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Firm-Level Attitudes and Actions to the "Twin Transition" Challenges of Digitalisation and Climate Change

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Abstract: There are increasing pressures on firms to adjust to the major global challenges of climate change and rapid developments in digital technologies. To date, the impacts of these two challenges on firms have largely been examined as separate issues. However there are suggestions of overlap, with the potential of digital technologies to help economies and firms shift to greener production methods. This paper provides a novel contribution to this literature on a "twin transition" by examining for the first time the overlap at a firm level between climate actions and digitalisation. The data are drawn from a large-scale survey of 3,000 firms in Ireland in 2020. The report includes novel questions on energy use, climate adaption priorities and digital strategies along with a wide range of firm characteristics. Our key outcome variables are the degree of digitalisation in the firm, if it has a climate plan and does it implement climate actions such as monitoring emissions. We find considerable overlap between having a climate and a digital plan in place across firms, while controlling for a range of other firm characteristics. At the same time, we find a reasonably large share of firms have positive attitudes to the importance of climate planning but without reporting corresponding concrete actions, suggesting a gap for policy to address.

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I INTRODUCTION

Two long-term structural shifts are being faced by firms both in Ireland and internationally in the form of increasing pressure to mitigate the impacts of global climate change and the increasing speed of technological development in the area of digitalisation. To date, there has much research on these issues in terms of firm-level impacts and investment decisions, but this research has tended to focus on one or the other of the two challenges. Both climate and digital developments pose challenges for firms and policymakers and there is also a potential intersection of the two structural shifts that has led them to be described as a "twin transition" (for example, Revoltella, 2020, p.6). The two elements of the twin transition are (1) the increasing pace of technological change and the impacts that this may have on employment, productivity and business activities and (2) the transition to a greener economy to limit carbon emissions and mitigate the broad-based risks arising from climate change. The twin aspect of the two challenges comes from the role that could be played by technology in averting the worst impacts of changing climate, whether this comes directly through technological shifts or indirectly through efficiency improvements (Bernstein and Madlener, 2010; Dwivedi *et al.,* 2022; Elkerbout *et al.*, 2021).

This paper aims to fill the gap in the literature on the extent to which these challenges and strategies to address them overlap at a firm level. We make this contribution by using a novel dataset of Irish firms that includes for the first time questions on the determinants of climate and digitalisation strategies. This allows us to examine the key factors at a firm-level that can be identified as increasing participation in either digitalisation, climate adaption or both simultaneously. Our results give valuable insight for policymakers on the potential to leverage policy interventions to achieve objectives in both areas, and provides a base for developing further academic work in this area. The contribution that this paper makes on the twin element of the climate and digital challenges facing firms relies on direct questions to firms on their awareness and strategies on each. For digitalisation, firms are asked to rank their level of digital readiness on a five-point scale, ranging from "none or limited" to "fully embedded and optimised". Climate adaptation strategies are measured using several questions to gauge the importance to the firm of climate adaption and whether they have a specific plan in place to address it. Information on energy intensity and monitoring of emissions is also measured.

Our first key finding is that each of the indicators of digitalisation and climate action plans are significantly related to firm size and productivity. This is in keeping with the patterns of the literature on green and digital technologies when investigated separately (described in more detail later in this section). Secondly, however, we find some heterogeneity in how some other firm characteristics relate to the climate and digital strategies of firms. For example, firm productivity is positively linked to climate actions in the case of having a climate plan in place

and measuring carbon dioxide (CO_2) emissions, but does not impact how the firm ranks the importance of having a climate plan in place. A third key finding is that energy intensity is significantly related to measurement of emissions and generation of own on-site energy.

In terms of the overlap in the different strategies, our main finding is that there exists a strong statistically significant link between having a climate and a digital plan while controlling for a range of other firm characteristics. Although the data do not allow us to infer causation from one to the other, this is a potentially important result in a policy context as it suggests that a holistic or integrated approach to supports for both digital and green technologies may deliver greater impact than treating the challenges separately. A further potentially important finding from our analysis for policy interventions is that almost twice as many firms respond that a climate response plan is either very or moderately important than report having a climate action plan in place. These are typically smaller firms, suggesting this is a group requiring targeted policy support if the gap between a positive attitude to climate planning and action at a firm level is to be bridged.

The literature on the overlap between firm strategies to adapt to climate change and to digitalisation is limited, a gap that this paper aims to address. However, there is a wide range of relevant work that looks separately at the two elements of the twin transition and identifies a number of salient characteristics that will inform our examination of the overlap between the strategies. The remainder of this section gives some brief highlights of the key findings of the most closely related work, looking first at green technology adaption and then at firm-level factors correlated with digitalisation more broadly.

The key common theme of the existing literature is that there exist strong links between firm investments in both aspects of technological adaptation (both green and digital), with firms that are already larger and more productive consistently more likely to undertake investments in both areas. Uncertainty about technology evaluation and access to finance emerge as potential barriers to investment, particularly for smaller firms. We find that these characteristics also relate to overlaps in the two strategies as well as correlating between them individually. A second strong theme that emerges consistently is the need for complementary investments in skills which also relates to variations in investment across firm types. In our empirical work, we note that research and development (R&D) investment as well as overall productivity are important factors in several of the measures of activity used to gauge firm activity in climate and digital strategies.

The literature on firm investment in lower carbon technologies and production methods includes a number of studies that note the potential for technology to support transitions to lower carbon methods of production (Bernstein and Madlener, 2010; Dwivedi *et al.,* 2022; Elkerbout *et al.*, 2021). The immediate costs of transitioning to new technologies, and perhaps new skills requirements, could however be substantial (Balsmeier and Woerter, 2019). Boone and Revoltella (2019)

and Revoltella (2020) argue that there is an important policy gap in incentivising investment in a direction that helps to address climate change. They point to uncertainty as a barrier with firms potentially delaying investments in climate-friendly technologies as they await clarity on the evolution of the technologies, carbon prices, standards and regulation. The need for complementary investments in labour market skills to fully exploit the new technologies is also an important factor in gaining the full productivity benefits both at a firm and national level (Boone and Revoltella, 2019; Balsmeier and Woerter, 2019, Cirillo *et al.,* 2021).

Examining investments in green technologies amongst firms in Ireland's industry sector, Siedschlag and Yan (2020) found that green investments have positive effects on average across a range of performance outcomes. However, the positive benefits were not evenly spread with larger, foreign-owned and more productive firms more likely to gain benefits from investments in green technologies as well as firms in lower-technology industries. They interpret this variation in performance impact as suggesting that there may be complementary factors needed for firms to fully exploit the benefits from green investments enough to overweigh the associated costs. This parallels the point made by Boone and Revoltella (2019) about digital investments requiring complementary skills investments alongside the direct investment in the technologies themselves for the full benefits to emerge. Looking at green investments from another angle, Siedschlag and Yan (2021) also found that larger firms were more likely to invest in cleaner technologies in the first instance. Looking at environmental expenditures as a component of broader corporate social responsibility, Blasi *et al.* (2018) find somewhat mixed results on the links between these activities and firm financial performance, and suggest further work on heterogeneity across firm types and sectors would be beneficial.

Turning from green to digital technologies, the determinants of investment in digitalisation have been extensively investigated across countries. Gal *et al.* (2019) combine firm-level data from across the OECD and find evidence that digital adoption in an industry is associated with productivity gains at the firm level. They also echo the finding that the firms that benefited the most from digital technologies also invested in other forms of human and organisational capital. Cirillo *et al.* (2021) and DeStefano *et al.* (2017) also highlight the role of skills and also the variety of potential digital technology options available to firms, with smaller firms focusing on single technology types while bundles of different technologies are used by larger firms. DeStefano *et al.* (2017) find that a focus on investment spend can somewhat mask the constant churning of bundles of digital technologies being used by firms over time including a shift from purchasing of hardware to acquiring technology services. The relationship between digital investments and productivity growth is substantial, with Adarov *et al.* (2022) finding that differences in digital capital could account for as much as one-quarter of the overall productivity gap between the EU and US.

Drawing the two strands of research together, there is a consistent finding in relation to both the determinants of green and digital investments that larger firms are more likely to invest and to gain greater benefits from their investments. This suggests particular challenges of the twin transition for small and medium enterprises (SMEs). In counterpoint to this, George *et al.* (2021) and George and Schillebeeckx (2021) point to some ways in which digitalisation in particular may allow smaller companies to benefit from economies of scale, by reducing the costs of coordination and enabling a wider consumer reach through common exchange platforms. Some policy support may be required to support greater engagement of smaller firms with new technologies, with Mollet (2021) suggesting several areas where intervention may be needed. Accessing finance for intangible asset investment is one particular potential barrier for SMEs, as well as the need for supporting infrastructure and skills investment. Drawing together the digital and climate strands of the existing research on firm investment, Axenbeck and Niebel (2021) find a small but statistically significant negative link between indicators of firm-level digitalisation and the energy intensity of the firm.

The rest of the paper is organised as follows: Section II describes the data source. Section III provides summary statistics on the patterns of firm responses on digital and climate plans. Section IV presents the econometric results on the determinants of the two strategies separately at a firm level and their joint occurrence. Section V concludes.

II DATA DESCRIPTION

The data we use come from a wide-ranging firm survey called the Annual Business Survey of Economic Impact (ABSEI), which is collected by the Department of Enterprise, Trade and Employment. This survey covers approximately 4,200 firms in total, drawn from a sampling frame of client companies of three enterprise promotion agencies in Ireland: Enterprise Ireland, IDA Ireland and Údarás na Gaeltachta. The survey is used extensively by the Department and agencies to monitor export activity and to provide evidence for strategy development and policymaking.

The survey covers firms employing ten or more employees in Ireland in the manufacturing, information and communication and other internationally traded services sectors. There are also some responses from smaller (micro) firms where these are considered as high potential growth firms. As such, the results from micro firms throughout the paper may be less representative of this group in the population than the results from the other size classes. Weights are used to account for non-respondents and are based on sector, ownership, size and region. The data include some imputations where a large company has not responded and are usually based on their responses to previous surveys.

The survey collects information on a range of key firm characteristics, including sales, exports, employment, costs and training. For the purposes of this paper, the key questions of interest relate to climate, energy and digitalisation which were added to the survey in 2021 and referred to activities in 2020. The questions are shown in Box 1.

Box 1: Questions from Annual Business Survey of Economic Impact

Q14a How important is having a climate action response for your business?
☐ Not important
☐ Moderately important
☐ Very important

Q14b Have you developed a climate action response for your business?
☐ Yes
☐ No
☐ Don't know

Q14c Does your company measure CO_2 emissions?
☐ Yes
☐ No
☐ Don't know

Q14d Which of the following energy resources does your company use?
Yes / No / Don't know
☐ Natural gas
☐ Fuel oil, kerosene, gas oil, diesel, LPG
☐ Other fuels (e.g. coal, petroleum coke)
☐ Biogas/biomass including renewable waste
☐ On-site renewable electricity generation (e.g. heat pumps, solar panels, wind)

Q15 Digitalisation is the process of leveraging digital data and technologies to drive business value. How would you assess your readiness for the use of established (e.g. data analytics) and emerging (e.g. Artificial Intelligence) digital technologies to this end? Please tick one of the following options:
☐ No digital plan; limited or no digital initiatives in place
☐ Tentative plan in place; some experience of exploring and delivering digital initiatives
☐ Defined digital plans in place with activities underway
☐ Digital innovation strategy in place with implementation activities underway
☐ Digital is fully embedded and optimised across all aspects of our business

Source: Annual Business Survey of Economic Impact.

These questions are currently available for a single wave of the survey so we are limited to cross-sectional data. For most explanatory variables (number of employees, value-added, exporter status, ownership, R&D intensity, and energy intensity) we therefore use data referring to the year 2020. For two other variables (long-term turnover growth rates and long-term change in energy intensity) we take the average growth rate over five years, thereby exploiting the time span of the survey before the digital and climate questions were added. This gives us some additional insight into the trajectory of firm performance. Additionally, we winsorize the continuous variables to address the presence of extreme values that could lead to excessive influence of outliers in the regression models in Section IV. For log number of employees the winsorizing was not necessary.

The summary statistics for the firms in the survey are shown in Table 1 and the outcome variables discussed further in the following section.

Table 1: Summary Statistics

	Observations	*Mean*	*Std. dev.*	*Minimum*	*Maximum*
ln(empl)	3,203	3.485	1.465	0	8.571
VA per empl	2,993	0.101	0.118	0	0.500
Exporter dummy	3,231	0.829	0.376	0	1
Foreign dummy	3,228	0.230	0.421	0	1
5-year growth	3,023	0.121	0.322	–1	1.500
R&D intensity	3,047	0.094	0.163	0	0.500
Energy intensity	2,969	0.023	0.039	0	0.250
5-year energy change	3,031	–0.001	0.007	–0.030	0.030
Digital readiness	2,301	2.581	1.439	1	5
Climate action importance	2,348	2.032	0.692	1	3
Have climate plan	2,637	0.231	0.421	0	1
Measure CO_2	2,648	0.137	0.344	0	1
Have on-site renewables	2,259	0.126	0.332	0	1

Source: Annual Business Survey of Economic Impact.

III DESCRIPTIVE RESULTS

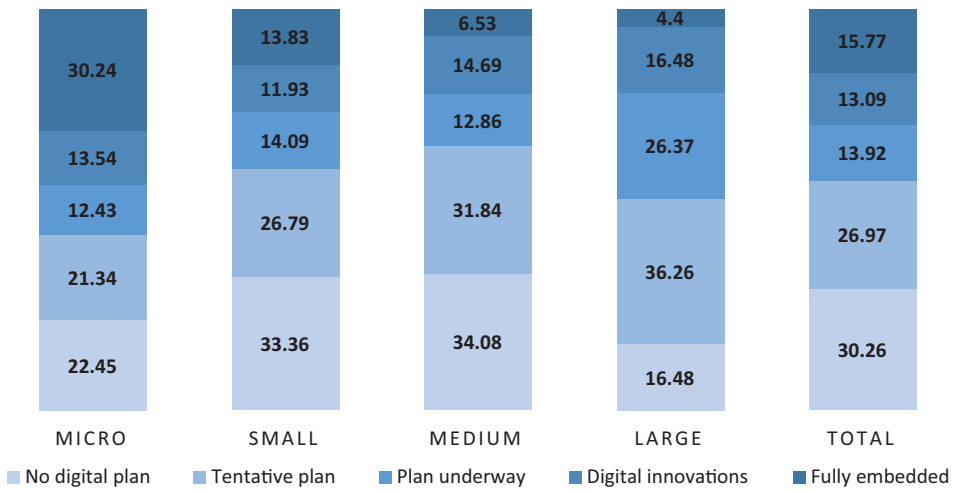
In this section, we describe the patterns of responses to the survey questions on digital readiness and climate plans, looking at how these vary across firm characteristics such as size and sector. The following section will then look more deeply at the determinants of the responses in an econometric framework. This section is arranged to look at digital preparation in the first subsection, then the responses to the questions on climate change, with the final subsection looking at the extent of the overlap in the responses.

3.1 Digital Preparation

The first question we examine is the extent of digital readiness by the firm. This question had five potential answers ranging from no digital plan to digitalisation being fully embedded in the firm. Figure 1 shows how the intensity of digitalisation varies across firm size groups. For all firms in the sample in 2020, 30 per cent responded that they had no digital plan and a further 27 per cent that a tentative plan was in place; 16 per cent reported having fully embedded digitalisation within the firm.

Across size groups, we find some evidence of a U-shaped relationship between digital readiness and firm size. The smallest and largest of our four size groups are the least likely to report having no digital plan. The largest size group have almost 40 per cent of firms reporting plans underway or digital innovations but this size category has the smallest share of firms reporting fully embedded digitalisation. On the other end of the scale, the smallest firms are most likely to report fully embedded digitalisation. A positive correlation between size and digital investments has been observed in a number of studies, such as Gal *et al*. (2019), Cirillo *et al*. (2021) and DeStefano *et al*. (2017), but the high rate of digitalisation in smaller firms is in contrast to most of the literature in this area. A likely explanation of this is that the smaller firms in the survey are more likely to be high-potential start-up firms and, as noted above, some caveats therefore need to be applied to the patterns from this group. The survey does not include a question on firm age so this hypothesis cannot be tested directly. Figure 2 depicts the U-shape between digital readiness and size across the entire size distribution, showing the average score of the 5-point scale across all employment levels.

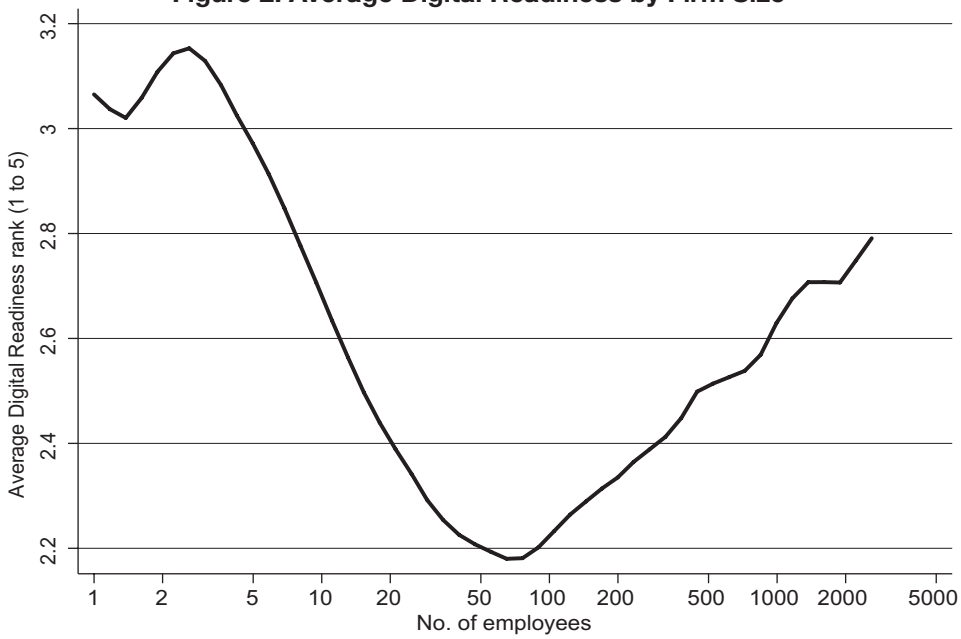
Figure 1: Digital Readiness by Firm Size Group (% of Responses)



Source: Annual Business Survey of Economic Impact.

We also find considerable variation in the degree of digital readiness across sectors but here the pattern is rather more in line with ex ante expectations and work such as that by Gal *et al*. (2019) across a range of countries. Both the food, drink and primary sector and traditional manufacturing have the highest shares of firms – approximately half – with no digital plans in place and only around 2 per cent of firms reporting fully embedded digitalisation. Services sectors in information and communications technology (ICT) and business and professional services are considerably more likely to report high levels of digitalisation.

Figure 2: Average Digital Readiness by Firm Size



Source: Annual Business Survey of Economic Impact.

Table 2: Digital Readiness by Sector

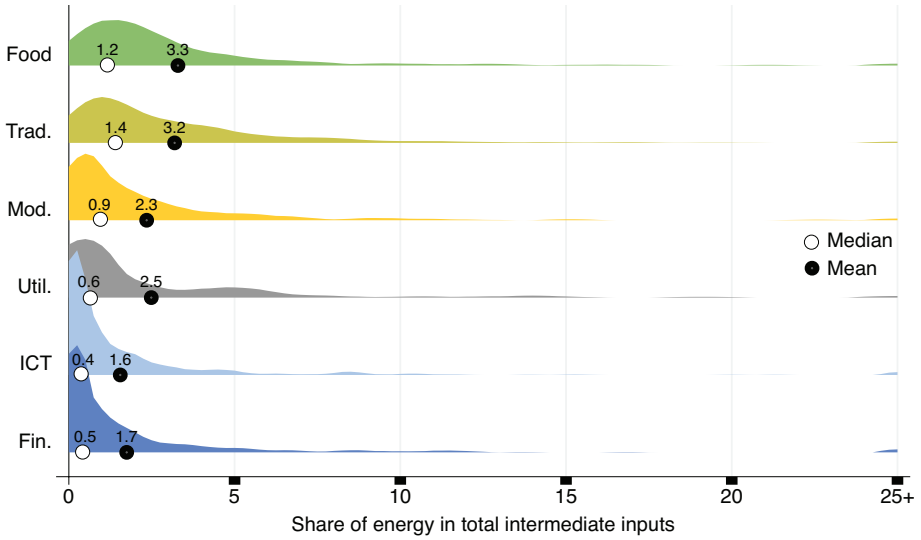
	No digital plan	*Tentative plan*	*Defined plan*	*Digital innovate*	*Fully embedded*	*Total*
Food, drink & primary	48.82	29.63	11.78	7.74	2.02	100
Traditional manufacturing	50.18	31.21	9.75	6.21	2.66	100
Modern manufacturing	34.19	32.91	14.96	11.11	6.84	100
Utilities	30.84	41.12	13.08	12.15	2.80	100
ICT	7.07	18.69	15.15	20.88	38.22	100
Business, fin. & prof. services	21.78	23.96	18.02	16.04	20.20	100
Total	30.12	26.81	13.91	13.12	16.04	100

Source: Annual Business Survey of Economic Impact.

3.2 Climate Adaption

This section looks at the firms' responses to the questions on climate adaption – including if they have a climate action plan, the importance they attach to having a plan and if they measure CO_2 emissions. A potentially relevant factor in the answers to these questions is the energy intensity of the firm, as the greater the share of energy in overall expenditures, the more incentive there may be to develop plans to increase energy efficiency. We therefore begin this subsection by looking at how energy intensity varies across broad sectors.

Figure 3: Variation in Energy Intensity (Share of Expenditure) by Broad Sector, Kernel Density Estimates



Source: Annual Business Survey of Economic Impact.
Note: Sectors: Food, drink and primary production; Traditional manufacturing; Modern manufacturing; Energy, water, waste and construction; Information, communication and computer services; Business, financial and other services.

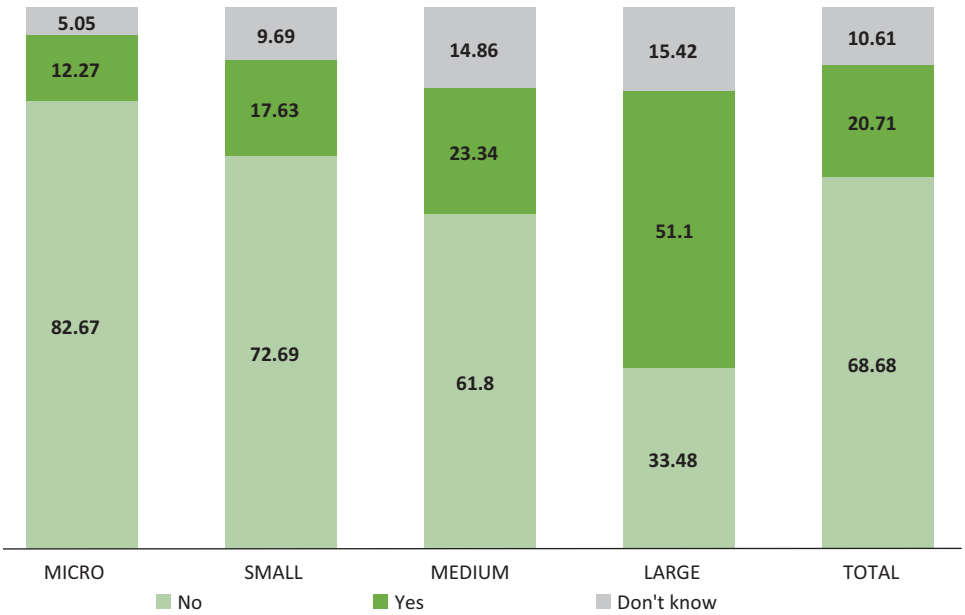
For the majority of firms energy accounts for less than 2.5 per cent of total expenditures, but the distribution plots in Figure 3 shows considerable variation both within and across sectors (the graph is top coded at 25 per cent of expenditures so excludes outliers greater than that level).[1]

The first question we look at in relation to climate is if the firm had a climate action plan. Approximately 69 per cent of firms responded that they did not, with

[1] It should be noted that these data on expenditure shares pre-date the increase in energy costs occurring in 2022. The shares are calculated from information on the firms' direct expenditures on energy. They cannot therefore be interpreted as a measure of total exposure of firms to energy price increases as they do not include indirect exposures through energy-intensive intermediate inputs.

21 per cent answering yes and a further 10 per cent giving a "don't know" response. Across size categories, Figure 4 shows a marked increase in the share of firms responding that a climate action plan was in place as we move up the firm size groups. Micro firms were relatively unlikely to have a climate action plan in place with over 80 per cent responding no to this question. The negative response reduced to 73 per cent amongst small firms and further to 62 per cent amongst medium firms. For large firms, more than half reported having a climate action plan. Although their work focused on green investment expenditure, this relationship between firm size and climate planning is in keeping with the results of Siedschlag and Yan (2020 and 2021).

Figure 4: Business Climate Action Plan by Firm Size Group (% of Responses)



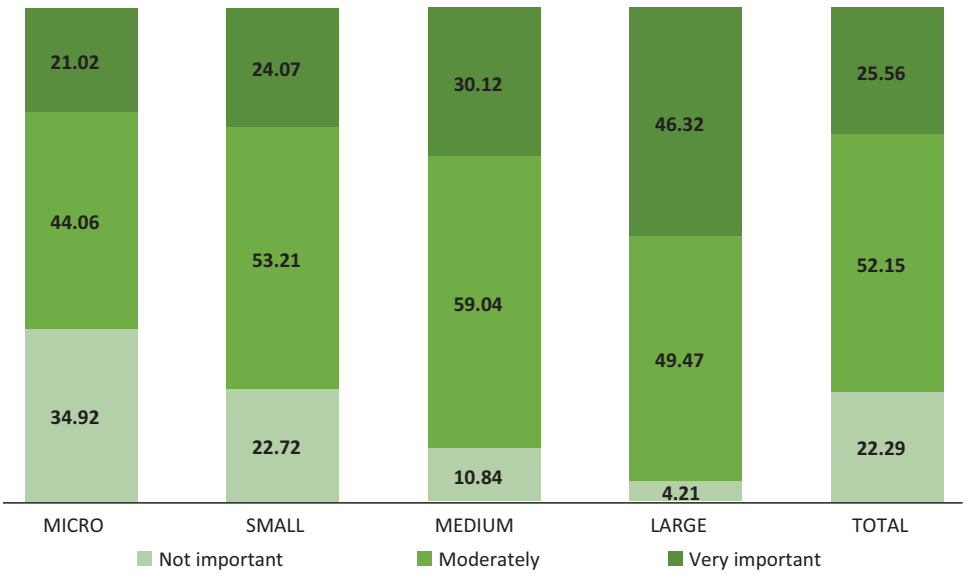
Source: Annual Business Survey of Economic Impact.

An interesting contrast emerges between the share of firms with a climate action plan in place and the responses of firms to the next question regarding whether they consider a climate response as being important for their business. A much greater proportion of firms agree with the importance of a climate response than have a current climate action plan in place, as can be seen contrasting Figures 4 and 5. Almost twice as many firms respond that a climate response plan is either very or moderately important than report having a climate action plan in place. This may reflect the relatively small share of energy in expenditures for many firms as shown in Figure 3. The gap between positive attitudes towards the importance of climate

plans and the concrete actions being taken by firms mirrors to some extent evidence at the household level from Douenne and Fabre (2020) where a greater percentage of respondents reported positive attitudes to general questions on climate-friendly policies than reported being in favour of specific policy actions such as carbon taxes.

Increases in energy costs that began to build after the period of this survey may change the incentives for more direct action on climate change and will be important from a policy perspective to monitor. Bridging this gap between positive attitude to climate planning and action at a firm level is likely to be a key challenge although the difference in responses does show that firms are aware of the relevance of the issue of climate change even if they have not formulated a plan for how their own individual business should respond to it.

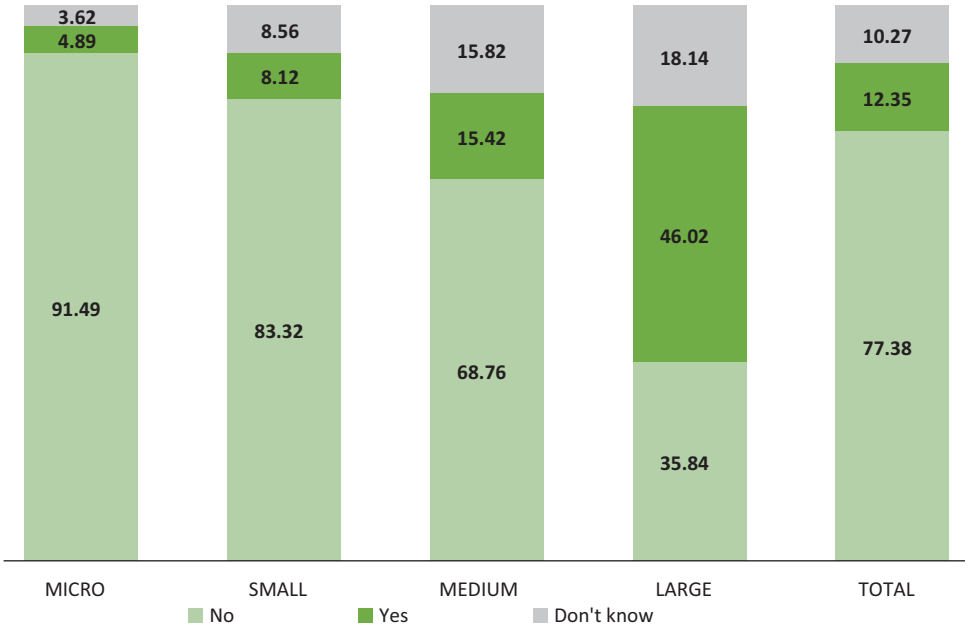
Figure 5: Importance of a Climate Action Response (% of Responses)



Source: Annual Business Survey of Economic Impact.

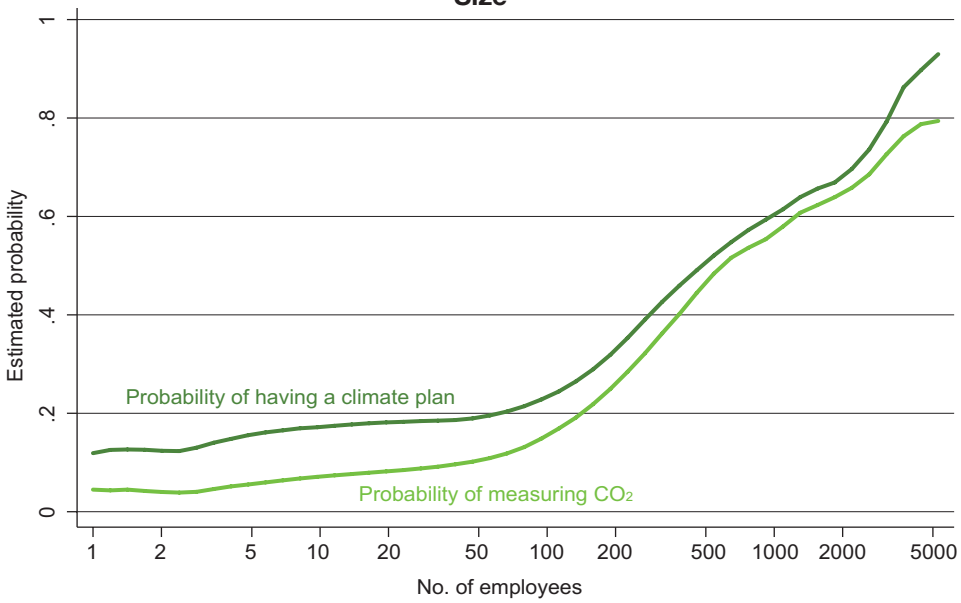
The distinction between the attitude question and concrete action is also seen in the responses to the question of whether the firm measures CO_2 emissions. Figure 6 shows that direct measurement of emissions is carried out by a minority of firms overall and is rare amongst micro and small firms. However, measurement of emissions is undertaken by a substantial proportion of larger firms, with more reporting that emissions are measured than those that report that they are not measured (albeit with a relatively large number of "don't know" responses). The strong positive relationship between firm size and both having a climate plan and measuring CO_2 emissions is shown across the entire size distribution in Figure 7.

Figure 6: Does the Business Measure CO_2 Emissions? (% of Responses)



Source: Annual Business Survey of Economic Impact.

Figure 7: Probability of Having a Climate Plan and Measuring CO_2 by Firm Size

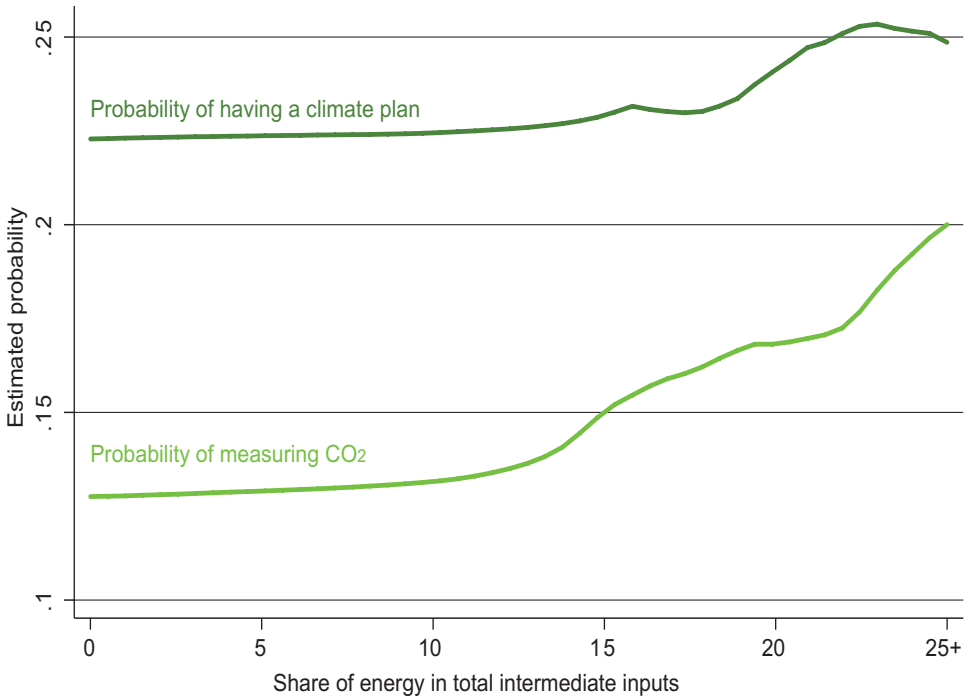


Source: Annual Business Survey of Economic Impact.
Note: Kernel-weighted local polynomial smoothing estimates.

This shows that across the whole distribution, having a climate plan is somewhat more common at all size points than measuring CO_2 emissions. Both follow broadly the same path however, rising sharply as firm size increases. Again, this is in keeping with the results of Siedschlag and Yan (2020 and 2021) on green investment determinants.

One explanation for the strong link between firm size and climate planning is that larger firms use larger amounts of energy and therefore the benefits to greater energy efficiency are more immediate to them than to smaller (or rather less energy intensive) firms. We look in Figure 8 at the overall probabilities of having a climate plan and measuring emissions across the range of firm energy intensities. In this case, the probability of having a climate plan is relatively flat across most levels of energy intensity until the point at which energy accounts for over 20 per cent of expenditures. The relationship between energy intensity and measurement of CO_2 is stronger, beginning to increase steadily once energy begins to account for over one-eighth of expenditures.

Figure 8: Probability of Having a Climate Plan and Measuring CO_2 by Energy Intensity



Source: Annual Business Survey of Economic Impact.
Note: Kernel-weighted local polynomial smoothing estimates.

Having noted the relationship between energy intensity and climate action plans, we would expect to see a variation in their use across sectors. Table 3 shows how the responses to the three survey questions on climate were answered across broad sector groups. In the responses to whether the firm has a climate action plan in place, however, we find relatively less variation across sectors than we did across firm size groups. Firms in the food, drink and primary production sector were the most likely to report having a climate action plan with over one-third responding yes. This was followed by modern manufacturing where one-quarter of firms had a climate action plan in place. The relatively high rate of "don't know" responses is informative as it suggests that if a plan is in place in these firms, it may not have a high degree of visibility.

When it comes to attitudes towards the importance of having a climate plan in place, we find that firms are much more likely to agree that it is very or moderately important, compared to the share reporting that such a plan is currently in place. Climate action importance is particularly strong in the food, drink and primary production sector and reported as relatively less important for firms in services sectors. Likewise, firms in the services sectors (ICT and business/professional services) are amongst the least likely to measure CO_2 emissions.

Table 3: Climate Actions and Attitudes by Sector (% of Sector Responses)

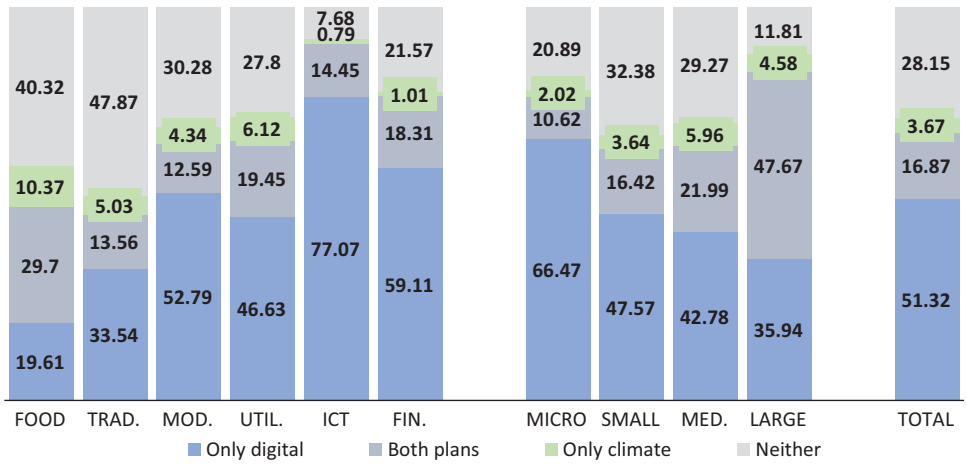
	Food, drink & primary	*Trad manuf.*	*Modern manuf.*	*Utilities*	*ICT*	*Business, financial & prof.*	*Total*
Does firm have a climate plan?							
No	51.8	73.1	63.1	65.8	74.0	69.9	68.9
Yes	36.4	18.8	25.5	24.3	14.7	19.2	20.6
Don't know	11.8	8.0	11.4	9.9	11.3	11.0	10.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Climate plan importance to firm							
Not important	6.2	16.4	20.7	13.1	32.3	29.8	22.4
Moderately	47.9	57.6	57.4	54.2	51.6	46.1	52.1
Very	45.9	26.0	21.9	32.7	16.1	24.1	25.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Does firm measure CO_2?							
No	62.2	80.8	68.3	68.5	84.1	80.1	77.5
Yes	21.7	9.4	18.9	18.0	8.4	11.0	12.3
Don't know	16.1	9.8	12.9	13.5	7.5	9.0	10.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Annual Business Survey of Economic Impact.

3.3 Overlap of Digital and Climate Plans

In this section, we look at some summary evidence of the overlap between digitalisation and climate action planning. Figure 9 shows how many firms have either a digital plan only, a climate plan only, both plans, or have neither plan in place. In the overall sample, 17 per cent of firms have both plans. Most notably, the overlap is the largest among large businesses where almost half of them have both plans. There are very few firms with only a climate plan – the majority of firms with climate plans also have a digital plan in place. This shows some indicative evidence that the two strategies are correlated at the firm-level. Having a digital plan without a climate plan is however more common, perhaps suggesting that this pillar of the twin transition is more accessible to firms than is climate-related investment. As the data are cross-sectional, we cannot explore if having one plan leads in time to adoption of the other or if decisions are made simultaneously, but this is a question that could be investigated in time as more data become available.

Figure 9: Overlap Between Digital and Climate Plans by Sector and Size Category (% of Responses Excluding Firms With "Don't Know" or Missing Data in Either of Two Underlying Variables)

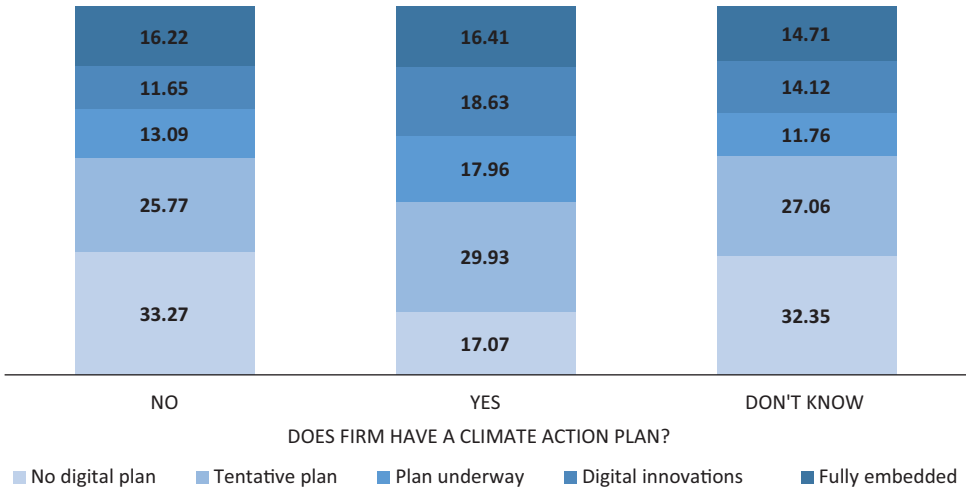


Source: Annual Business Survey of Economic Impact.
Note: Sectors: Food, drink and primary production; Traditional manufacturing; Modern manufacturing; Energy, water, waste and construction; Information, comm. and computer services; Business, financial and other services.

Figure 10 explores this overlap further by looking how the degree of digitalisation readiness corresponds with whether a climate action plan is in place. A substantially smaller proportion of the firms with a climate action plan in place reported that they had no digitalisation plan. The link is less apparent, however, at the highest degree of digitalisation (fully embedded) where the proportion is

approximately equal whether or not the firm has a climate action plan in place. These patterns of overlap broadly reflect the findings by Axenbeck and Niebel (2021) of a small but statistically significant negative link between indicators of firm-level digitalisation and the energy intensity of the firm. The next section looks more deeply at the potential firm factors linked to both digital and climate actions and the linkages between them.

Figure 10: Digital Readiness and Climate Plan (% of Responses)



Source: Annual Business Survey of Economic Impact.

IV ECONOMETRIC ANALYSIS

In this section we explore the links between firm characteristics and both digital and climate plans or actions. As in the descriptive analysis above, we first look at each of the two strategies separately and then the interaction between them. We look at several outcome variables on both digital and climate attitudes and actions and then at the determinants of having both plans simultaneously. Given the categorical nature of these variables (with two to five potential outcomes), we use either logit, ordered logit or multinomial logit specifications as the most appropriate for each question structure. For each outcome, we examine the relationship with firm employment (including squared term), productivity (measured as value-added per employee), R&D intensity, five-year turnover growth and energy intensity, nationality of ownership and sector.

4.1 Estimation of Digital Readiness

As the responses to the question on digital readiness were on a 5-point scale, we use an ordered logit specification to examine which characteristics are most

associated with increasing levels of digital preparedness. In this section, we present the results as average marginal effects.[2] The average marginal effects for determinants of firm digitalisation are presented in Table 4. The results for each response category are shown across columns 1a to 1e in Table 4 and were estimated as a single regression. The final column (specification 2) in Table 4 combined the categories of digital readiness into a single indicator of whether the firm has a digital plan or not, to apply a binary logit specification. We assign a zero to firms responding that they had no digital plan in place and a 1 to those with any plan, including a tentative one, in place.

For both the five-point scale and the binary outcomes, the results show a significant positive relationship between firm size and the likelihood of having a digital plan in place, and of having a higher degree of digital readiness. Higher firm productivity (proxied by value-added per employee) is also positively related to greater digital readiness, although this is more apparent in having some type of digital plan in place than it is for the difference in probabilities across the 5-point scale of digital readiness. Firms with greater research and development expenditure (scaled by firm sales) are considerably more likely to have higher degrees of digital readiness. The positive relationships between degree of digitalisation and firm performance characteristics such as size, productivity, exporting and R&D are all in keeping with a wide range of existing literature on the determinants of investment in digital technologies (e.g. Adarov *et al*., 2022; Cirillo *et al*., 2021; DeStefano *et al*., 2017). Given the cross-sectional data that we use, we are unable to look deeper into the potential complexities of the relationship between digitalisation and firm productivity, with some evidence (e.g. Gal *et al*., 2019) that there is a two-way relationship with digital technologies also contributing to further productivity within the firm. Our result on energy intensity mirrors that of Axenbeck and Niebel (2021) who also find a small but statistically significant negative link between indicators of firm-level digitalisation and the energy intensity of the firm.

We also control for a longer-term growth trajectory of the firm using average turnover growth between 2015 and 2020, which shows that higher growth firms are more likely to be more digitally advanced (although the direction of causation may go in both directions here). This question allows us to exploit some of the time series of the survey prior to the introduction of digitalisation and climate-related questions in 2020. We also find that the patterns across the sector controls are broadly in line with those noted in the summary statistics even once other firm characteristics are accounted for, with services sector firms considerably more likely to have higher levels of digitalisation in place (relative to the reference sector of traditional manufacturing).

[2] The corresponding logistic regression coefficients and predicted values across a range of different values are available on request.

Table 4: Digitalisation Regression Average Marginal Effects Results

	(1a)	*(1b)*	*(1c)*	*(1d)*	*(1e)*	*(2)*
			Digital readiness			
	No plan	*Tentative plan*	*Defined plan*	*Innovation strategy*	*Fully embedded*	*Have any digital plan*
ln(empl)	–0.015**	0.002*	0.004***	0.005***	–0.015**	0.030***
	(0.006)	(0.001)	(0.001)	(0.002)	(0.006)	(0.008)
VA per empl.	0.802*	–0.138*	–0.007	0.022*	0.038*	0.288**
	(0.447)	(0.077)	(0.004)	(0.012)	(0.021)	(0.117)
Exporter dummy	0.367***	–0.065**	–0.000	0.011**	0.018**	0.092***
	(0.141)	(0.025)	(0.001)	(0.005)	(0.007)	(0.028)
Foreign dummy	0.507	–0.082*	–0.012	0.011**	0.022*	0.073
	(0.310)	(0.046)	(0.012)	(0.005)	(0.013)	(0.067)
5-year growth	0.422***	–0.073***	–0.004*	0.012***	0.020***	0.090**
	(0.152)	(0.026)	(0.002)	(0.004)	(0.007)	(0.037)
R&D intensity	2.850***	–0.490***	–0.024**	0.078***	0.134***	0.438***
	(0.359)	(0.062)	(0.009)	(0.013)	(0.018)	(0.094)
Energy intensity	–2.595**	0.446**	0.022	–0.071**	–0.122**	–0.269
	(1.148)	(0.197)	(0.014)	(0.032)	(0.054)	(0.227)
5-year energy change	–13.899**	2.391**	0.118	–0.380**	–0.652**	–1.859
	(6.524)	(1.121)	(0.072)	(0.181)	(0.308)	(1.405)
Food, Drink & Primary	–0.080	0.018	–0.005	–0.005	–0.004	–0.030
	(0.141)	(0.033)	(0.009)	(0.009)	(0.008)	(0.036)
Modern Manuf.	0.399**	–0.089**	0.015***	0.026**	0.025**	0.102**
	(0.158)	(0.035)	(0.006)	(0.010)	(0.010)	(0.041)
Energy, Water, Waste	0.519***	–0.115***	0.016***	0.033***	0.033***	0.148***
	(0.185)	(0.040)	(0.005)	(0.012)	(0.013)	(0.051)

Table 4: Digitalisation Regression Average Marginal Effects Results (Contd.)

	(1a)	*(1b)*	*(1c)*	*(1d)*	*(1e)*	*(2)*
			Digital readiness			
	No plan	*Tentative plan*	*Defined plan*	*Innovation strategy*	*Fully embedded*	*Have any digital plan*
ICT	2.062***	–0.345***	–0.098***	0.071***	0.141***	0.358***
	(0.135)	(0.022)	(0.014)	(0.008)	(0.012)	(0.027)
Business, Fin. & Prof.	1.384***	–0.267***	–0.025**	0.073***	0.099***	0.244***
	(0.131)	(0.024)	(0.010)	(0.008)	(0.010)	(0.030)
Observations			2,058			2,058
Pseudo R-squared			0.121			0.169

Source: Annual Business Survey of Economic Impact.
Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Climate Action Regression Average Marginal Effects Results

	(3a)	*(3b)*	*(3c)*	*(4)*	*(5)*	*(6)*	*(7)*
	Importance of climate action			*Have climate plan*	*Measure CO_2*	*On-site renewab.*	*Important, no action*
	Not	*Moderate*	*Very*				
ln(empl)	–0.031***	–0.007***	0.038***	0.058***	0.058***	0.028***	–0.036***
	(0.007)	(0.003)	(0.007)	(0.007)	(0.006)	(0.006)	(0.010)
VA per empl.	0.030	0.004	–0.034	0.293***	0.182***	0.048	–0.180
	(0.081)	(0.010)	(0.091)	(0.072)	(0.056)	(0.073)	(0.142)
Exporter dummy	0.000	0.000	–0.000	0.035	–0.047*	–0.001	0.046
	(0.022)	(0.003)	(0.025)	(0.027)	(0.025)	(0.024)	(0.036)
Foreign dummy	0.050	–0.001	–0.049	0.002	0.043**	–0.073***	–0.212**
	(0.060)	(0.009)	(0.052)	(0.024)	(0.021)	(0.017)	(0.097)

Table 5: Climate Action Regression Average Marginal Effects Results (Contd.)

	(3a)	*(3b)*	*(3c)*	*(4)*	*(5)*	*(6)*	*(7)*
	Importance of climate action			*Have climate plan*	*Measure CO_2*	*On-site renewab.*	*Important, no action*
	Not	*Moderate*	*Very*				
5-year growth	–0.042*	–0.005	0.047*	–0.004	0.029	0.000	0.012
	(0.025)	(0.004)	(0.028)	(0.031)	(0.028)	(0.027)	(0.040)
R&D intensity	–0.014	–0.002	0.015	0.127*	0.054	–0.000	–0.040
	(0.056)	(0.007)	(0.063)	(0.066)	(0.052)	(0.061)	(0.097)
Energy intensity	–0.284	–0.035	0.319	0.155	0.415***	0.291*	–0.032
	(0.182)	(0.025)	(0.204)	(0.245)	(0.146)	(0.161)	(0.305)
5-year energy change	1.048	0.129	–1.177	–2.949**	–1.287	–0.433	2.009
	(1.031)	(0.135)	(1.157)	(1.229)	(0.979)	(1.018)	(1.723)
Food, Drink & Primary	–0.082***	–0.077***	0.160***	0.142***	0.104***	0.075***	–0.172***
	(0.015)	(0.018)	(0.031)	(0.034)	(0.027)	(0.028)	(0.037)
Modern Manuf.	0.015	0.004	–0.019	0.005	0.030	0.057**	0.028
	(0.024)	(0.006)	(0.030)	(0.030)	(0.024)	(0.027)	(0.045)
Energy, Water, Waste	–0.014	–0.006	0.020	0.002	0.035	0.150***	–0.084
	(0.030)	(0.015)	(0.045)	(0.047)	(0.039)	(0.051)	(0.059)
ICT	0.112***	–0.004	–0.108***	–0.065**	–0.028	–0.026	0.011
	(0.024)	(0.007)	(0.022)	(0.026)	(0.020)	(0.020)	(0.039)
Business, Fin. & Prof.	0.061***	0.007	–0.068***	–0.000	0.020	0.003	–0.035
	(0.023)	(0.005)	(0.025)	(0.028)	(0.022)	(0.022)	(0.038)
Observations		2,100		2,311	2,318	2,008	1,658
Pseudo R-squared		0.041		0.085	0.153	0.066	0.032

Source: Annual Business Survey of Economic Impact.
Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.2 Estimation of Firm Climate Actions

We next examine how these firm characteristics are associated with the different measures of climate adaption action. The average marginal effects are shown in Table 5. Four different dependent variables are examined: a 3-point scale of the importance of climate action (columns 3a-3c, estimated with ordered logit); a binary indicator for whether the firm has a climate plan in place (column 4); a binary indicator for whether the firm measures their CO_2 emissions (column 5); and an indicator for whether the firm provides some of its own energy through on-site renewables (column 6). The final column (7) looks at the firm characteristics associated with reporting a positive attitude to climate action (agreeing to its importance) but without taking any of the specific actions mentioned in the survey (no climate plan, not measuring CO_2, no on-site renewables). The first of the specifications in Table 5 is estimated using an ordered logit and the others use a logit specification. The same firm characteristics are used as in the digital estimations. Some of the regressions have relatively low pseudo-R-squared. However, this is common in cross-section studies including those in the related literature with similar empirical approach.[3]

A number of differences are apparent between the characteristics associated with digitalisation and those associated with the different climate responses. The key point of similarity is in firm size, which is strongly positively related to all of the climate strategies examined. Firm productivity is also positively linked to climate actions in the case of having a climate plan in place and measuring CO_2 emissions, but does not impact how the firm ranks the importance of having a climate plan in place. The relationship between firm characteristics and climate actions is broadly similar to the findings of Siedschlag and Yan (2020), who examined the determinants of investments in green technologies.

In contrast to the results on digitalisation, R&D intensity is significant only in the case of having a climate plan but not for the other indicators, and turnover growth has limited effect. As anticipated, energy intensity is significantly related to measurement of emissions and generation of own on-site energy. More surprisingly, we do not find any link between energy intensity and having a climate plan or ranking climate plans as important to the business once the other firm characteristics have been controlled for.

Examining the characteristics of the group of firms reporting a positive disposition towards the importance of climate action but not having any specific plan in place are shown in the final column of Table 5. These are consistently found to be smaller firms and significantly more likely to be Irish-owned. There is little significant variation across sectors with the exception of the food, drink and primary sector, where fewer firms fall into this category.

[3] For example, Douenne and Fabre (2020), Siedschlag and Yan (2021) or Mole *et al.* (2017).

4.3 Overlap of Digital and Climate Plans

The final element of the analysis is to examine the correlation between having a climate and a digital plan while controlling for a range of other firm characteristics. We approach this question in two separate ways. In first approach we use multinomial logit, with variable with four possible outcomes (no plans, only digital, only climate, both plans) as described in Section 3.3. This way we investigate the characteristics of firms based on each outcome. In our second approach we use a digital readiness index as explanatory variable of climate action, to see if more digital firms are more likely to have climate action, while controlling for all other firm characteristics.

The average marginal effects reported in Table 6 show the results of the multinomial logit regression. The regression compares firms with neither a digital nor climate plan to those with a digital plan only, a climate plan only and firms that have both. This allows for the firm characteristics to vary in their impact for the different options. These results show a strong correlation of both strategies at the firm level, particularly as firm size increases. Where firms have one of a digital or climate plan in place, the digital plan is more likely across a range of firm characteristics. As the data are cross-sectional, we cannot however draw any line of causation from one to the other. The correlation is however one of potential importance in terms of how policy might be coordinated to achieve both aims simultaneously.

The final set of results in Table 7 again looks at climate action outcomes. This table is analogous to Table 5, with the addition of four dummies that measure firm's digital readiness. The inclusion of digital readiness does not substantially change the predictions for other covariates. Thus, this section will only focus on how digital readiness correlates with climate action, while controlling for other observable firm characteristics. Because we are limited to cross-sectional data, we cannot establish the direction of causality or if some unobserved characteristics are driving both climate and digital action.

The predictions of digital-readiness dummies are shown in Figures 11 and 12. The results show that more digital firms are significantly more likely to say that climate action is very important for their business, more likely to have climate action plan, measure CO_2 and have on-site renewables, even after controlling for other firm characteristics. However more digital firms are less likely to say climate action is important while also not reporting any of the three climate actions in the survey. In all five regressions, the probabilities increase rapidly at lower levels of digital readiness, while the highly digital companies are not more involved in climate action compared to moderately digital-ready companies.

Table 6: Overlap of Digital and Climate Plans, Average Marginal Effects Results

	(8a) Neither	*(8b) Only digital plan*	*(8c) Only climate plan*	*(8d) Both plans*
ln(empl)	–0.030***	–0.016*	0.001	0.044***
	(0.008)	(0.009)	(0.004)	(0.008)
VA per empl.	–0.301**	0.111	0.017	0.173*
	(0.123)	(0.118)	(0.040)	(0.093)
Exporter dummy	–0.080***	0.032	–0.006	0.053**
	(0.029)	(0.032)	(0.015)	(0.026)
Foreign dummy	0.011	–0.197*	–0.041***	0.227**
	(0.085)	(0.104)	(0.005)	(0.109)
5-year growth	–0.078**	0.071**	0.005	0.003
	(0.037)	(0.036)	(0.023)	(0.034)
R&D intensity	–0.307***	0.243***	–0.130	0.194***
	(0.098)	(0.088)	(0.082)	(0.073)
Energy intensity	0.403*	–0.352	–0.041	–0.010
	(0.229)	(0.285)	(0.103)	(0.249)
5-year energy change	1.629	0.466	–0.028	–2.067
	(1.414)	(1.571)	(0.733)	(1.273)
Food, Drink & Primary	–0.011	–0.133***	0.051**	0.093***
	(0.038)	(0.037)	(0.020)	(0.033)
Modern Manuf.	–0.105***	0.123***	0.004	–0.022
	(0.041)	(0.043)	(0.018)	(0.032)
Energy, Water, Waste	–0.142***	0.134**	–0.004	0.011
	(0.051)	(0.057)	(0.021)	(0.043)
ICT	–0.322***	0.378***	–0.035***	–0.022
	(0.028)	(0.034)	(0.012)	(0.028)
Business, Fin. & Prof.	–0.217***	0.215***	–0.030***	0.033
	(0.031)	(0.035)	(0.011)	(0.029)
Observations		1,897		
Pseudo R-squared		0.130		

Source: Annual Business Survey of Economic Impact.
Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Digital Readiness as Corelate of Climate Action, Average Marginal Effects Results

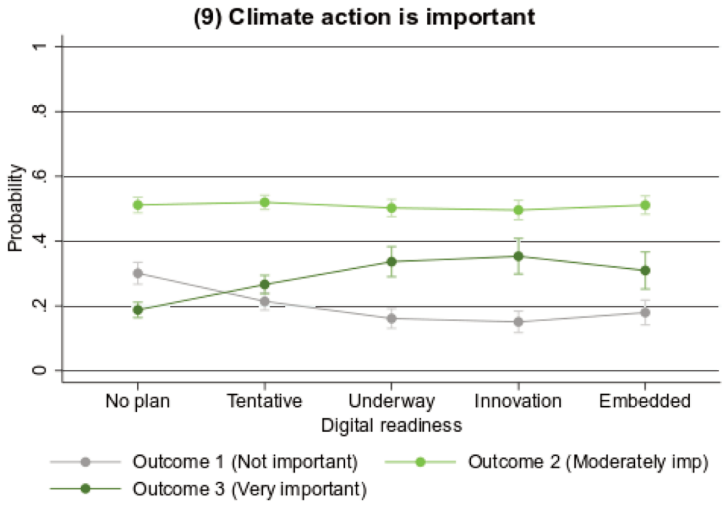
	(9a)	(9b)	(9c)	(10)	(11)	(12)	(13)
	Importance of climate action			Have climate plan	Measure CO_2	On-site renewab.	Important no action
	Not	Moderate	Very				
Digital tentative plan	–0.087***	0.008*	0.079***	0.119***	0.037**	0.029	–0.090***
	(0.019)	(0.005)	(0.017)	(0.021)	(0.017)	(0.020)	(0.032)
Digital defined plan	–0.140***	–0.009	0.149***	0.180***	0.085***	0.069**	–0.114***
	(0.022)	(0.009)	(0.026)	(0.029)	(0.024)	(0.030)	(0.039)
Digital innovation	–0.150***	–0.016	0.166***	0.248***	0.093***	0.093***	–0.207***
	(0.023)	(0.012)	(0.030)	(0.035)	(0.027)	(0.033)	(0.041)
Digital embedded	–0.121***	–0.000	0.122***	0.249***	0.061**	0.029	–0.189***
	(0.028)	(0.008)	(0.032)	(0.037)	(0.027)	(0.031)	(0.044)
ln(empl)	–0.029***	–0.005*	0.034***	0.038***	0.048***	0.019***	–0.034***
	(0.007)	(0.003)	(0.007)	(0.008)	(0.006)	(0.007)	(0.011)
VA per empl.	0.065	0.008	–0.072	0.112	0.147**	–0.104	–0.170
	(0.081)	(0.010)	(0.091)	(0.094)	(0.074)	(0.103)	(0.147)
Exporter dummy	0.004	0.000	–0.004	0.033	–0.050*	–0.010	0.046
	(0.022)	(0.003)	(0.025)	(0.029)	(0.026)	(0.027)	(0.037)
Foreign dummy	0.066	–0.004	–0.062	0.123	0.246***	–0.075*	–0.207**
	(0.058)	(0.012)	(0.046)	(0.088)	(0.091)	(0.040)	(0.098)
5-year growth	–0.040	–0.005	0.044	–0.015	0.036	–0.012	0.018
	(0.025)	(0.003)	(0.027)	(0.034)	(0.029)	(0.030)	(0.040)
R&D intensity	0.052	0.006	–0.058	–0.033	0.024	–0.040	0.042
	(0.058)	(0.007)	(0.065)	(0.075)	(0.056)	(0.068)	(0.101)
Energy intensity	–0.321*	–0.039	0.360*	0.065	0.328**	0.248	–0.048
	(0.182)	(0.026)	(0.203)	(0.243)	(0.160)	(0.183)	(0.309)

Table 7: Digital Readiness as Corelate of Climate Action, Average Marginal Effects Results (Contd.)

	(9a)	*(9b)*	*(9c)*	*(10)*	*(11)*	*(12)*	*(13)*
	Importance of climate action			*Have climate plan*	*Measure CO_2*	*On-site renewab.*	*Important no action*
	Not	*Moderate*	*Very*				
5-year energy change	0.721	0.087	–0.808	–1.704	–1.896**	–1.087	1.261
	(1.045)	(0.129)	(1.170)	(1.350)	(0.959)	(1.117)	(1.747)
Food, Drink & Primary	–0.079***	–0.099***	0.178***	0.167***	0.080***	0.079**	–0.169***
	(0.013)	(0.020)	(0.031)	(0.037)	(0.029)	(0.032)	(0.035)
Modern Manuf.	0.026	0.011	–0.038	–0.036	–0.022	0.025	0.043
	(0.022)	(0.009)	(0.031)	(0.038)	(0.026)	(0.034)	(0.046)
Energy, Water, Waste	0.000	0.000	–0.001	–0.018	0.011	0.145***	–0.064
	(0.029)	(0.017)	(0.046)	(0.049)	(0.037)	(0.054)	(0.059)
ICT	0.168***	–0.008	–0.161***	–0.133***	–0.037*	–0.044*	0.099**
	(0.026)	(0.010)	(0.024)	(0.030)	(0.022)	(0.024)	(0.042)
Business, Fin. & Prof.	0.094***	0.014**	–0.108***	–0.063**	0.004	–0.016	0.013
	(0.023)	(0.007)	(0.025)	(0.031)	(0.023)	(0.025)	(0.039)
Observations		2,054		2,054	2,054	1,888	1,884
Pseudo R-squared		0.056		0.104	0.144	0.063	0.046

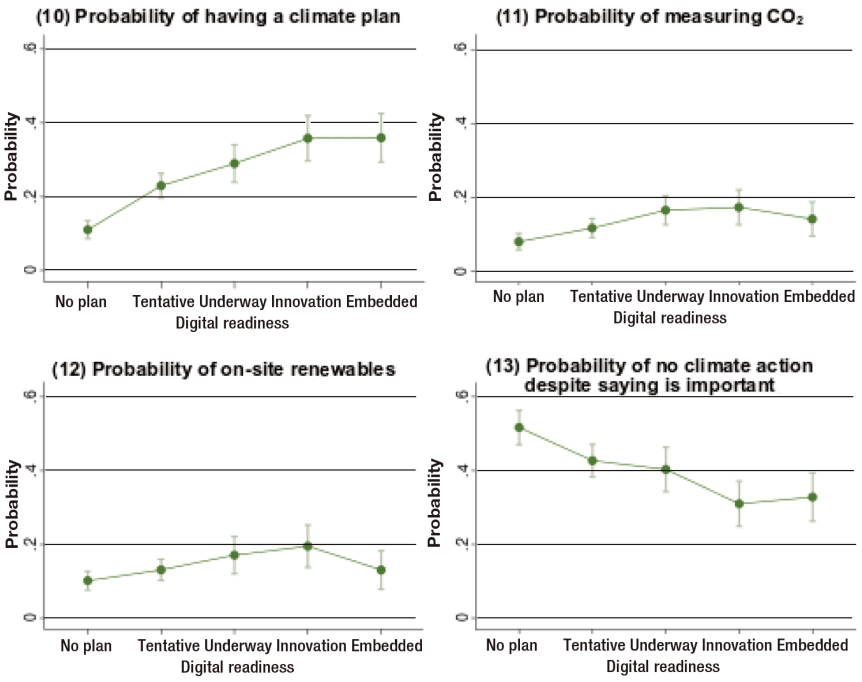
Source: Annual Business Survey of Economic Impact.
Note: Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Figure 11: Predictive Margins of Digital Readiness of Ordered Logit Regression on Importance of Climate Action



Source: Annual Business Survey of Economic Impact.

Figure 12: Predictive Margins of Digital Readiness of Logit Regressions on Climate Action



Source: Annual Business Survey of Economic Impact.

V CONCLUSIONS AND POLICY IMPLICATIONS

Firms across the world are facing a "twin transition" in the form of structural shifts in increased digital technologies and in the adaptation to climate change (Revoltella, 2020, p.6). This paper looks at the how firms in Ireland are undertaking actions to meet these challenges. We examine the extent to which firm characteristics are related to the degree of digital usage and how firms have developed climate plans and actions such as measuring their CO_2 emissions and having on-site renewables like solar panels or heat pumps. A key focus of the paper is how actions to meet these dual challenges are correlated within firms. The potential intersection of the twin transition challenges has been emphasised in much discussion of policy implications, particularly in regard to the potential for digital technologies to help reduce reliance on high-carbon sources of energy (Bernstein and Madlener, 2010; Dwivedi *et al.,* 2022; Elkerbout *et al.*, 2021). However, data constraints have meant that empirical analysis has tended to examine one or the other of the two challenges (e.g. Boone and Revoltella, 2019, on green technologies, or Gal *et al*., 2019 on digitalisation). The contribution of this paper is therefore to take advantage of a novel dataset that allows us to gain insight into the determinants of firm strategies with regard to both of these challenges and, most importantly, thereby to identify complementarities between them.

This research examines this overlap, initially examining actions on both digitalisation and climate actions separately and then exploring if there is evidence suggesting that they are used as complementary strategies at the level of the individual firm. Our most consistent finding relates to the strong relationship between firm size and all measures of digitalisation and of climate action planning. Higher degrees of digital readiness are demonstrated in particular by companies with higher expenditure on productivity and R&D. This is in keeping with a number of the related papers in the literature on each strategy individually (e.g. Siedschlag and Yan, 2021 on green investments, and Cirillo *et al*., 2021 on digital technologies). Another factor that appears to strongly motivate climate actions is the proportion of firm expenditures that are allocated to energy.

On the key question of overlap between digitalisation and climate planning, we find a strong correlation between pursuing both strategies simultaneously while controlling for a range of other firm characteristics such as size which impacts both directly. The correlation is of potential importance to policy design in terms of having a holistic approach to addressing both challenges in a complementary way. One caveat to the analysis is that the short time span of data available did not allow us to infer causation from one strategy to another or to examine the ordering, if any, of the firm's actions.

Specifically on the climate transition challenge, we find a relatively sizeable gap between the share of firms that regard addressing the climate challenge as being important and those that have taken active steps such as developing a climate action

plan or measuring CO_2 emissions. Almost twice as many firms respond that a climate response plan is either very or moderately important than report having a climate action plan in place. These are typically smaller firms, suggesting this is a group requiring targeted policy support if the gap between a positive attitude to climate planning and action at a firm level is to be bridged.

Examples of returns to government policy initiatives in related domains, such as those targeted at encouraging firms to invest more in strategically important R&D, could provide a template for the effective design of policies targeting joint investment in green and digital technologies. Work on the impact of R&D supports has been evaluated by Mulligan *et al.* (2022) and Lenihan *et al*. (2023). The former research shows the impact of publicly funded research centres in driving research collaborations with firms. This type of intervention is a specific example of how capacity can be developed in firms and hence overcome the skills gap identified in other research. Lenihan *et al.* (2023) shows that targeting of direct grants and tax credits towards specific activities such as R&D can increase performance. An important point in policy design is that, while a range of different instruments and initiatives are necessary to maximise impact across different activities and sectors, maintaining consistency and coherence across the portfolio policy interventions can generate substantial additionality in terms of impact (Mulligan *et al.,* 2017 and 2019).

The consistent finding that actions on both digitalisation and climate change are less likely amongst smaller firms is a key one for policy development. The greater challenges facing smaller firms in undertaking investments in new technologies, be they green or digital, has been highlighted in other studies in both of these areas (e.g. Gal *et al*., 2019; De Stefano *et al.*, 2017; Mollet, 2021), with the need for complementary skills identified as one potential barrier. In addition, a deeper understanding is needed of the extent to which uncertainty about digital and climate-friendly technologies (given their rapid evolution) is delaying investments, relative to other barriers to general investment such as access to finance. This suggests a fruitful avenue of further research in this area.

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