-0.050***	-0.009***	-0.014***	-0.005***	-0.008***	-0.005**	-0.005***	-0.004	-0.003
	(0.005)	(0.005)	(0.007)	(0.005)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
Log MFP (t-1)			-0.124***	-0.096***			-0.102***	-0.101***			-0.025***	-0.013***
			(0.024)	(0.017)			(0.009)	(0.008)			(0.005)	(0.003)
Size Group 2 Dummy (50 - 499 employees)	0.046***	0.056***	0.112***	0.103***	0.012***	0.017***	0.059***	0.061***	0.046***	0.034***	0.050***	0.036***
	(0.011)	(0.009)	(0.020)	(0.013)	(0.004)	(0.003)	(0.007)	(0.005)	(0.004)	(0.003)	(0.007)	(0.004)
Size Group 3 Dummy (500 - 4,999 employees)	0.130***	0.151***	0.262***	0.272***	0.037***	0.044***	0.137***	0.154***	0.102***	0.078***	0.115***	0.087***
	(0.027)	(0.023)	(0.046)	(0.034)	(0.010)	(0.009)	(0.019)	(0.016)	(0.014)	(0.009)	(0.016)	(0.010)
Size Group 4 Dummy (5,000+ employees)	0.100***	0.129***	0.238***	0.291***	0.040**	0.058***	0.181***	0.212***	0.147***	0.115***	0.158***	0.120***
	(0.033)	(0.031)	(0.049)	(0.041)	(0.018)	(0.013)	(0.028)	(0.021)	(0.019)	(0.021)	(0.020)	(0.018)
Observations	703,689	991,043	397,101	789,409	703,666	991,028	397,083	789,388	653,839	940,601	363,288	743,364
R-squared	0.060	0.084	0.149	0.130	0.528	0.537	0.592	0.577	0.951	0.957	0.963	0.961
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Industry-Year FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Firm FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the industry-year level. ***p<0.01 **p<0.05, *p<0.10
Source: authors' estimates based on Orbis® data.

Table A.8. Regression of Log MFP on Size Groups Split by Cycle

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Dependent Variable	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP
Cycle	1	2	1	2	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	-0.031***	-0.048***	-0.026***	-0.042***	-0.020***	-0.041***	0.006***	-0.016***	0.001	-0.013***	0.009***	-0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log age (t-1)	0.123***	0.097***	0.093***	0.068***	0.038***	0.047***	0.030***	0.031***	0.055***	0.054***	0.057***	0.050***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)	(0.002)	(0.004)	(0.002)
Log Markup (t-1)			-0.713***	-0.540***			-0.526***	-0.584***			-0.165***	-0.145***
			(0.008)	(0.006)			(0.007)	(0.006)			(0.008)	(0.005)
Size Group 2 Dummy (50 - 499 employees)	0.304***	0.350***	0.359***	0.394***	0.342***	0.359***	0.369***	0.392***	-0.035***	0.019***	-0.047***	0.024***
	(0.004)	(0.003)	(0.004)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
Size Group 3 Dummy (500 - 4,999 employees)	0.566***	0.839***	0.713***	0.950***	0.782***	0.853***	0.846***	0.944***	-0.050***	0.036***	-0.081***	0.054***
	(0.011)	(0.009)	(0.012)	(0.010)	(0.007)	(0.006)	(0.008)	(0.006)	(0.008)	(0.007)	(0.009)	(0.007)
Size Group 4 Dummy (5,000+ employees)	0.961***	1.437***	1.047***	1.534***	1.275***	1.230***	1.361***	1.353***	-0.086***	0.069***	-0.113***	0.094***
	(0.036)	(0.033)	(0.042)	(0.037)	(0.029)	(0.025)	(0.033)	(0.027)	(0.031)	(0.022)	(0.031)	(0.024)
Observations	530,873	930,591	397,155	814,849	530,860	930,583	397,143	814,835	493,984	885,779	363,170	769,479
R-squared	0.164	0.311	0.250	0.348	0.646	0.656	0.677	0.693	0.961	0.961	0.966	0.963
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Industry-Year FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Firm FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	id	id	id	id	id	id	id	id	id	id	id	id

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. Cycle 1 runs from 2001 – 2007, and Cycle 2 runs from 2008 – 2014. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Dependent Variable	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP
Cycle	1	2	1	2	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	-0.031	-0.048***	-0.026	-0.042***	-0.020***	-0.041***	0.006	-0.016***	0.001	-0.013***	0.009***	-0.007***
	(0.020)	(0.012)	(0.022)	(0.013)	(0.005)	(0.004)	(0.006)	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)
Log age (t-1)	0.123***	0.097***	0.093***	0.068***	0.038***	0.047***	0.030***	0.031***	0.055***	0.054***	0.057***	0.050***
	(0.016)	(0.013)	(0.013)	(0.011)	(0.005)	(0.005)	(0.005)	(0.004)	(0.006)	(0.006)	(0.007)	(0.006)
Log Markup (t-1)			-0.713***	-0.540***			-0.526***	-0.584***			-0.165***	-0.145***
			(0.142)	(0.098)			(0.041)	(0.038)			(0.030)	(0.025)
Size Group 2 Dummy (50 - 499 employees)	0.304***	0.350***	0.359***	0.394***	0.342***	0.359***	0.369***	0.392***	-0.035***	0.019***	-0.047***	0.024***
	(0.026)	(0.020)	(0.021)	(0.017)	(0.012)	(0.012)	(0.011)	(0.011)	(0.011)	(0.006)	(0.012)	(0.006)
Size Group 3 Dummy (500 - 4,999 employees)	0.566***	0.839***	0.713***	0.950***	0.782***	0.853***	0.846***	0.944***	-0.050**	0.036**	-0.081***	0.054***
	(0.065)	(0.059)	(0.062)	(0.044)	(0.026)	(0.027)	(0.026)	(0.027)	(0.023)	(0.014)	(0.025)	(0.013)
Size Group 4 Dummy (5,000+ employees)	0.961***	1.437***	1.047***	1.534***	1.275***	1.230***	1.361***	1.353***	-0.086	0.069**	-0.113**	0.094***
	(0.117)	(0.085)	(0.117)	(0.084)	(0.064)	(0.043)	(0.064)	(0.046)	(0.057)	(0.027)	(0.046)	(0.027)
Observations	530,873	930,591	397,155	814,849	530,860	930,583	397,143	814,835	493,984	885,779	363,170	769,479
R-squared	0.164	0.311	0.250	0.348	0.646	0.656	0.677	0.693	0.961	0.961	0.966	0.963
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Industry-Year FE	NO	NO	NO	NO	YES	YES	YES	YES	NO	NO	NO	NO
Firm FE	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind

Regressions with Errors Clustered at the Industry-Year Level

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the industry-year level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Table A.9. Regression of Log Mark-up on Size Group and Digitalisation Dummies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	0.010***	0.003***	-0.000	-0.001	0.012***	0.010***	0.010***	0.009***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
Log age (t-1)	-0.045***	-0.056***	-0.040***	-0.049***	-0.006***	-0.005***	-0.005***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Log MFP (t-1)			-0.125***	-0.096***			-0.025***	-0.013***
			(0.001)	(0.001)			(0.001)	(0.001)
Size Group 2 Dummy (50 - 499 employees)	0.007***	0.020***	0.077***	0.070***	0.036***	0.020***	0.038***	0.021***
	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Digital Dummy (Size Group 1)	-0.020***	-0.010***	-0.050***	0.006***	0.114***	0.051	0.186***	0.064
	(0.002)	(0.001)	(0.002)	(0.002)	(0.025)	(0.112)	(0.034)	(0.124)
Size Group 2 x Digital Dummy	0.062***	0.057***	0.053***	0.057***	0.015***	0.022***	0.018***	0.025***
	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Size Group 3 Dummy (500 - 4,999 employees)	0.070***	0.103***	0.233***	0.237***	0.065***	0.045***	0.073***	0.050***
	(0.005)	(0.005)	(0.007)	(0.006)	(0.003)	(0.003)	(0.005)	(0.004)
Size Group 3 x Digital Dummy	0.086***	0.068***	0.046***	0.048***	0.054***	0.049***	0.058***	0.057***
	(0.007)	(0.007)	(0.010)	(0.008)	(0.006)	(0.005)	(0.009)	(0.006)
Size Group 4 Dummy (5,000+ employees)	0.151***	0.171***	0.450***	0.376***	0.075***	0.058***	0.065***	0.072***
	(0.016)	(0.019)	(0.034)	(0.040)	(0.013)	(0.015)	(0.020)	(0.024)
Size Group 4 x Digital Dummy	-0.059***	-0.051**	-0.217***	-0.099**	0.094***	0.076***	0.111***	0.068**
	(0.021)	(0.023)	(0.038)	(0.043)	(0.020)	(0.022)	(0.025)	(0.027)
Observations	703,689	991,043	397,101	789,409	653,839	940,601	363,288	743,364
R-squared	0.064	0.087	0.153	0.135	0.951	0.957	0.963	0.961
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	id	id	id	id	id	id	id	id

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10
Source: authors' estimates based on Orbis® data.

Regressions with Errors Clustered at the Industry-Year Level

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Dependent Variable	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	0.010	0.003	-0.000	-0.001	0.012***	0.010***	0.010***	0.009***
	(0.007)	(0.005)	(0.009)	(0.006)	(0.001)	(0.001)	(0.001)	(0.001)
Log age (t-1)	-0.045***	-0.056***	-0.040***	-0.049***	-0.006***	-0.005***	-0.005	-0.003*
	(0.005)	(0.005)	(0.007)	(0.005)	(0.002)	(0.002)	(0.003)	(0.002)
Log MFP (t-1)			-0.125***	-0.096***			-0.025***	-0.013***
			(0.023)	(0.017)			(0.005)	(0.003)
Size Group 2 Dummy (50 - 499 employees)	0.007	0.020*	0.077***	0.070***	0.036***	0.020***	0.038***	0.021***
	(0.010)	(0.011)	(0.020)	(0.016)	(0.005)	(0.003)	(0.008)	(0.003)
Digital Dummy (Size Group 1)	-0.020	-0.010	-0.050*	0.006	0.114***	0.051	0.186**	0.064
	(0.021)	(0.021)	(0.030)	(0.027)	(0.044)	(0.092)	(0.074)	(0.102)
Size Group 2 x Digital Dummy	0.062***	0.057***	0.053***	0.057***	0.015*	0.022***	0.018	0.025***
	(0.013)	(0.013)	(0.019)	(0.017)	(0.008)	(0.005)	(0.012)	(0.006)
Size Group 3 Dummy (500 - 4,999 employees)	0.070**	0.103***	0.233***	0.237***	0.065***	0.045***	0.073***	0.050***
	(0.027)	(0.026)	(0.047)	(0.035)	(0.009)	(0.006)	(0.015)	(0.007)
Size Group 3 x Digital Dummy	0.086**	0.068*	0.046	0.048	0.054**	0.049***	0.058**	0.057***
	(0.036)	(0.036)	(0.052)	(0.043)	(0.021)	(0.014)	(0.026)	(0.016)
Size Group 4 Dummy (5,000+ employees)	0.151***	0.171***	0.450***	0.376***	0.075***	0.058***	0.065**	0.072***
	(0.036)	(0.037)	(0.089)	(0.069)	(0.020)	(0.018)	(0.027)	(0.027)
Size Group 4 x Digital Dummy	-0.059	-0.051	-0.217***	-0.099	0.094***	0.076**	0.111***	0.068*
	(0.042)	(0.046)	(0.077)	(0.066)	(0.032)	(0.032)	(0.036)	(0.036)
Observations	703,689	991,043	397,101	789,409	653,839	940,601	363,288	743,364
R-squared	0.064	0.087	0.153	0.135	0.951	0.957	0.963	0.961
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the industry-year level. ***p<0.01 **p<0.05, *p<0.10
Source: authors' estimates based on Orbis® data.

Table A.10. Regression of Log MFP on Size Group and Digitalisation Dummies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	-0.048***	-0.038***	-0.045***	-0.026***	0.001	-0.013***	0.009***	-0.007***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log age (t-1)	0.119***	0.097***	0.089***	0.067***	0.055***	0.054***	0.057***	0.050***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.004)	(0.002)
Log Markup (t-1)			-0.706***	-0.544***			-0.165***	-0.145***
			(0.008)	(0.006)			(0.008)	(0.005)
Size Group 2 Dummy (50 - 499 employees)	0.407***	0.418***	0.451***	0.457***	-0.033***	0.025***	-0.045***	0.030***
	(0.007)	(0.005)	(0.007)	(0.005)	(0.004)	(0.003)	(0.004)	(0.003)
Digital Dummy (Size Group 1)	-0.093***	0.165***	-0.082***	0.204***		-1.444***		-1.482***
	(0.005)	(0.004)	(0.006)	(0.004)		(0.102)		(0.100)
Size Group 2 x Digital Dummy	-0.160***	-0.118***	-0.144***	-0.107***	-0.003	-0.010***	-0.002	-0.011***
	(0.008)	(0.006)	(0.008)	(0.006)	(0.005)	(0.004)	(0.005)	(0.004)
Size Group 3 Dummy (500 - 4,999 employees)	0.873***	1.063***	1.063***	1.201***	-0.030*	0.066***	-0.063***	0.072***
	(0.027)	(0.022)	(0.026)	(0.021)	(0.016)	(0.010)	(0.016)	(0.011)
Size Group 3 x Digital Dummy	-0.382***	-0.329***	-0.440***	-0.370***	-0.026	-0.044***	-0.025	-0.027**
	(0.029)	(0.024)	(0.028)	(0.024)	(0.018)	(0.013)	(0.019)	(0.013)
Size Group 4 Dummy (5,000+ employees)	2.298***	1.684***	2.394***	1.964***	0.051	0.060	-0.042	0.039
	(0.144)	(0.158)	(0.152)	(0.173)	(0.092)	(0.056)	(0.132)	(0.069)
Size Group 4 x Digital Dummy	-1.424***	-0.331**	-1.446***	-0.553***	-0.151	0.001	-0.080	0.057
	(0.147)	(0.161)	(0.156)	(0.176)	(0.098)	(0.061)	(0.136)	(0.074)
Observations	530,873	930,591	397,155	814,849	493,984	885,779	363,170	769,479
R-squared	0.179	0.316	0.263	0.355	0.961	0.961	0.966	0.963
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	id	id	id	id	id	id	id	id

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Regressions with Errors Clustered at the Industry-Year Level

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Dependent Variable	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	-0.048***	-0.038***	-0.045***	-0.026***	0.001	-0.013***	0.009***	-0.007***
	(0.014)	(0.009)	(0.016)	(0.010)	(0.002)	(0.002)	(0.002)	(0.002)
Log age (t-1)	0.119***	0.097***	0.089***	0.067***	0.055***	0.054***	0.057***	0.050***
	(0.017)	(0.012)	(0.013)	(0.011)	(0.006)	(0.006)	(0.007)	(0.006)
Log Markup (t-1)			-0.706***	-0.544***			-0.165***	-0.145***
			(0.139)	(0.101)			(0.030)	(0.025)
Size Group 2 Dummy (50 - 499 employees)	0.407***	0.418***	0.451***	0.457***	-0.033**	0.025***	-0.045***	0.030***
	(0.042)	(0.033)	(0.040)	(0.032)	(0.015)	(0.010)	(0.016)	(0.009)
Digital Dummy (Size Group 1)	-0.093	0.165**	-0.082	0.204***		-1.444***		-1.482***
	(0.133)	(0.076)	(0.130)	(0.078)		(0.086)		(0.084)
Size Group 2 x Digital Dummy	-0.160***	-0.118**	-0.144***	-0.107**	-0.003	-0.010	-0.002	-0.011
	(0.057)	(0.047)	(0.055)	(0.048)	(0.021)	(0.012)	(0.023)	(0.012)
Size Group 3 Dummy (500 - 4,999 employees)	0.873***	1.063***	1.063***	1.201***	-0.030	0.066***	-0.063	0.072***
	(0.166)	(0.122)	(0.137)	(0.110)	(0.034)	(0.019)	(0.039)	(0.019)
Size Group 3 x Digital Dummy	-0.382**	-0.329**	-0.440***	-0.370***	-0.026	-0.044*	-0.025	-0.027
	(0.192)	(0.152)	(0.167)	(0.138)	(0.044)	(0.026)	(0.050)	(0.025)
Size Group 4 Dummy (5,000+ employees)	2.298***	1.684***	2.394***	1.964***	0.051	0.060	-0.042	0.039
	(0.219)	(0.232)	(0.204)	(0.256)	(0.123)	(0.059)	(0.158)	(0.068)
Size Group 4 x Digital Dummy	-1.424***	-0.331	-1.446***	-0.553*	-0.151	0.001	-0.080	0.057
	(0.245)	(0.256)	(0.235)	(0.283)	(0.139)	(0.066)	(0.167)	(0.073)
Observations	530,873	930,591	397,155	814,849	493,984	885,779	363,170	769,479
R-squared	0.179	0.316	0.263	0.355	0.961	0.961	0.966	0.963
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the industry-year level. ***p<0.01 **p<0.05, *p<0.10
Source: authors' estimates based on Orbis® data.

Table A.11. Regression of Log Mark-up on Size Groups and Digital Quartile 3 / 4 Dummies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	0.011***	0.008***	0.004***	0.005***	0.012***	0.010***	0.010***	0.009***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
Log age (t-1)	-0.021***	-0.028***	-0.014***	-0.023***	-0.006***	-0.005***	-0.006***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Log MFP (t-1)			-0.068***	-0.051***			-0.024***	-0.013***
			(0.001)	(0.001)			(0.001)	(0.001)
Size Group 2 Dummy (50 - 499 employees)	0.009***	0.014***	0.047***	0.043***	0.038***	0.020***	0.038***	0.021***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Digital Quartile 3 Dummy	-0.093***	-0.097***	-0.131***	-0.106***	0.162***	0.038	0.260***	0.059
	(0.001)	(0.001)	(0.002)	(0.001)	(0.025)	(0.076)	(0.034)	(0.097)
Size Group 2 x Digital Quartile 3	0.019***	0.025***	0.008***	0.012***	-0.008***	0.000	-0.011***	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Size Group 3 Dummy (500 + employees)	0.072***	0.092***	0.165***	0.176***	0.067***	0.045***	0.075***	0.050***
	(0.004)	(0.005)	(0.007)	(0.006)	(0.003)	(0.003)	(0.006)	(0.004)
Size Group 3 x Digital Quartile 3	0.006	-0.009	-0.018**	-0.050***	-0.010**	-0.007*	-0.021***	-0.013***
	(0.005)	(0.005)	(0.008)	(0.007)	(0.004)	(0.004)	(0.007)	(0.005)
Size Group 4 Dummy (5,000+ employees)	0.145***	0.135***	0.298***	0.258***	0.079***	0.058***	0.068***	0.072***
	(0.015)	(0.019)	(0.033)	(0.039)	(0.013)	(0.015)	(0.020)	(0.024)
Size Group 4 x Digital Quartile 3	-0.082***	-0.071***	-0.092**	-0.100**	0.003	-0.015	0.003	-0.034
	(0.019)	(0.021)	(0.045)	(0.045)	(0.017)	(0.018)	(0.022)	(0.026)
Digital Quartile 4 Dummy	0.243***	0.262***	0.231***	0.271***		0.077		0.071
	(0.003)	(0.003)	(0.004)	(0.003)		(0.073)		(0.088)
Size Group 2 x Digital Quartile 4	0.035***	0.024***	0.043***	0.032***	0.059***	0.062***	0.070***	0.065***
	(0.004)	(0.004)	(0.005)	(0.004)	(0.003)	(0.003)	(0.004)	(0.003)
Size Group 3 x Digital Quartile 4	-0.054***	-0.077***	-0.093***	-0.090***	0.132***	0.118***	0.134***	0.118***
	(0.009)	(0.009)	(0.012)	(0.010)	(0.010)	(0.008)	(0.012)	(0.008)
Size Group 4 x Digital Quartile 4	-0.283***	-0.253***	-0.381***	-0.294***	0.174***	0.156***	0.188***	0.135***
	(0.023)	(0.025)	(0.038)	(0.043)	(0.022)	(0.026)	(0.027)	(0.029)
Observations	703,689	991,043	397,101	789,409	653,839	940,601	363,288	743,364
R-squared	0.254	0.279	0.338	0.325	0.951	0.958	0.963	0.961
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	id	id	id	id	id	id	id	id

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. There are two digital dummies, the first equal to one if the firm is in an industry in the third quartile of digitalisation, and the second equal to one for industries in the fourth quartile. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Regressions with Errors Clustered at the Industry-Year Level

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Dependent Variable	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	0.011**	0.008*	0.004	0.005	0.012***	0.010***	0.010***	0.009***
	(0.006)	(0.005)	(0.007)	(0.005)	(0.001)	(0.001)	(0.001)	(0.001)
Log age (t-1)	-0.021***	-0.028***	-0.014***	-0.023***	-0.006***	-0.005***	-0.006*	-0.004*
	(0.003)	(0.004)	(0.004)	(0.004)	(0.002)	(0.002)	(0.003)	(0.002)
Log MFP (t-1)			-0.068***	-0.051***			-0.024***	-0.013***
			(0.016)	(0.011)			(0.005)	(0.003)
Size Group 2 Dummy (50 - 499 employees)	0.009	0.014	0.047***	0.043***	0.038***	0.020***	0.038***	0.021***
	(0.008)	(0.009)	(0.016)	(0.013)	(0.004)	(0.003)	(0.008)	(0.003)
Digital Quartile 3 Dummy	-0.093***	-0.097***	-0.131***	-0.106***	0.162***	0.038	0.260***	0.059
	(0.014)	(0.016)	(0.023)	(0.018)	(0.035)	(0.073)	(0.071)	(0.091)
Size Group 2 x Digital Quartile 3	0.019**	0.025**	0.008	0.012	-0.008	0.000	-0.011	-0.001
	(0.008)	(0.011)	(0.013)	(0.012)	(0.005)	(0.003)	(0.008)	(0.004)
Size Group 3 Dummy (500 + employees)	0.072***	0.092***	0.165***	0.176***	0.067***	0.045***	0.075***	0.050***
	(0.020)	(0.024)	(0.040)	(0.030)	(0.008)	(0.006)	(0.015)	(0.007)
Size Group 3 x Digital Quartile 3	0.006	-0.009	-0.018	-0.050*	-0.010	-0.007	-0.021	-0.013
	(0.023)	(0.026)	(0.033)	(0.028)	(0.010)	(0.007)	(0.016)	(0.008)
Size Group 4 Dummy (5,000+ employees)	0.145***	0.135***	0.298***	0.258***	0.079***	0.058***	0.068**	0.072***
	(0.029)	(0.031)	(0.070)	(0.058)	(0.019)	(0.018)	(0.027)	(0.027)
Size Group 4 x Digital Quartile 3	-0.082**	-0.071*	-0.092	-0.100	0.003	-0.015	0.003	-0.034
	(0.035)	(0.039)	(0.073)	(0.064)	(0.022)	(0.021)	(0.029)	(0.029)
Digital Quartile 4 Dummy	0.243***	0.262***	0.231***	0.271***		0.077		0.071
	(0.029)	(0.026)	(0.029)	(0.022)		(0.058)		(0.068)
Size Group 2 x Digital Quartile 4	0.035	0.024	0.043	0.032	0.059***	0.062***	0.070***	0.065***
	(0.023)	(0.021)	(0.030)	(0.022)	(0.014)	(0.009)	(0.017)	(0.009)
Size Group 3 x Digital Quartile 4	-0.054	-0.077	-0.093	-0.090	0.132***	0.118***	0.134***	0.118***
	(0.051)	(0.057)	(0.065)	(0.063)	(0.037)	(0.022)	(0.035)	(0.022)
Size Group 4 x Digital Quartile 4	-0.283***	-0.253***	-0.381***	-0.294***	0.174***	0.156***	0.188***	0.135***
	(0.046)	(0.048)	(0.065)	(0.061)	(0.046)	(0.045)	(0.043)	(0.043)
Observations	703,689	991,043	397,101	789,409	653,839	940,601	363,288	743,364
R-squared	0.254	0.279	0.338	0.325	0.951	0.958	0.963	0.961
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. There are two digital dummies, the first equal to one if the firm is in an industry in the third quartile of digitalisation, and the second equal to one for industries in the fourth quartile. All controls at t-1. Errors clustered at the industry-year level. ***p<0.01 **p<0.05, *p<0.10.

Source: authors' estimates based on Orbis® data.

Table A.12. Regression of Log MFP on Size Groups and Digital Quartile 3 / 4 Dummies

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	-0.051***	-0.043***	-0.046***	-0.031***	0.001	-0.013***	0.009***	-0.007***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log age (t-1)	0.074***	0.065***	0.070***	0.054***	0.055***	0.054***	0.058***	0.050***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.004)	(0.002)
Log Markup (t-1)			-0.479***	-0.358***			-0.165***	-0.145***
			(0.009)	(0.007)			(0.008)	(0.005)
Size Group 2 Dummy (50 - 499 employees)	0.407***	0.424***	0.446***	0.458***	-0.033***	0.025***	-0.046***	0.030***
	(0.007)	(0.005)	(0.007)	(0.005)	(0.004)	(0.003)	(0.004)	(0.003)
Digital Quartile 3 Dummy	0.038***	0.284***	0.016***	0.291***		-0.984***		-1.044***
	(0.006)	(0.005)	(0.006)	(0.005)		(0.256)		(0.243)
Size Group 2 x Digital Quartile 3	-0.078***	-0.066***	-0.107***	-0.079***	0.007	0.004	0.009	0.001
	(0.009)	(0.007)	(0.009)	(0.007)	(0.005)	(0.004)	(0.006)	(0.004)
Size Group 3 Dummy (500 - 4,999 employees)	0.864***	1.067***	1.028***	1.183***	-0.030*	0.066***	-0.061***	0.072***
	(0.027)	(0.022)	(0.026)	(0.022)	(0.015)	(0.010)	(0.015)	(0.011)
Size Group 3 x Digital Quartile 3	-0.215***	-0.390***	-0.348***	-0.455***	0.006	0.008	0.010	0.004
	(0.032)	(0.028)	(0.032)	(0.028)	(0.019)	(0.015)	(0.019)	(0.016)
Size Group 4 Dummy (5,000+ employees)	2.286***	1.679***	2.367***	1.923***	0.052	0.060	-0.040	0.040
	(0.140)	(0.158)	(0.148)	(0.173)	(0.092)	(0.056)	(0.132)	(0.070)
Size Group 4 x Digital Quartile 3	-1.608***	-1.047***	-1.606***	-1.281***	-0.356*	0.054	-0.130	0.151*
	(0.195)	(0.187)	(0.227)	(0.205)	(0.203)	(0.089)	(0.185)	(0.079)
Digital Quartile 4 Dummy	-0.479***	-0.133***	-0.336***	-0.023***		-1.765***		-1.698***
	(0.007)	(0.005)	(0.008)	(0.006)		(0.218)		(0.158)
Size Group 2 x Digital Quartile 4	-0.105***	-0.074***	-0.116***	-0.090***	-0.023***	-0.031***	-0.022***	-0.030***
	(0.010)	(0.007)	(0.010)	(0.007)	(0.006)	(0.005)	(0.007)	(0.005)
Size Group 3 x Digital Quartile 4	-0.114***	-0.076***	-0.266***	-0.184***	-0.058***	-0.083***	-0.061***	-0.056***
	(0.029)	(0.025)	(0.029)	(0.025)	(0.020)	(0.015)	(0.021)	(0.015)
Size Group 4 x Digital Quartile 4	-1.036***	0.019	-1.177***	-0.249	-0.173*	-0.038	-0.111	0.017
	(0.143)	(0.161)	(0.152)	(0.176)	(0.098)	(0.062)	(0.136)	(0.076)
Observations	530,873	930,591	397,155	814,849	493,984	885,779	363,170	769,479
R-squared	0.239	0.345	0.282	0.368	0.961	0.961	0.966	0.963
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	id	id	id	id	id	id	id	id

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. There are two digital dummies, the first equal to one if the firm is in an industry in the third quartile of digitalisation, and the second equal to one for industries in the fourth quartile. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.1.
Source: authors' estimates based on Orbis® data.

Regressions with Errors Clustered at the Industry-Year Level

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Dependent Variable	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	-0.051***	-0.043***	-0.046***	-0.031***	0.001	-0.013***	0.009***	-0.007***
	(0.013)	(0.009)	(0.015)	(0.010)	(0.002)	(0.002)	(0.002)	(0.002)
Log age (t-1)	0.074***	0.065***	0.070***	0.054***	0.055***	0.054***	0.058***	0.050***
	(0.012)	(0.010)	(0.013)	(0.012)	(0.006)	(0.006)	(0.007)	(0.006)
Log Markup (t-1)			-0.479***	-0.358***			-0.165***	-0.145***
			(0.109)	(0.080)			(0.030)	(0.025)
Size Group 2 Dummy (50 - 499 employees)	0.407***	0.424***	0.446***	0.458***	-0.033**	0.025***	-0.046***	0.030***
	(0.039)	(0.032)	(0.039)	(0.032)	(0.015)	(0.010)	(0.016)	(0.009)
Digital Quartile 3 Dummy	0.038	0.284***	0.016	0.291***		-0.984***		-1.044***
	(0.147)	(0.092)	(0.150)	(0.096)		(0.218)		(0.230)
Size Group 2 x Digital Quartile 3	-0.078	-0.066	-0.107	-0.079	0.007	0.004	0.009	0.001
	(0.064)	(0.061)	(0.065)	(0.061)	(0.024)	(0.014)	(0.026)	(0.013)
Size Group 3 Dummy (500 - 4,999 employees)	0.864***	1.067***	1.028***	1.183***	-0.030	0.066***	-0.061	0.072***
	(0.156)	(0.122)	(0.133)	(0.112)	(0.033)	(0.019)	(0.037)	(0.019)
Size Group 3 x Digital Quartile 3	-0.215	-0.390**	-0.348*	-0.455**	0.006	0.008	0.010	0.004
	(0.225)	(0.183)	(0.205)	(0.180)	(0.050)	(0.027)	(0.055)	(0.026)
Size Group 4 Dummy (5,000+ employees)	2.286***	1.679***	2.367***	1.923***	0.052	0.060	-0.040	0.040
	(0.204)	(0.229)	(0.195)	(0.255)	(0.122)	(0.059)	(0.158)	(0.068)
Size Group 4 x Digital Quartile 3	-1.608***	-1.047***	-1.606***	-1.281***	-0.356*	0.054	-0.130	0.151*
	(0.398)	(0.294)	(0.419)	(0.323)	(0.196)	(0.109)	(0.166)	(0.077)
Digital Quartile 4 Dummy	-0.479***	-0.133*	-0.336***	-0.023		-1.765***		-1.698***
	(0.101)	(0.070)	(0.095)	(0.063)		(0.186)		(0.117)
Size Group 2 x Digital Quartile 4	-0.105**	-0.074	-0.116**	-0.090**	-0.023	-0.031**	-0.022	-0.030*
	(0.046)	(0.046)	(0.046)	(0.042)	(0.025)	(0.016)	(0.028)	(0.016)
Size Group 3 x Digital Quartile 4	-0.114	-0.076	-0.266*	-0.184	-0.058	-0.083***	-0.061	-0.056*
	(0.168)	(0.154)	(0.145)	(0.135)	(0.050)	(0.032)	(0.057)	(0.031)
Size Group 4 x Digital Quartile 4	-1.036***	0.019	-1.177***	-0.249	-0.173	-0.038	-0.111	0.017
	(0.220)	(0.246)	(0.206)	(0.269)	(0.143)	(0.068)	(0.170)	(0.076)
Observations	530,873	930,591	397,155	814,849	493,984	885,779	363,170	769,479
R-squared	0.239	0.345	0.282	0.368	0.961	0.961	0.966	0.963
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. There are two digital dummies, the first equal to one if the firm is in an industry in the third quartile of digitalisation, and the second equal to one for industries in the fourth quartile. All controls at t-1. Errors clustered at the industry-year level. ***p<0.01 **p<0.05, *p<0.10

Source: authors' estimates based on Orbis® data

Table A.13. Regression of Log Mark-up on Size Groups, Digitalisation and Manufacturing / Services

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	0.012***	0.004***	0.002***	-0.002***	0.012***	0.010***	0.010***	0.009***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
Log age (t-1)	-0.038***	-0.049***	-0.037***	-0.046***	-0.006***	-0.005***	-0.005***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Log MFP (t-1)			-0.115***	-0.089***			-0.025***	-0.013***
			(0.001)	(0.001)			(0.001)	(0.001)
Size Group 2 Dummy (50 - 499 employees)	-0.001	0.007***	0.067***	0.058***	0.030***	0.013***	0.027***	0.013***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Manufacuring Digital Dummy	-0.002	0.011***	-0.055***	0.059***	0.155***	-0.128**	0.313***	-0.182***
	(0.001)	(0.001)	(0.003)	(0.002)	(0.027)	(0.064)	(0.036)	(0.045)
Size Group 2 x Digital Manufacuring	0.024***	0.015***	0.008**	-0.003	0.008***	0.006***	0.013***	0.001
	(0.002)	(0.002)	(0.004)	(0.003)	(0.002)	(0.002)	(0.004)	(0.002)
Less Digital Services Dummy	0.134***	0.104***	0.075***	0.088***		-0.362***		-0.435***
	(0.002)	(0.002)	(0.003)	(0.002)		(0.062)		(0.040)
Size Group 2 x Less Digital Services	0.048***	0.054***	0.022***	0.034***	0.019***	0.021***	0.022***	0.021***
	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)
More Digital Services Dummy	0.041***	0.034***	-0.003	0.034***	0.043*	-0.153**	0.097***	-0.215***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.026)	(0.062)	(0.036)	(0.040)
Size Group 2 x More Digital Services	0.096***	0.095***	0.069***	0.076***	0.027***	0.037***	0.030***	0.037***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Size Group 3 Dummy (500 - 4,999 employees)	0.056***	0.056***	0.237***	0.199***	0.052***	0.020***	0.052***	0.019***
	(0.004)	(0.004)	(0.006)	(0.005)	(0.003)	(0.003)	(0.005)	(0.004)
Size Group 3 x Digital Manufacuring	0.016***	-0.014***	-0.040***	-0.106***	0.011**	0.011**	-0.009	-0.008
	(0.006)	(0.005)	(0.011)	(0.013)	(0.005)	(0.005)	(0.011)	(0.011)
Size Group 3 x Less Digital Services	0.046***	0.101***	-0.021	0.053***	0.042***	0.061***	0.044***	0.069***
	(0.011)	(0.010)	(0.015)	(0.011)	(0.009)	(0.007)	(0.012)	(0.008)
Size Group 3 x More Digital Services	0.122***	0.143***	0.039***	0.090***	0.085***	0.093***	0.086***	0.094***
	(0.008)	(0.007)	(0.010)	(0.008)	(0.007)	(0.006)	(0.009)	(0.006)
Size Group 4 Dummy (5,000+ employees)	0.163***	0.105***	0.467***	0.283***	0.047***	0.001	0.041*	0.014
	(0.018)	(0.018)	(0.037)	(0.037)	(0.015)	(0.011)	(0.022)	(0.016)
Size Group 4 x Digital Manufacuring	-0.094***	-0.044	-0.115	-0.038	0.044	0.046**	0.001	0.026
	(0.034)	(0.035)	(0.101)	(0.091)	(0.033)	(0.019)	(0.024)	(0.022)
Size Group 4 x Less Digital Services	-0.062**	0.072**	-0.090	0.143*	0.092***	0.121***	0.068***	0.115***
	(0.031)	(0.034)	(0.074)	(0.073)	(0.023)	(0.028)	(0.025)	(0.042)
Size Group 4 x More Digital Services	-0.079***	0.012	-0.250***	-0.012	0.141***	0.155***	0.143***	0.132***
	(0.024)	(0.023)	(0.041)	(0.040)	(0.022)	(0.020)	(0.027)	(0.021)
Observations	703,689	991,043	397,101	789,409	653,839	940,601	363,288	743,364
R-squared	0.106	0.115	0.164	0.147	0.951	0.957	0.963	0.961
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	id	id	id	id	id	id	id	id

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is split by manufacturing / services, with less digital intensive manufacturing designated as the base category. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Regressions with Errors Clustered at the Industry-Year Level

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Dependent Variable	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup	Log Markup
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	0.012**	0.004	0.002	-0.002	0.012***	0.010***	0.010***	0.009***
	(0.006)	(0.004)	(0.008)	(0.005)	(0.001)	(0.001)	(0.001)	(0.001)
Log age (t-1)	-0.038***	-0.049***	-0.037***	-0.046***	-0.006***	-0.005***	-0.005	-0.003*
	(0.005)	(0.005)	(0.006)	(0.005)	(0.002)	(0.002)	(0.003)	(0.002)
Log MFP (t-1)			-0.115***	-0.089***			-0.025***	-0.013***
			(0.026)	(0.017)			(0.005)	(0.003)
Size Group 2 Dummy (50 - 499 employees)	-0.001	0.007	0.067***	0.058***	0.030***	0.013***	0.027***	0.013***
	(0.010)	(0.010)	(0.021)	(0.017)	(0.004)	(0.002)	(0.004)	(0.003)
Manufacuring Digital Dummy	-0.002	0.011	-0.055**	0.059***	0.155***	-0.128*	0.313***	-0.182***
	(0.011)	(0.013)	(0.023)	(0.017)	(0.031)	(0.069)	(0.053)	(0.033)
Size Group 2 x Digital Manufacuring	0.024***	0.015	0.008	-0.003	0.008	0.006*	0.013*	0.001
	(0.009)	(0.010)	(0.014)	(0.014)	(0.006)	(0.003)	(0.007)	(0.005)
Less Digital Services Dummy	0.134***	0.104***	0.075*	0.088***		-0.362***		-0.435***
	(0.025)	(0.024)	(0.039)	(0.028)		(0.067)		(0.026)
Size Group 2 x Less Digital Services	0.048***	0.054***	0.022	0.034*	0.019	0.021***	0.022	0.021***
	(0.017)	(0.018)	(0.021)	(0.020)	(0.013)	(0.006)	(0.015)	(0.006)
More Digital Services Dummy	0.041	0.034	-0.003	0.034	0.043	-0.153**	0.097*	-0.215***
	(0.030)	(0.029)	(0.028)	(0.029)	(0.043)	(0.068)	(0.052)	(0.027)
Size Group 2 x More Digital Services	0.096***	0.095***	0.069***	0.076***	0.027***	0.037***	0.030***	0.037***
	(0.018)	(0.016)	(0.022)	(0.018)	(0.010)	(0.006)	(0.010)	(0.007)
Size Group 3 Dummy (500 - 4,999 employees)	0.056**	0.056***	0.237***	0.199***	0.052***	0.020***	0.052***	0.019***
	(0.023)	(0.020)	(0.047)	(0.037)	(0.006)	(0.004)	(0.008)	(0.005)
Size Group 3 x Digital Manufacuring	0.016	-0.014	-0.040*	-0.106***	0.011	0.011	-0.009	-0.008
	(0.018)	(0.021)	(0.022)	(0.037)	(0.010)	(0.008)	(0.015)	(0.015)
Size Group 3 x Less Digital Services	0.046	0.101***	-0.021	0.053	0.042	0.061***	0.044	0.069***
	(0.043)	(0.035)	(0.050)	(0.033)	(0.026)	(0.012)	(0.030)	(0.012)
Size Group 3 x More Digital Services	0.122***	0.143***	0.039	0.090**	0.085***	0.093***	0.086***	0.094***
	(0.041)	(0.041)	(0.053)	(0.044)	(0.026)	(0.017)	(0.024)	(0.016)
Size Group 4 Dummy (5,000+ employees)	0.163***	0.105***	0.467***	0.283***	0.047**	0.001	0.041	0.014
	(0.041)	(0.038)	(0.081)	(0.072)	(0.019)	(0.010)	(0.026)	(0.017)
Size Group 4 x Digital Manufacuring	-0.094**	-0.044	-0.115	-0.038	0.044	0.046**	0.001	0.026
	(0.046)	(0.045)	(0.113)	(0.079)	(0.031)	(0.021)	(0.030)	(0.025)
Size Group 4 x Less Digital Services	-0.062	0.072	-0.090	0.143	0.092**	0.121***	0.068*	0.115**
	(0.049)	(0.051)	(0.114)	(0.094)	(0.039)	(0.029)	(0.039)	(0.049)
Size Group 4 x More Digital Services	-0.079	0.012	-0.250***	-0.012	0.141***	0.155***	0.143***	0.132***
	(0.053)	(0.053)	(0.072)	(0.070)	(0.036)	(0.033)	(0.037)	(0.030)
Observations	703,689	991,043	397,101	789,409	653,839	940,601	363,288	743,364
R-squared	0.106	0.115	0.164	0.147	0.951	0.957	0.963	0.961
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is split by manufacturing / services, with less digital intensive manufacturing designated as the base category. All controls at t-1. Errors clustered at the industry-year level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Table A.14. Regression of Log MFP on Size Groups, Digitalisation and Manufacturing / Services

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	-0.039***	-0.046***	-0.031***	-0.034***	0.001	-0.013***	0.009***	-0.007***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Log age (t-1)	0.098***	0.083***	0.077***	0.058***	0.055***	0.054***	0.057***	0.050***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.004)	(0.002)
Log Markup (t-1)			-0.613***	-0.496***			-0.165***	-0.145***
			(0.008)	(0.006)			(0.008)	(0.005)
Size Group 2 Dummy (50 - 499 employees)	0.453***	0.477***	0.483***	0.506***	-0.009*	0.037***	-0.029***	0.044***
	(0.007)	(0.005)	(0.007)	(0.005)	(0.005)	(0.004)	(0.006)	(0.004)
Manufacuring Digital Dummy	-0.603***	0.407***	-0.541***	0.462***	-0.011	-0.357	-0.502***	-0.892*
	(0.008)	(0.008)	(0.008)	(0.008)	(0.043)	(0.619)	(0.053)	(0.492)
Size Group 2 x Digital Manufacuring	-0.069***	-0.118***	-0.070***	-0.126***	-0.028***	0.057***	-0.034***	0.049***
	(0.012)	(0.013)	(0.012)	(0.013)	(0.010)	(0.008)	(0.012)	(0.008)
Less Digital Services Dummy	-0.693***	-0.205***	-0.530***	-0.133***		0.347***		0.371***
	(0.007)	(0.006)	(0.007)	(0.006)		(0.019)		(0.022)
Size Group 2 x Less Digital Services	-0.180***	-0.178***	-0.160***	-0.161***	-0.046***	-0.032***	-0.034***	-0.038***
	(0.011)	(0.009)	(0.012)	(0.010)	(0.008)	(0.006)	(0.009)	(0.006)
More Digital Services Dummy	-0.432***	0.030***	-0.318***	0.099***		-1.228***		-1.232***
	(0.006)	(0.005)	(0.006)	(0.005)		(0.019)		(0.021)
Size Group 2 x More Digital Services	-0.222***	-0.178***	-0.196***	-0.159***	-0.027***	-0.032***	-0.017**	-0.034***
	(0.009)	(0.007)	(0.009)	(0.007)	(0.006)	(0.005)	(0.007)	(0.005)
Size Group 3 Dummy (500 - 4,999 employees)	1.027***	1.341***	1.167***	1.415***	0.011	0.090***	-0.034	0.097***
	(0.023)	(0.023)	(0.022)	(0.023)	(0.023)	(0.014)	(0.023)	(0.014)
Size Group 3 x Digital Manufacuring	0.000	-1.064***	-0.086**	-1.106***	-0.017	0.110***	0.011	0.102***
	(0.039)	(0.049)	(0.036)	(0.050)	(0.035)	(0.036)	(0.035)	(0.037)
Size Group 3 x Less Digital Services	-0.351***	-0.560***	-0.367***	-0.493***	-0.082***	-0.056***	-0.061**	-0.064***
	(0.043)	(0.040)	(0.045)	(0.041)	(0.031)	(0.021)	(0.031)	(0.022)
Size Group 3 x More Digital Services	-0.590***	-0.559***	-0.616***	-0.543***	-0.071***	-0.081***	-0.059**	-0.065***
	(0.026)	(0.025)	(0.025)	(0.025)	(0.025)	(0.017)	(0.026)	(0.016)
Size Group 4 Dummy (5,000+ employees)	1.604***	1.799***	1.832***	2.046***	0.004	0.088	-0.110	0.072
	(0.157)	(0.185)	(0.164)	(0.211)	(0.120)	(0.084)	(0.124)	(0.096)
Size Group 4 x Digital Manufacuring	-0.158	-0.975***	-0.234	-1.177***	-0.017	0.326*	0.059	0.336*
	(0.190)	(0.255)	(0.192)	(0.283)	(0.123)	(0.168)	(0.126)	(0.174)
Size Group 4 x Less Digital Services	1.549***	-0.156	1.415***	-0.112	0.165	-0.062	0.446***	-0.077
	(0.259)	(0.323)	(0.276)	(0.348)	(0.150)	(0.113)	(0.126)	(0.137)
Size Group 4 x More Digital Services	-0.768***	-0.393**	-0.938***	-0.585***	-0.108	-0.044	-0.017	0.006
	(0.159)	(0.187)	(0.167)	(0.213)	(0.124)	(0.087)	(0.128)	(0.099)
Observations	530,873	930,591	397,155	814,849	493,984	885,779	363,170	769,479
R-squared	0.269	0.341	0.317	0.373	0.961	0.961	0.966	0.963
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	id	id	id	id	id	id	id	id

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is split by manufacturing / services, with less digital intensive manufacturing designated as the base category. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Regressions with Errors Clustered at the Industry-Year Level

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Dependent Variable	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP	Log MFP
Cycle	1	2	1	2	1	2	1	2
Log capital intensity (t-1)	-0.039***	-0.046***	-0.031*	-0.034***	0.001	-0.013***	0.009***	-0.007***
	(0.013)	(0.009)	(0.016)	(0.009)	(0.002)	(0.002)	(0.002)	(0.002)
Log age (t-1)	0.098***	0.083***	0.077***	0.058***	0.055***	0.054***	0.057***	0.050***
	(0.018)	(0.013)	(0.014)	(0.011)	(0.006)	(0.006)	(0.007)	(0.006)
Log Markup (t-1)			-0.613***	-0.496***			-0.165***	-0.145***
			(0.144)	(0.103)			(0.030)	(0.025)
Size Group 2 Dummy (50 - 499 employees)	0.453***	0.477***	0.483***	0.506***	-0.009	0.037***	-0.029	0.044***
	(0.033)	(0.037)	(0.031)	(0.036)	(0.016)	(0.014)	(0.019)	(0.011)
Manufacuring Digital Dummy	-0.603***	0.407***	-0.541***	0.462***	-0.011	-0.357	-0.502***	-0.892**
	(0.063)	(0.094)	(0.058)	(0.092)	(0.064)	(0.532)	(0.069)	(0.421)
Size Group 2 x Digital Manufacuring	-0.069*	-0.118	-0.070*	-0.126	-0.028	0.057***	-0.034	0.049**
	(0.041)	(0.087)	(0.038)	(0.087)	(0.025)	(0.021)	(0.028)	(0.019)
Less Digital Services Dummy	-0.693***	-0.205**	-0.530***	-0.133		0.347***		0.371***
	(0.102)	(0.085)	(0.117)	(0.091)		(0.045)		(0.049)
Size Group 2 x Less Digital Services	-0.180***	-0.178**	-0.160***	-0.161**	-0.046*	-0.032*	-0.034	-0.038**
	(0.056)	(0.069)	(0.058)	(0.074)	(0.028)	(0.018)	(0.031)	(0.017)
More Digital Services Dummy	-0.432***	0.030	-0.318**	0.099		-1.228***		-1.232***
	(0.127)	(0.092)	(0.130)	(0.094)		(0.042)		(0.046)
Size Group 2 x More Digital Services	-0.222***	-0.178***	-0.196***	-0.159***	-0.027	-0.032*	-0.017	-0.034**
	(0.049)	(0.050)	(0.048)	(0.051)	(0.023)	(0.016)	(0.026)	(0.014)
Size Group 3 Dummy (500 - 4,999 employees)	1.027***	1.341***	1.167***	1.415***	0.011	0.090***	-0.034	0.097***
	(0.097)	(0.097)	(0.092)	(0.094)	(0.040)	(0.027)	(0.047)	(0.025)
Size Group 3 x Digital Manufacuring	0.000	-1.064***	-0.086	-1.106***	-0.017	0.110	0.011	0.102
	(0.118)	(0.149)	(0.103)	(0.151)	(0.051)	(0.070)	(0.058)	(0.072)
Size Group 3 x Less Digital Services	-0.351*	-0.560***	-0.367*	-0.493**	-0.082	-0.056	-0.061	-0.064*
	(0.210)	(0.209)	(0.194)	(0.210)	(0.065)	(0.036)	(0.077)	(0.037)
Size Group 3 x More Digital Services	-0.590***	-0.559***	-0.616***	-0.543***	-0.071	-0.081**	-0.059	-0.065**
	(0.123)	(0.129)	(0.121)	(0.119)	(0.050)	(0.032)	(0.059)	(0.030)
Size Group 4 Dummy (5,000+ employees)	1.604***	1.799***	1.832***	2.046***	0.004	0.088	-0.110	0.072
	(0.172)	(0.231)	(0.175)	(0.255)	(0.148)	(0.069)	(0.149)	(0.076)
Size Group 4 x Digital Manufacuring	-0.158	-0.975***	-0.234	-1.177***	-0.017	0.326	0.059	0.336
	(0.220)	(0.314)	(0.191)	(0.344)	(0.154)	(0.202)	(0.153)	(0.206)
Size Group 4 x Less Digital Services	1.549***	-0.156	1.415***	-0.112	0.165	-0.062	0.446***	-0.077
	(0.258)	(0.453)	(0.283)	(0.499)	(0.171)	(0.111)	(0.163)	(0.128)
Size Group 4 x More Digital Services	-0.768***	-0.393	-0.938***	-0.585**	-0.108	-0.044	-0.017	0.006
	(0.203)	(0.250)	(0.211)	(0.276)	(0.163)	(0.076)	(0.158)	(0.081)
Observations	530,873	930,591	397,155	814,849	493,984	885,779	363,170	769,479
R-squared	0.269	0.341	0.317	0.373	0.961	0.961	0.966	0.963
Country-Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES	YES	YES
Cluster	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind	country-ind

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is split by manufacturing / services, with less digital intensive manufacturing designated as the base category. All controls at t-1. Errors clustered at the industry-year level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Table A.15. Summary of Mark-up Size Dummies Using a Single Production Technology

Regression of Log Mark-ups on Size Dummies

	1	2	3	4	5	6
Size Group 2	0.05***	0.11***	0.02***	0.10***	0.04***	0.04***
Size Group 3	0.14***	0.25***	0.04***	0.25***	0.09***	0.11***
Size Group 4	0.12***	0.25***	0.06***	0.35***	0.14***	0.16***
Controls	K intensity, Firm Age	K intensity, Firm Age, MFP	K intensity, Firm Age	K intensity, Firm Age, MFP	K intensity, Firm Age	K intensity, Firm Age, MFP
Fixed Effects	Country-year	Country-year	Country-year, industry-year	Country-year, industry-year	Country-year, firm	Country-year, firm
Observations	1 713 880	1 442 529	1 713 838	1 442 504	1 660 639	1 396 957
R-squared	0.08	0.41	0.69	0.69	0.94	0.94

Source: authors' estimates based on Orbis® data.

Regression of Log Mark-ups on Size Groups Split by Cycle

	1a	1b	2a	2b	3a	3b
	Cycle 1	**Cycle 1**	**Cycle 1**	**Cycle 1**	**Cycle 1**	**Cycle 1**
Size Group 2	0.05***	0.11***	0.02***	0.10***	0.04***	0.05***
Size Group 3	0.13***	0.25***	0.04***	0.24***	0.10***	0.11***
Size Group 4	0.11***	0.24***	0.05***	0.34***	0.15***	0.17***
Controls	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Firm Age	K intensity, Age, MFP
Fixed Effects	Country-year	Country-year	Country-year, industry-year	Country-year, industry-year	Country-year, firm	Country-year, firm
Observations	729,478	614,861	729,452	614,847	679,382	572,319
R-squared	0.06	0.40	0.53	0.69	0.95	0.96
	Cycle 2	**Cycle 2**	**Cycle 2**	**Cycle 2**	**Cycle 2**	**Cycle 2**
Size Group 2	0.05***	0.11***	0.01***	0.10***	0.03***	0.04***
Size Group 3	0.15***	0.26***	0.04***	0.24***	0.08***	0.09***
Size Group 4	0.13***	0.26***	0.07***	0.35***	0.12***	0.13***
Controls	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Firm Age	K intensity, Age, MFP
Fixed Effects	Country-year	Country-year	Country-year, industry-year	Country-year, industry-year	Country-year, firm	Country-year, firm
Observations	984,402	827,668	984,386	827,657	933,734	784,038
R-squared	0.08	0.42	0.54	0.69	0.96	0.96

Source: authors' estimates based on Orbis® data.

Regression of Log Mark-ups on Size Group and Digitalisation Dummies

	1a	1b	2a	2b
	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 2	0.01***	0.01***	0.09***	0.10***
Size Group 3	0.07***	0.09***	0.28***	0.28***
Size Group 4	0.16***	0.17***	0.51***	0.50***
S1*More Digital	-0.02***	-0.02***	0.03***	0.03***
S2*More Digital	0.05***	0.05***	0.15***	0.15***
S3*More Digital	0.14***	0.15***	0.27***	0.28***
S4*More Digital	0.08***	0.11***	0.23***	0.25***
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age, MFP	K intensity, Firm Age, MFP
Fixed Effects	Country-year	Country-year	Country-year	Country-year
Observations	729,478	984,402	614,861	827,668
R-squared	0.07	0.09	0.40	0.43

Source: authors' estimates based on Orbis® data.

Regression of Log Mark-ups on Size Groups on Size Groups and Digital Quartile 3 / 4 Dummies

#	1a	1b	2a	2b
	Cycle 1	Cycle 2	Cycle 1	Cycle 2
Size Group 1*Q3	-0.10***	-0.11***	-0.02***	-0.02***
Size Group 2*Q3	-0.07***	-0.07***	0.06***	0.07***
Size Group 3*Q3	-0.02***	-0.02***	0.17***	0.19***
Size Group 4*Q3	-0.03***	-0.03***	0.24***	0.24***
Size Group 1*Q4	0.22***	0.28***	0.26***	0.12***
Size Group 2*Q4	0.26***	0.29***	0.26***	0.14***
Size Group 3*Q4	0.14***	0.25***	0.30***	0.20***
Size Group 4*Q4	0.15***	0.25***	0.30***	0.23***
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age, MFP	K intensity, Firm Age, MFP
Fixed Effects	Country-year	Country-year	Country-year	Country-year
Observations	729,478	984,402	614,861	827,668
R-squared	0.25	0.28	0.44	0.46

Source: authors' estimates based on Orbis® data

Regression of Log Mark-ups on Size Groups, Digitalisation and Manufacturing / Services Dummies

	Dummy Values Less-Digital Manufacturing				Dummy Values More-Digital Manufacturing			
	Cycle 1	**Cycle 2**	**Cycle 1**	**Cycle 2**	**Cycle 1**	**Cycle 2**	**Cycle 1**	**Cycle 2**
Size Group 1	-	-	-	-	0.02	-0.01	0.05	0.04
Size Group 2	0.01	0.00	0.10	0.11	0.04	0.02	0.15	0.15
Size Group 3	0.06	0.05	0.30	0.32	0.07	0.05	0.31	0.33
Size Group 4	0.15	0.12	0.56	0.48	0.09	0.08	0.21	0.11
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Age, MFP	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Age, MFP
Fixed Effects	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year
Observations	729,478	984,402	614,861	827,668	729,478	984,402	614,861	827,668
R-squared	0.10	0.12	0.40	0.43	0.10	0.12	0.40	0.43

	Dummy Values Less-Digital Services				Dummy Values More-Digital Services			
Cycle	**Cycle 1**	**Cycle 2**	**Cycle 1**	**Cycle 2**	**Cycle 1**	**Cycle 2**	**Cycle 1**	**Cycle 2**
Size Group 1	0.13	0.12	0.05	0.02	0.03	0.03	0.05	0.04
Size Group 2	0.18	0.16	0.14	0.11	0.13	0.13	0.17	0.17
Size Group 3	0.22	0.24	0.27	0.26	0.22	0.22	0.29	0.28
Size Group 4	0.25	0.28	0.50	0.53	0.13	0.15	0.24	0.26
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Age, MFP	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, MFP	K intensity, Age, MFP
Fixed Effects	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year
Observations	729,478	984,402	614,861	827,668	729,478	984,402	614,861	827,668
R-squared	0.10	0.12	0.40	0.43	0.10	0.12	0.40	0.43

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.

Table A.16. Summary of Multifactor Productivity Size Dummies Using a Single Production Technology

Regression of Log Multifactor Productivity on Size Dummies

	1	2	3	4	5	6
Size Group 2	0.24***	0.40***	0.35***	0.41***	0.01***	0.02***
Size Group 3	0.40***	0.83***	0.82***	1.01***	0.04***	0.07***
Size Group 4	0.54***	0.87***	1.14***	1.44***	0.03	0.07***
Controls	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year, industry-year	Country-year, industry-year	Country-year, firm	Country-year, firm
Observations	1,654,202	1,358,947	1,654,194	1,358,932	1,608,672	1,314,314
R-squared	0.14	0.45	0.68	0.82	0.97	0.98

Source: authors' estimates based on Orbis® data.

Regression of Log Multifactor Productivity on Size Groups Split by Cycle

	1a	1b	2a	2b	3a	3b
	Cycle 1	**Cycle 1**	**Cycle 1**	**Cycle 1**	**Cycle 1**	**Cycle 1**
Size Group 2	0.26***	0.41***	0.36***	0.41***	-0.05***	-0.06***
Size Group 3	0.47***	0.87***	0.85***	1.02***	-0.09***	-0.10***
Size Group 4	0.59***	0.88***	1.21***	1.48***	-0.15***	-0.18***
Controls	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year, industry-year	Country-year, industry-year	Country-year, firm	Country-year, firm
Observations	673,985	532,074	673,980	532,072	629,455	490,184
R-squared	0.122	0.429	0.687	0.821	0.98	0.984
	Cycle 2	**Cycle 2**	**Cycle 2**	**Cycle 2**	**Cycle 2**	**Cycle 2**
Size Group 2	0.23***	0.40***	0.34***	0.41***	0	0.01***
Size Group 3	0.35***	0.80***	0.79***	1.00***	-0.01	0.02***
Size Group 4	0.50***	0.86***	1.08***	1.41***	-0.01	0.03
Controls	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year, industry-year	Country-year, industry-year	Country-year, firm	Country-year, firm
Observations	915,062	826,873	915,061	826,860	870,872	782,929
R-squared	0.154	0.462	0.676	0.816	0.979	0.981

Source: authors' estimates based on Orbis® data.

Regression of Log Multifactor Productivity on Size Group and Digitalisation Dummies

	1a	1b	2a	2b
	Cycle 1	**Cycle 2**	**Cycle 1**	**Cycle 2**
Size Group 2	0.44***	0.39***	0.50***	0.49***
Size Group 3	1.01***	0.85***	1.35***	1.20***
Size Group 4	1.93***	1.42***	2.22***	2.02***
S1*More Digital	0.30***	0.29***	0.31***	0.31***
S2*More Digital	0.44***	0.41***	0.66***	0.65***
S3*More Digital	0.53***	0.44***	0.98***	0.94***
S4*More Digital	0.63***	0.58***	0.92***	0.92***
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age, Mark.	K intensity, Firm Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year	Country-year
Observations	673,985	915,062	532,074	826,873

Source: authors' estimates based on Orbis® data.

Regression of Log Multifactor Productivity on Size Groups on Size Groups and Digital Quartile 3 / 4 Dummies

	1a	1b	2a	2b
	Cycle 1	**Cycle 2**	**Cycle 1**	**Cycle 2**
Size Group 1*Q3	0.62***	0.68***	0.52***	0.57***
Size Group 2*Q3	0.95***	1.00***	0.93***	0.98***
Size Group 3*Q3	1.35***	1.37***	1.46***	1.50***
Size Group 4*Q3	1.17***	1.32***	1.47***	1.50***
Size Group 1*Q4	-0.82***	-0.79***	-0.46***	-0.39***
Size Group 2*Q4	-0.56***	-0.50***	-0.08***	0.01***
Size Group 3*Q4	0.03***	0.00***	0.43***	0.50***
Size Group 4*Q4	0.52***	0.51***	0.75***	0.80***
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Firm Age, Mark.	K intensity, Firm Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year	Country-year
Observations	673,985	915,062	532,074	826,873
R-squared	0.36	0.38	0.52	0.54

Source: authors' estimates based on Orbis® data.

Regression of Log Multifactor Productivity on Size Groups, Digitalisation and Manufacturing / Services Dummies

	Dummy Values Less-Digital Manufacturing				Dummy Values More-Digital Manufacturing			
	Cycle 1	**Cycle 2**	**Cycle 1**	**Cycle 2**	**Cycle 1**	**Cycle 2**	**Cycle 1**	**Cycle 2**
Size Group 1	-	-	-	-	0.14	0.19	0.24	0.24
Size Group 2	0.53	0.50	0.57	0.57	0.57	0.60	0.74	0.75
Size Group 3	1.32	1.29	1.57	1.55	1.35	1.24	1.59	1.52
Size Group 4	2.16	1.64	2.51	2.20	1.18	1.67	0.67	1.14
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year
Observations	673,985	915,062	532,074	826,873	673,985	915,062	532,074	826,873
R-squared	0.18	0.20	0.46	0.49	0.18	0.20	0.46	0.49

	Dummy Values Less-Digital Services				Dummy Values More-Digital Services			
Cycle	**Cycle 1**	**Cycle 2**	**Cycle 1**	**Cycle 2**	**Cycle 1**	**Cycle 2**	**Cycle 1**	**Cycle 2**
Size Group 1	-0.54	-0.49	-0.28	-0.27	0.08	0.06	0.21	0.20
Size Group 2	-0.32	-0.32	0.04	0.03	0.16	0.13	0.51	0.50
Size Group 3	0.09	-0.02	0.69	0.54	0.21	0.16	0.78	0.77
Size Group 4	1.38	0.85	1.78	1.67	0.41	0.37	0.80	0.80
Controls	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Age, Mark.	K intensity, Firm Age	K intensity, Firm Age	K intensity, Age, Mark.	K intensity, Age, Mark.
Fixed Effects	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year	Country-year
Observations	673,985	915,062	532,074	826,873	673,985	915,062	532,074	826,873
R-squared	0.18	0.20	0.46	0.49	0.18	0.20	0.46	0.49

Note: The base category for the size dummy is firms with less than 50 employees. Group 2 is 50 – 499, Group 3 is 500 – 4,999 and Group 4 is 5,000+. The digital dummy is equal to 1 if greater than the digital median. All controls at t-1. Errors clustered at the firm level. ***p<0.01 **p<0.05, *p<0.10.
Source: authors' estimates based on Orbis® data.