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The anatomy of employment in Ireland:

How has the structure of the labour market changed from crisis to crisis?

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THE ANATOMY OF EMPLOYMENT IN IRELAND: HOW HAS THE STRUCTURE OF THE LABOUR MARKET CHANGED FROM CRISIS TO CRISIS?

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ABSTRACT
This study examines how the anatomy of employment in sectoral and occupational terms has been changing in terms of the structure and nature of jobs in Ireland from the 2008 Global financial crisis up until the crisis precipitated by Covid-19. In particular, we focus upon the effects of the major present and forecast structural trends of automation and the transition to a less carbon intensive society between 2007/8 and 2019. In the case of automation, the evidence for change is somewhat mixed. The data do not indicate net employment losses, although there is evidence that would support theories that covert technological unemployment has taken place to some extent. Employment also appears to have been biased to high-skilled, non-routine abstract and service work, consistent with labour substitution theories positing greater displacement where work had higher proportions of routine tasks which are more readily automatable.

Where the green transition is concerned, we find that such a structural shift is more prospective than currently in evidence. In the Irish case, the data suggest that the Republic of Ireland may have begun a process of decoupling economic activity and employment from emissions, though this is still not occurring at the requisite rate. Ireland also appears to be showing growth in terms of "green employment" according to more restrictive industry-based definitions of green jobs, and other occupation/skills-based definition would likely show a more significant employment profile.

While our examination of recent labour market trends is not suggestive of mass unemployment arising from these structural forces, these trends may have more significant/disruptive implications for certain workers. In light of these differential impacts, a common Just Transition style approach could ensure that broader cohorts benefit from these shifts.

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[1] Esmé Sheridan and Ian Walsh carried out this piece of work during their time working with the NERI on an internship from their studies at UCD.

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SECTION 1: INTRODUCTION AND CONTEXT

The Covid-19 crisis hit Europe in the first quarter of 2020. Since these first cases were notified, the world has faced the single biggest public health emergency of our lifetimes. In an attempt to slow the spread of Covid-19 and following measures put into place across the world the Republic of Ireland put into place a 'national lockdown' encompassing confinement measures and restrictions on our economic and social activities. These measures led to a previously unfathomable disruption to our labour market as the Government effectively ordered all but essential workers to stop going to work. The Government advised that all of those who could carry out their work from home should do so. For those who could not continue to work from home the Government still mandated workers not to attend work and ordered businesses to close. As mentioned above there was an exception made for essential workers and essential businesses - who were allowed/required to continue to operate - albeit were required to follow new public health guidance in doing so which, of course, in many cases, meant changes to working practices and so on were required.

Now, at the time of writing, we are more than one year on from the initial national lockdown, and have since been in and out of various levels of lockdown and following various public health measures such as the wearing of face masks in public spaces and exercising social distancing. However, as we optimistically approach the beginning of the end of the pandemic with vaccinations being rolled out across the country, increased attention will necessarily have to be given to the likely legacy affects which the pandemic will have on our labour

market, not just in terms of the quantity of work, but also on the types of jobs that workers do.

Economists and policy makers are querying whether or not the Covid-19 crisis will ultimately impact our labour market. There are particular concerns as to whether there will be a longer-term structural increase in unemployment. Others are raising the possibility of whether the impact will be principally one of labour market restructuring. This would involve the overall net number of people in employment being sustained or at least recovered in the short to medium term, whilst the economy adjusts and the structure of employment changes. This outcome would see the destruction of jobs in particular sectors and occupations and the creation of new jobs in others. Whilst, obviously it remains to be seen what the longer-term consequences of Covid-19 will be for our labour market, it is not the first time that economists have been faced with questions, albeit in the context of other factors.

For example, following large scale reductions in the level of employment, and in particular in the construction and manufacturing sectors, following the 2008 global financial crisis, recent years have shown headline labour market indicators to have been recovering well. Toward the end of 2019 a number of commentators remarked that the level of employment in Ireland could be described as nearing full employment and suggestions that the labour market was beginning to overheat (Byrne and McIndoe-Calder, 2019).

However, despite the fact that levels of employment had recovered does not mean that the structure and anatomy of employment returned to how it was before. The recovery following the 2008 economic crisis brought with it a reallocation in terms of the structure of employment meaning that the nature of the activity and the types of jobs which workers were involved changed. In this sense, during this recessionary period the economy went through an adjustment and in doing so the structure of employment and the nature of economic activity in which workers were involved changed significantly as jobs were destroyed during the fallout and new jobs were created during the recovery. An obvious example in this regard relates to the fall-out of the 'Construction' sector with the crisis and the significant scale of job losses in this sector, which did not rebound with the recovery.

Further to this, several other 'mega-trends' are well-documented in the literature as having affected or are likely in the future to have a substantial effect on the anatomy and structure of employment across most advanced industrialised economies. These include trends such as:

Deindustrialisation and the rise of the services sector;

The shift to a green economy and the need to reduce carbon emissions;

Technological advancements;

The digital economy;

Globalisation;

Demographic change and an ageing society;

Increased female labour market participation;

The decline of trade unions and collective workplace institutions.

This study will examine how the anatomy of employment has been changing in terms of the structure and nature of jobs in Ireland from the 2008 Global financial crisis up until the crisis precipitated by Covid-19. In particular, this study will focus on examining employment shifts across sectors and occupations. In doing so it will seek to determine the nature of employment shifts and identify some of the factors which may be driving structural changes. Particular attention will be paid to the theoretical impacts which automation technologies and the transition to a low carbon economy have had on the structure and the anatomy of the labour market over this period.

In terms of the impact on the labour market, discussions around technological advancements have mostly been concerned with the possibility that the speed of recent robotic and automation technologies will result in significant increases in unemployment. More recent discussions are beginning to centre around how automation technologies may alter the structure, nature and quality of employment. This paper seeks to assess how labour

market trends in the case of the Republic of Ireland are in line with theoretical propositions in terms of the apparent impact which automation technologies would have in changing the structure of employment.

On the labour market impacts of a transition to a low-carbon economy the consensus across the literature is one which suggests that whilst the longer-term impact may be a positive one in terms of net employment, there will be some job destruction, job creation and indeed job change effects in the short to medium term. In particular, because of the intensity of emissions it is reasonable to infer that there are risks of job destruction to jobs in the 'agriculture and food' and 'transport' sector and opportunities for growth in the 'environmental goods and services sector'.

It is important to note that the 'technology transition' and the 'green transition' are not occurring in isolation from each other or from the other megatrends identified above. Of course, untangling the effects of various megatrends on labour markets is difficult, not least because they are contemporaneous events but also because these trends are often highly interrelated. Nevertheless, in so far as is possible, this paper takes specific interest in how technological advances and the requirement to rapidly transition to a low carbon economy and society are reshaping or have the prospective in the coming years to drastically reshape the labour market and the structure and anatomy of employment.

SECTION 2: AN OVERVIEW OF LABOUR MARKET TRENDS IN THE REPUBLIC OF IRELAND

We begin the empirical analysis in this paper by looking at broad trends in the labour market over the period 2007 through 2019 using key summary indicators including labour market participation, employment, and unemployment data. We then look at sectoral and occupational data allowing us to explore in further detail structural shifts in the labour market overtime and the changing anatomy of employment in Ireland. The data examined covers the period from 2007 through 2019, allowing us to capture both the decline in the labour market owing to the global financial crisis and the nature of the recovery which followed. Data from the Central Statistics Office Statbank is used to monitor summary trends, whilst detailed micro data from the Labour Force survey is used to examine sectoral and occupational transitions.

2.1 Labour market recovery

Much of the analysis in terms of the labour market in 2019 focused upon the strong growth in employment with discussions centred on whether Ireland had reached full employment or full capacity (Taylor, 2019; Power, 2020). In this respect, whilst there is no consensus on what is meant by full employment there was no denying the strong growth in employment and sharp decline in the rate of unemployment. Nevertheless, claims that the labour market was beginning to overheat (Cassidy, 2019; Power, 2020) towards the end of 2019 were a stretch too far.

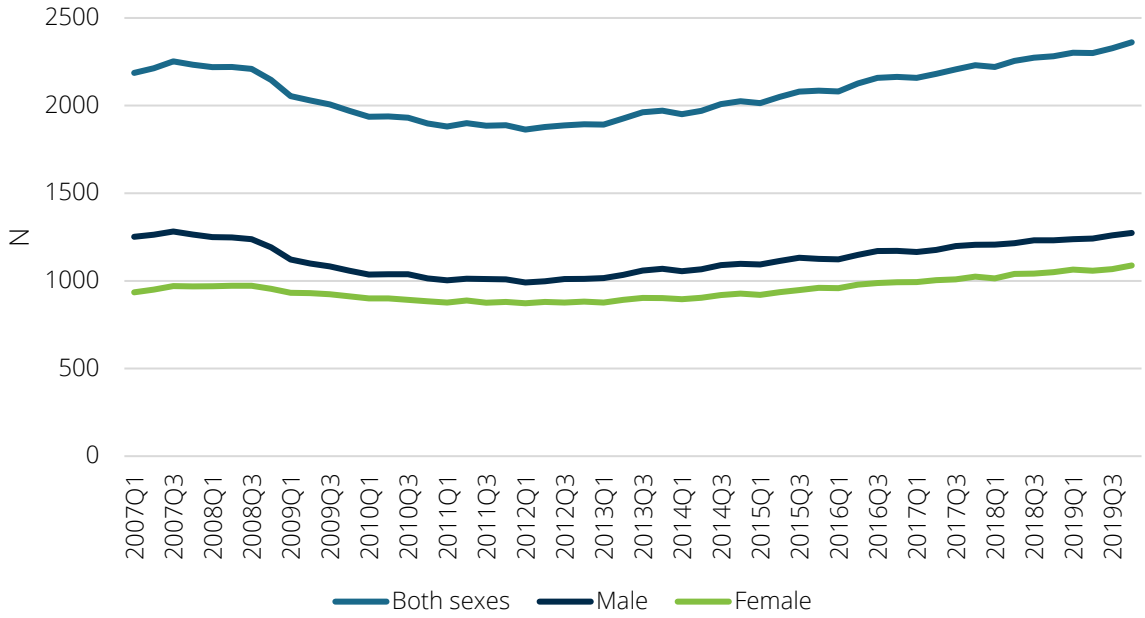
To understand why claims that the Irish labour market were reaching full capacity were exaggerated one needs to read across various indicators in order to get a more accurate account of labour market performance. In summarising analysis of various indicators, we conclude the following. The labour market had been performing very strongly in the years recent to 2019, with a number of key summary measures suggesting that the labour market had finally made a full recovery by 2018, following the 2008 financial crisis. However, analysis of rates of labour market participation would suggest that there was not a full labour market rebound and that fundamentally our labour market remained significantly weakened as a

result of the 2008 financial crisis. In this respect, there had been a rather steep decline in the rate of labour market participation observed in the years since the 2008 financial crisis, which did not reverse with the recovery. Whilst structural factors account for the decline in the labour market participation rate, it nonetheless remains the case that the 2008 financial crisis precipitated a substantive drop in labour supply to the Irish economy.

2.2 Employment and unemployment trends

As shown in Figure 1 below the 2008 global financial crisis brought about a very sharp and somewhat sustained decline in employment numbers, with around 400,000 workers less in employment by Q2 2012 than there was in 2007 there has been a strong recovery in total employment since Q2 2012. By 2019 total employment numbers eventually exceeded the 2007 peak.

Figure 1: Trends in employment (15-64), by gender

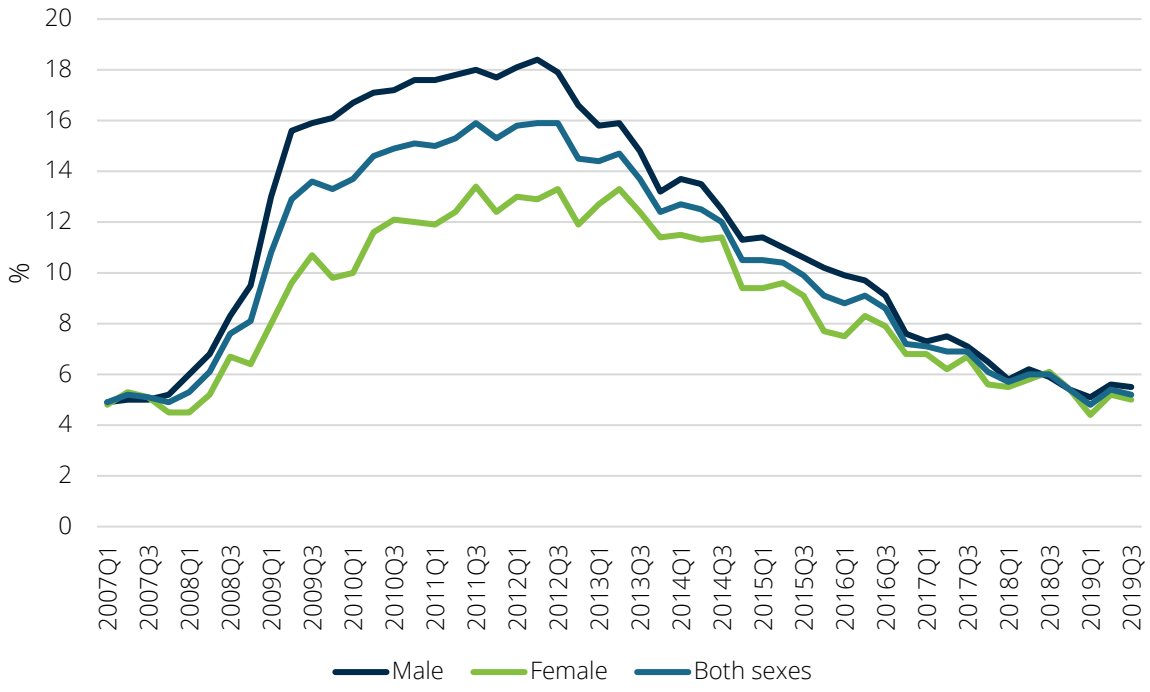


Similarly, whilst climbing rapidly during the recessionary years the rate of unemployment had been declining steadily from 2012 until 2019. Indeed, what is visibly clear from the chart below is that the years since the 2008 financial crisis were exceptional in terms of the climb and descent in the rate of unemployment. Nevertheless, by 2019 the unemployment rate remained slightly above its pre-crisis level, and in particular male unemployment remained

elevated at 5.5% by Q4 2019, compared to 4.9% in Q1 2007.

Thus, while the female unemployment rate rose between 2007 and 2012 (where it peaked at 12.8%), the increase was not as great as that for men. Male unemployment increased dramatically, from the onset of the financial crisis in 2008 until 2012, when it reached 17.8%. Since then the unemployment rate has fallen quite rapidly, and indeed the large gap that emerged between male and females in the recessionary period narrowed almost completely during the recovery. By Q4 2019 the female unemployment rate stood at 5%, compared to 5.5% for males.

Figure 2: Trends in seasonally adjusted unemployment rate (15-74), by gender



2.3 Labour market participation

Figure 3 below presents trends in labour market participation rates including by gender over the period 2007 to 2019. The labour force participation rate is calculated as the labour force divided by the total working-age population (15 +).

In looking at the trends in labour market participation what is most notable is the continued and substantially lower participation rate than before the 2008 global financial crisis. By Q4

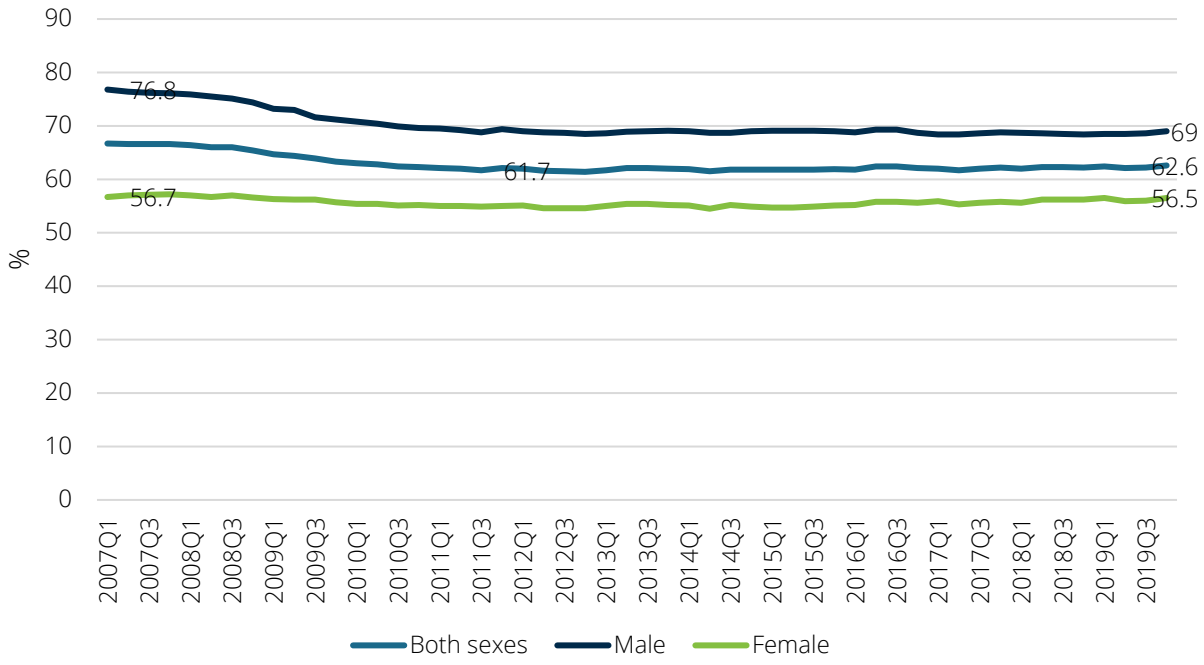
2019 the labour market participation rate stood at 62.7 per cent, notably lower than pre-financial crisis peak which of 67.4 per cent which was recorded in Q3 2007. From then labour market participation rates declined steadily until 2012. Over the period until 2019 the rate

hovered around 61 or 62 per cent. With little to no sign of it returning to pre-recession levels, the trend suggests structural changes in labour market participation.

Particularly interesting in terms of labour market participation rates is the gendered differences over time. By Q4 2019 male labour market participation rates had still not recovered the sharp declines experienced during the financial crisis. Specifically, in Q1 2007 male labour market participation was 76.8%, whilst in Q4 2019 male labour market participation was 69%.

In contrast to male labour market participation, female participation declined only marginally (-2pps) during the 2008 economic crisis. Nevertheless, similar to that seen in the rates of male labour market participation there is also a stagnation in female labour market participation, with little overall change over the period 2007 to 2019.

Figure 3: Trends in labour market participation rate, by gender, 2007-2019

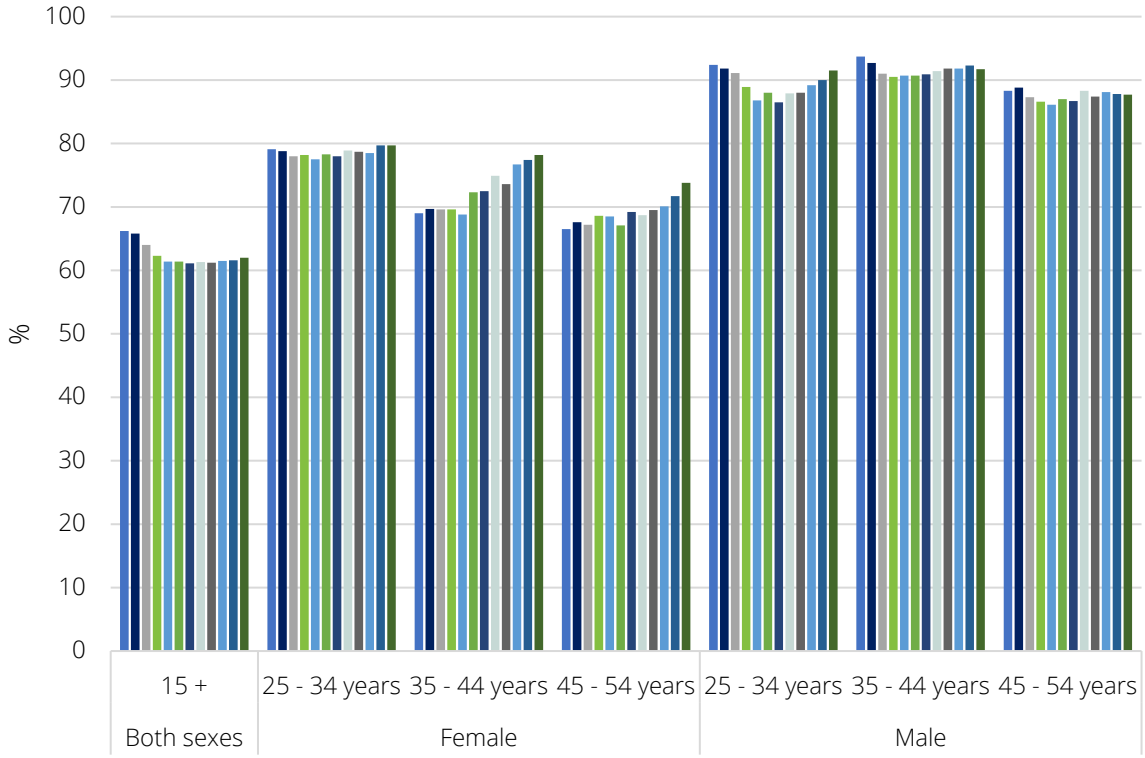


Whilst the overall decline in labour market participation rates tends to be attributed in policy discussions to the impact which two structural factors amongst younger age groups are having on driving the aggregate rate of labour market participation. Firstly, the activity rate of young people (15-24), which used to be extremely high, has converged towards the EU average, as young people have been staying longer in education and training. Secondly, the age distribution of the working age population is less supportive (Byrne and O'Brien, 2016; Faubert, 2019). However, as shown in Figure 3, there has also been a notable decline in labour market participation amongst prime-age working males. Specifically, male labour market participation rates amongst prime working-age males had not recovered by Q1 2019 to what they were in Q1 2007. It is worth making clear, however, that by Q4 2019 the labour market participation rate of those aged 45-54 had surpassed the previous peak (CSO, 2020).

Whilst it difficult to say for certain why prime-working age males were not returning to the labour force even as the labour market was making a strong recovery, one obvious explanation is that the demand for the skills that were lost did not recover. A number of studies have pointed to 'skills-biased technological change' and have identified declining labour market opportunities for low-skilled workers as the most likely explanation for the decline of prime-age male labour force participation (Juhn and Potter 2006). This will be examined further in the next section.

Furthermore, whilst the monumental fall-out of the 'Construction' sector explains the bulk of the jobs that were lost, the fact that rates of labour market participation for prime-age working males had not recovered by 2019 despite the total number of jobs having surpassed the peak prior to the 2008 financial crisis suggests that the labour market recovery did not create a like-for-like to the jobs that were lost, leaving some workers who lost their job unable to find a replacement job as the economy and labour market recovered.

Figure 4: Labour market participation rates for those of prime-working age, by gender, 2007-2019



Source: Labour Force Survey, NISRA.

Table 1: Reasons for not seeking work by prime-age working adults, by gender, 2007-2019

	2019			2007		
	Prime working-age		All working age (15-74)	Prime working-age		All working age (15-74)
	Male	Female	Both sexes	Male	Female	Both sexes
Awaiting recall to work	1.2	0.2	0.2	3.3	3	2.7
Own illness or disability	50.2	19.3	17.9	46.1	22	27
Looking after children or incapacitated adults	10.6	42.4	11.5	4.9	39	16.6
Other personal or family responsibilities	7.3	23.7	10.3	8.6	15.3	9.8
Currently in school/college or other education or training	14	6.6	26.5	14.6	10.9	30.5
Retired	0.9	0.6	27.2	0.1	0	0.4
You believe no work is available	6.4	1.3	1.9	7	2.2	4.6
Other reasons	7.3	4.2	3.3	15.4	7.5	8.5
Not applicable	2.1	1.7	1	0	0	0

Source: Labour Force Survey, NISRA.

Interestingly, in taking a look at the reasons given by prime-working age males for not participating in the labour market in both 2007 and 2019 we see that whilst there has been an increase in the percentage who state 'own illness or disability' as the reason, there has been more than a doubling in the proportion who state the reason as due to 'looking after children or incapacitated adults' from 4.9% to 10.6%. Without availability of other alternative options for care, it is unlikely that the participation of these workers would increase.

SECTION 3: WHAT EVIDENCE IS THERE FOR THE IMPACT OF TECHNOLOGY ON EMPLOYMENT IN THE IRISH LABOUR MARKET

3.1 Technology and the labour market: The re-emergence of automation anxiety

Automation technologies refer to technologies that are used to substitute labour in the performance of specific tasks in the production process. As well as replacing the need for human labour, automation technologies can augment the capabilities of, and demand for human labour. From the Industrial Revolution onwards, the utilisation of automation technologies in the production process has transformed how we work, produce, consume and live (Lawrence *et al,* 2017). The recent rapid advances in artificial intelligence (AI), robotics and other forms of smart technologies have led to widespread concern about the potential impact of such automation technologies for the future of work and sparked a lively debate about the ways in which technology is going to transform the world of work (Brynjolfsson and McAfee, 2014). Although there is no widely shared agreement on the expected impacts, broadly speaking, there are two camps with starkly different views.

On the one hand there are those who are pessimistic about the extensity and invasiveness of technological change and fear that automation, AI and new robotic technologies are going to wipe out large numbers of our jobs, bring about an end to work for many and ultimately culminate in an economic and social dystopia (Brynjolfsson and McAfee, 2014). Others criticise this view and argue that whilst there will be some disruption and change to the nature of work, the net effect of technological advancements will be positive (Autor, 2014). To support this position, they point to historical periods of rapid technological change when the same fears about technological unemployment existed, but which never materialised - a phenomena that Autor (2015) describes as 'automation anxiety'.

Recent years have seen a re-emergence of this 'automation anxiety'. Reports and media headlines warning that automation technologies are going to wipe out work have become increasingly frequent. Those most cautious about the potential negative impact of

automation technologies for employment make the point that the emergence of increasingly advancing computing power, AI and robotic technologies mean that the possibility of technology being used to replace labour is much more likely now than it has ever been. From this perspective it is thought that using past interactions between automation and employment provides no guide to future impacts. In particular, the emergence of greatly improved automation technologies in terms of computing power, artificial intelligence and robotics raises the possibility of labour replacement on a scale not previously observed and so does little to allay fears about the possibility of technological unemployment going forward (Akst, 2013).

These fears have, to a large extent, been heightened by a report published in 2013 by researchers Michael Frey and Carl Osborne. They predict that a substantial share of jobs are at new and unprecedented risk of automation over the next couple of decades as technological capabilities continue to advance, and machines are increasingly able to undertake tasks which have historically been the reserve of workers. They argue the risk of labour substitution arising from automation technologies is increasing due to the speed of technological advances which mean that machines are increasingly capable of performing a wide range of tasks that historically have been the preserve of human labour, including non-routine manual tasks. They posit that recent technological advances differ from previous technological advances and the current speed at which human labour is becoming automatable and the range of tasks which machines are capable of will 'put a substantial share of employment, across a wide range of occupations, at risk in the near future' (Frey and Osborne, 2013: 39). Their prediction is that given the rapid development of automation technologies jobs will be lost faster than new jobs are created.

3.2 The impact of automation technologies for employment in Ireland

It is intuitive to begin the empirical analysis in this section by assessing if there is any merit to the notion that the 'end of work' is on the horizon or if over the period of economic recovery following the 2008 financial crisis there is any evidence that automation technologies are having a labour substituting effect.

In doing so what is clear is that despite a re-emergence of 'automation anxiety', there is limited evidence that technological advancements have been having an overall labour substituting effect. Nevertheless, what is clear is that in the recovery our labour market remains significantly weakened since the 2008 financial crisis.

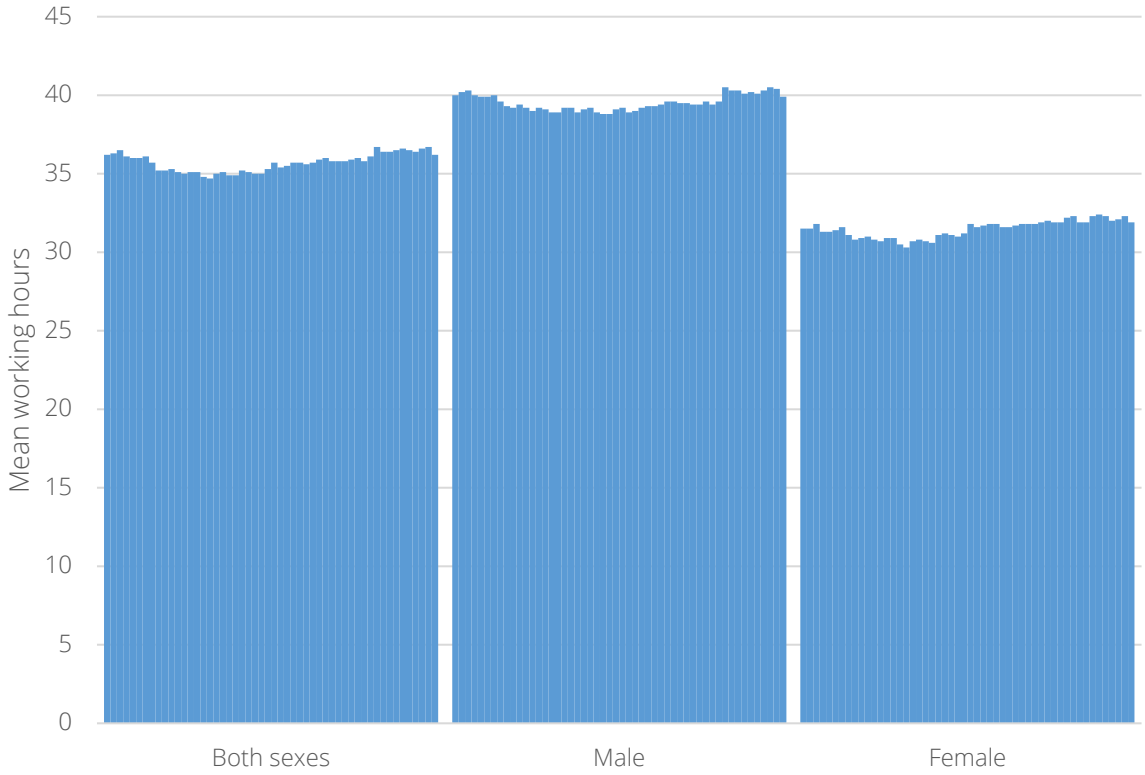
Specifically, as seen in the previous section, whilst the years preceding the 2008 financial crisis in 2019 total employment surpassed the previous peak. We can see this similarly through the unemployment rate trends presented in the previous section, which had been declining steadily from 2012 until 2019. It is nevertheless worth reinstating that despite the labour market having entered a recovery phase in 2012, by 2019 the unemployment rate remained slightly above its pre-crisis level, and in particular male unemployment. Furthermore, rates of labour market participation remain contracted, and again, particularly that of males.

3.2.1 Covert Technological unemployment

Academic literature argues that evidence of the impact of technological advances on employment and 'total work' need not only be evidenced through employment and unemployment trends and indeed that the impact may be more covert. A number of scholars have argued the need to analyse changes in working hours in order to determine whether the impact of automation on employment is hidden via reductions in working hours. From this point of view, it is argued that decreases in working hours could be stemming substantive increases in the rate of unemployment and so there could be in fact 'covert' or partial technological unemployment which is not visible from an assessment of the headline data.

In examining changes in average working hours over the period 2007 to 2019 there is no evidence that technological unemployment occurring over this period is being hidden by reductions in working hours. Indeed, as clear from Figure 5 below mean working hours did decline over the years of the financial crisis, however they have since made a full recovery. As illustrated, this is the case for both males and females. Furthermore, an examination of changes in average hours by full-time or part-time status also shows this conclusion as accurate (CSO, 2020).

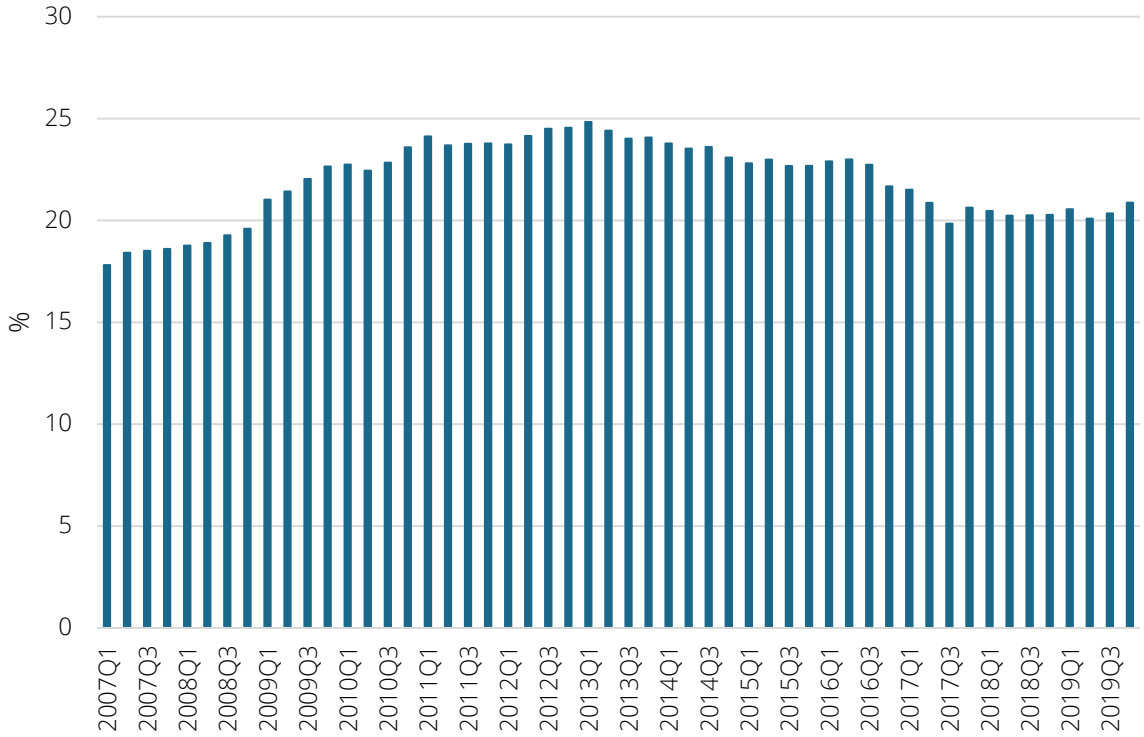
Figure 5: Average working hours across quarter by gender, 2007 to 2019



Source: Labour Force Survey, CSO.

However, whilst this examination of the average hours for full-time and part-time workers shows working hours to have stayed fairly stagnant over the period 2007 to 2019, it is the case that we have seen a structural rise in the share of employment which is part-time. This is indicative perhaps of a rise in partial unemployment, as in the face of recovery, total working hours have taken a structurally lower path since 2016.

Figure 6: Percentage of employment which is part-time, 2007-2019

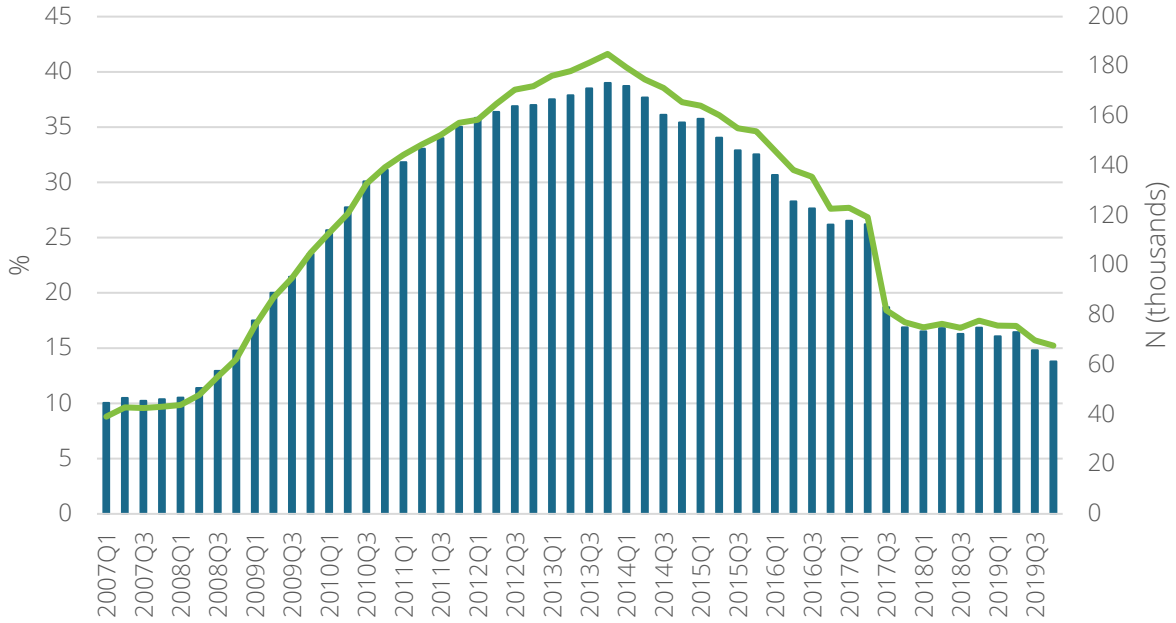


Source: Labour Force Survey, CSO.

Furthermore, an assessment of trends for those who could be described as being in 'enforced part-time work', such as they are only in part-time employment because they could not find a full-time job also points to the emergence of a new higher structural trend of partial unemployment or otherwise referred to as 'underemployment' as the labour market recovered from the 2008 crisis. In this regard, as illustrated in Figure 7 below, the years following the 2008 financial crisis experienced huge increases in the proportion in enforced part-time work. More recent years have seen a substantive decline in this enforced part-time work. However, the data suggest that this recovery has waned since 2017 with levels of enforced part-time work remaining significantly above their pre-crisis level.

Whilst it is difficult to determine if technological advances are responsible for this rise in partial unemployment it nonetheless is the case that it has occurred and indeed will have been vital in countering a slowdown in the decline in the rate of unemployment over the recovery period.

Figure 7: Percentage and number of part-time workers who could not find a full-time job, 2007-2019



Source: Labour Force Survey, CSO.

3.3 The technology transition? the impact of automation technologies for jobs and the structure of employment

While there is great debate about the employment impacts of automation and related technologies, there is a growing research consensus that some jobs will be likely impacted on more than others and which jobs these will be. Whilst the international evidence points to some risk to jobs across almost all industrial sectors and occupations, the risk is particularly amplified in some.

3.3.1 Estimates of how automation technologies will impact on jobs in Ireland

Doyle and Jacobs (2018) utilised two different methods from the international literature to measure risk of automation technologies for employment in Ireland. The occupation-based approach as utilised in Frey and Osborne (2013) and the task-based approach as utilised in Nedelkoska and Quintini (2018)

Using the Frey and Osborne method, this study found that there were eight occupational categories in which over half of the jobs possessed an automation risk of 70% or greater. Of these, certain occupational groups shared notably high levels of risk of automation – namely

Secretarial & related occupations of which 100% of jobs are at a high automation risk, *Sales occupations* which has 87.4% of jobs at high risk, and the *Process, plant & machine operatives*' occupational category of which 91.3% of jobs are classed as being at high risk of automation. On the opposite end of the risk scale, the least at-risk occupational categories were found to be *Corporate Managers & directors* with 89.6% of these jobs being classed as low risk, *Leisure, travel & related personal service occupations,* and *Science, research, engineering & technology professionals* which recorded 89.2% and 88.1% of jobs categorised as low risk respectively (Doyle and Jacobs, 2018).

Using the Nedelkoska and Quintini (2018) method only one occupation group under this methodology was found to have more than half of jobs in the high-risk category. It was estimated that 52% of jobs relating to *Agricultural, Forestry & Fishery Labourers* had a risk of automation of 70% or higher. The next largest proportion of jobs in the high-risk category was estimated for *Market-oriented Skilled Forestry, Fishery & Hunting Workers* at 47.2%, followed by *Stationary Plant & Machine Operators*; and *Assemblers* where in both cases 46.6% of jobs were categorised as having a high risk of automation.

While both methodologies result in variations in the extent to which different occupations are deemed at risk from automation, it was nevertheless estimated across both methods that two out five of those employed in Ireland faced either a high risk (probability of more than 70 per cent) or a significant risk (probability of 50 to 70 per cent) of automation. *Process, plant and machine* occupations and *elementary* type occupations were found to be most at risk in both models, while *Management* occupations and *Professions* were the least at risk.

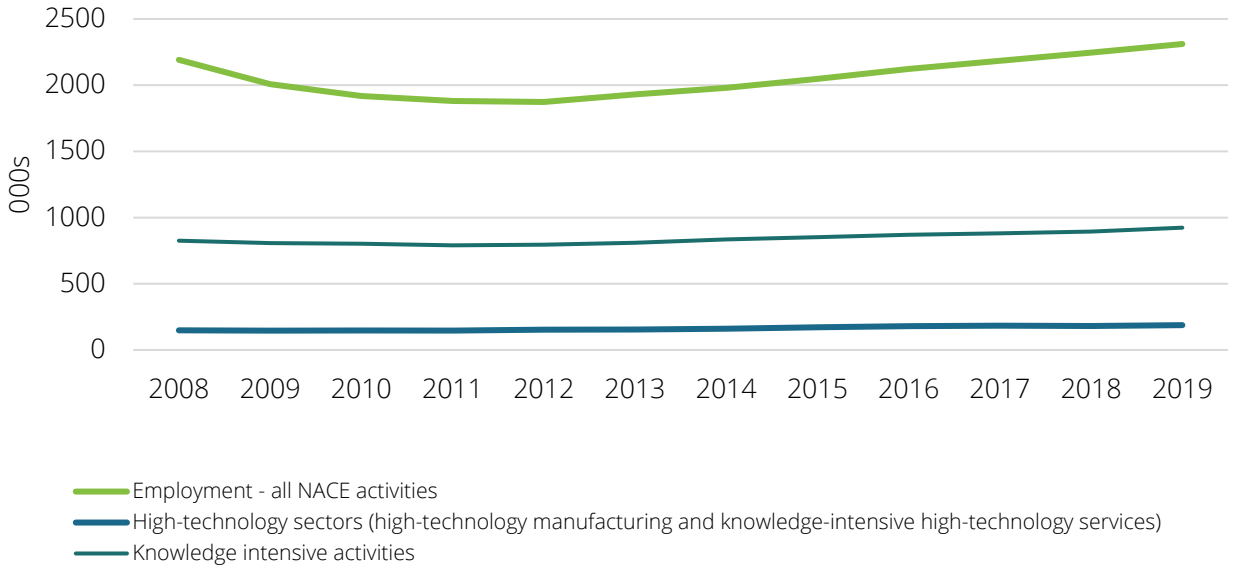
Doyle and Jacobs (2018) linked the data on occupational risk to NACE Rev 2 economic sectors and found six sectors in which at least 40 per cent of employment is at either high or significant risk: A*griculture; Industry; Construction; Wholesale and retail trade; Transport and storage*; and *Accommodation and Food service activities*. The lowest risks of automation were found in the *Education*; *Human health & social work activities*; and *Information & Communications* sectors.

3.4 Empirical evidence of the impact of technology on jobs in particular sectors and occupations in Ireland

3.4.1 Employment in high-technology and knowledge intensive services

High-technology knowledge-intensive services employment displayed resilience to the crisis with job numbers staying stable through the labour market downturn. For example, in 2008 high-technology sector employment accounted for close to 7.5 per cent of total employment. By 2019 high-technology sector employment accounted for around 8 per cent of total employment. Employment in knowledge intensive sector employment accounted for close to 38 per cent of total employment in 2008. By 2019, this increased to 40 per cent.

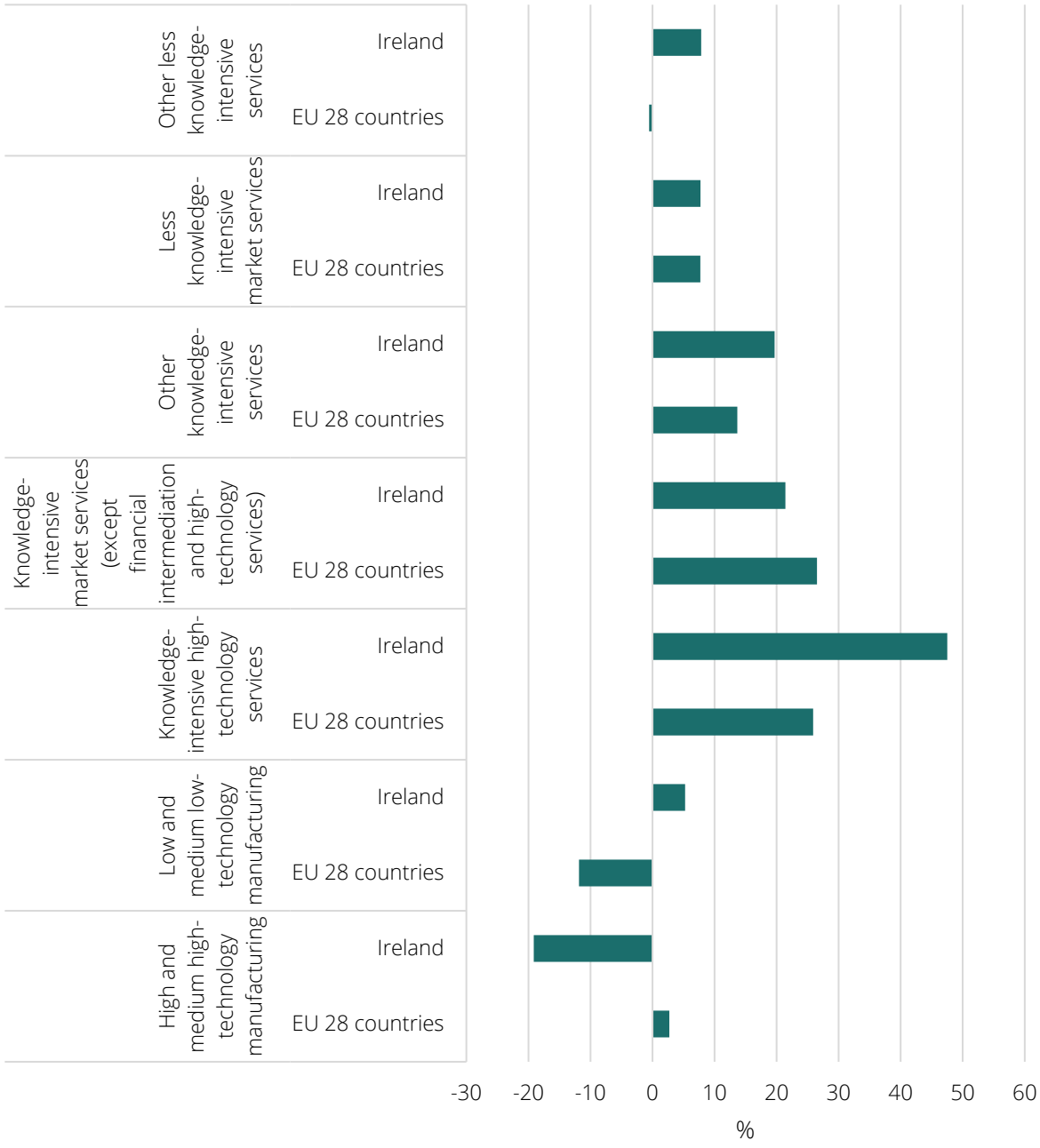
Figure 8: Employment trends overtime, all employment and high-technology sector employment, 2008-2019



Source: Eurostat (2021) High technology sector employment - htec_emp_nat2
Knowledge intensive activities employment – htec_kia_emp2

Looking in detail at how jobs have been changing in Ireland based on technology intensity over the period 2008 to 2019 what is particularly clear is the substantial increase in knowledge intensive service activity jobs, whilst at the same time high and medium-high technology manufacturing jobs have decreased.

Figure 9: Percentage change in jobs by technology intensity, 2008-2019



Source: Eurostat (2021).

3.4.1 Sectoral adjustments and automation technologies

What is most notable from Figure 8 below is the decline in the numbers in employment, across almost all sectors over the period 2007 to 2012, with the exception of the '*Information and communication*', '*Human health and social work activities*' and *'Education'* sector. This decline in the numbers in employment however can be explained by the deep recession precipitated by the 2008 global financial crisis. It is, however, worth noting that those sectors

which lost the least during the recession are those sectors which have been identified by Doyle and Jacob's (2018) as being at the lowest risk from automation technologies in Ireland. These sectors have also continued to experience increases in jobs through the recovery.

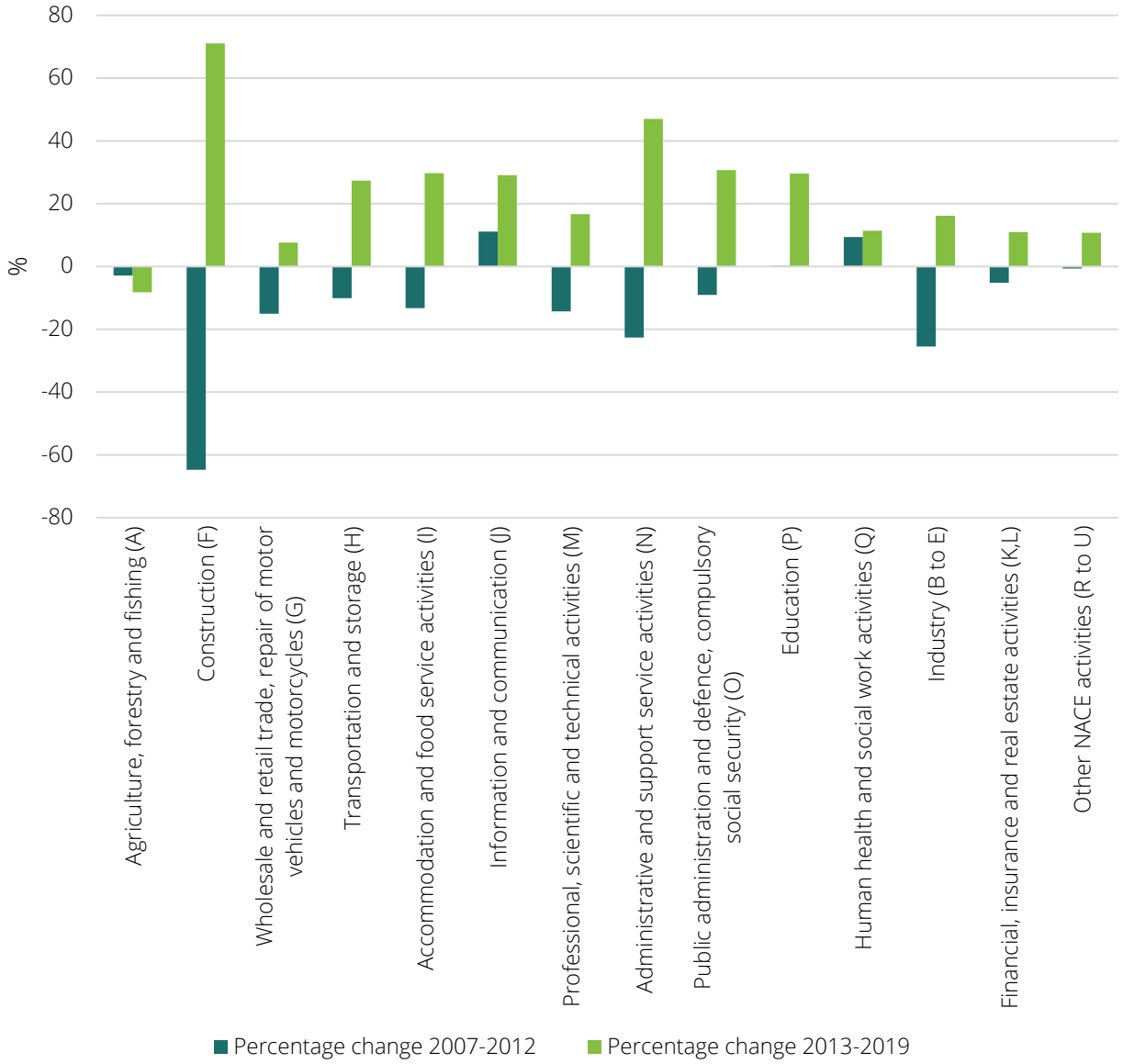
Nevertheless, the '*Administrative and Support service activities'*, '*Accommodation and Food service'* and *'Transportation and Storage'* sectors have all experienced significant increases in the number of jobs over the period 2013-2019 and the largest net increases in the number of jobs over 2007-2019. In the context of assessing the impact of automation technologies for employment these increases are curious as jobs in these sectors are amongst those identified as being at highest risk from automation technologies. This data would indicate that whilst the recessionary period had a negative impact on the number of jobs in these sectors that the effect was cyclical. In this regard, it does not appear with the recovery as though automation technologies are having a labour substitution 'bite' at jobs in these sectors.

The *'Construction'* sector experienced the largest percentage increases in jobs over the period 2013-2019, with an over 70 per cent increase in the number of jobs in the sector. This increase equates to more than the number of jobs that were lost with the monumental fall out of the '*Construction*' sector during the recessionary period.

That said, '*Agriculture, Forestry and Fishing'* the sector identified by Doyle and Jacobs (2018) using both methodologies as facing the highest risks from automation experienced around a 12 percent decline in the total number of jobs in the sector over the period 2007-2019. The extent of the decline in the number of jobs has been particularly acute since the onset of labour market recovery.

It is also worth noting that the '*Wholesale and Retail'* sector has still not recovered the job losses that were experienced during the recessionary period. In this regard, having experienced a 15 per cent decline in the number of jobs through 2007 to 2012, this sector has only seen a 7.6 per cent increase in the number of jobs through 2013-2019.

Figure 10: Percentage change in jobs by sector, 2007-2019



Source: CSO, Labour Force Survey.

Taking into consideration then the data outlined in the Doyle and Jacobs (2018) paper in terms of the risks which particular sectors face from automation technologies, alongside the data presented above in terms of sectoral employment trends over the period 2007-2019 it is difficult to maintain the argument that automation technologies are having a labour substitution effect on sectoral employment.

Employment numbers have been growing relatively fast in some of the sectors identified as facing amongst the highest automation risks, although relatively faster in those sectors facing

the lowest risks. In this regard, there does not appear to be a pattern in how sectoral employment has been changing that aligns with what we might expect if automation technologies were already having a labour substitution effect in the way predicted. It is of course possible that automation technologies will indeed have a labour substitution effect in the sectors identified as high risk in the future, although it is peculiar that the 'reset' afforded by the recessionary period did not provide the catalyst for labour substitution.

3.4.2 Occupational adjustments and automation technologies

Looking now at occupational adjustments in employment numbers over the period 2007 to 2019 what is particularly clear is the polarised nature of how job numbers have been changing depending upon occupation. In this respect, it is particularly stark that in spite of the recession employment numbers continued to grow across '*Managerial, Directors and Senior officials*', *'Professional'* and '*Associate Professional'* occupations through the period 2007 to 2012. In contrast, employment numbers in all other occupations declined substantially, although employment declined only very marginally in '*Caring, Leisure and other service*' occupations. Most notable, albeit unsurprising given the fall-out of the construction sector, was the sharp decline in the number of '*Skilled trades'* jobs over the period 2007 to 2012. The sharp decline in the numbers in *'Elementary'* occupations over this same period also draws attention.

In the context of trying to uncover evidence of whether automation technologies are having a labour substitution effect across different types of jobs there is probably more benefit of assessing job change across occupations during the labour market recovery period following 2012. In this regard, having experienced almost no decline in employment over 2007-2012 employment numbers in *'Caring, Leisure and other service*' occupations experienced the largest relative increases in employment over the period 2013-2019. These occupations are those which have been identified by Doyle and Jacobs (2018) as facing the lowest automation risks.

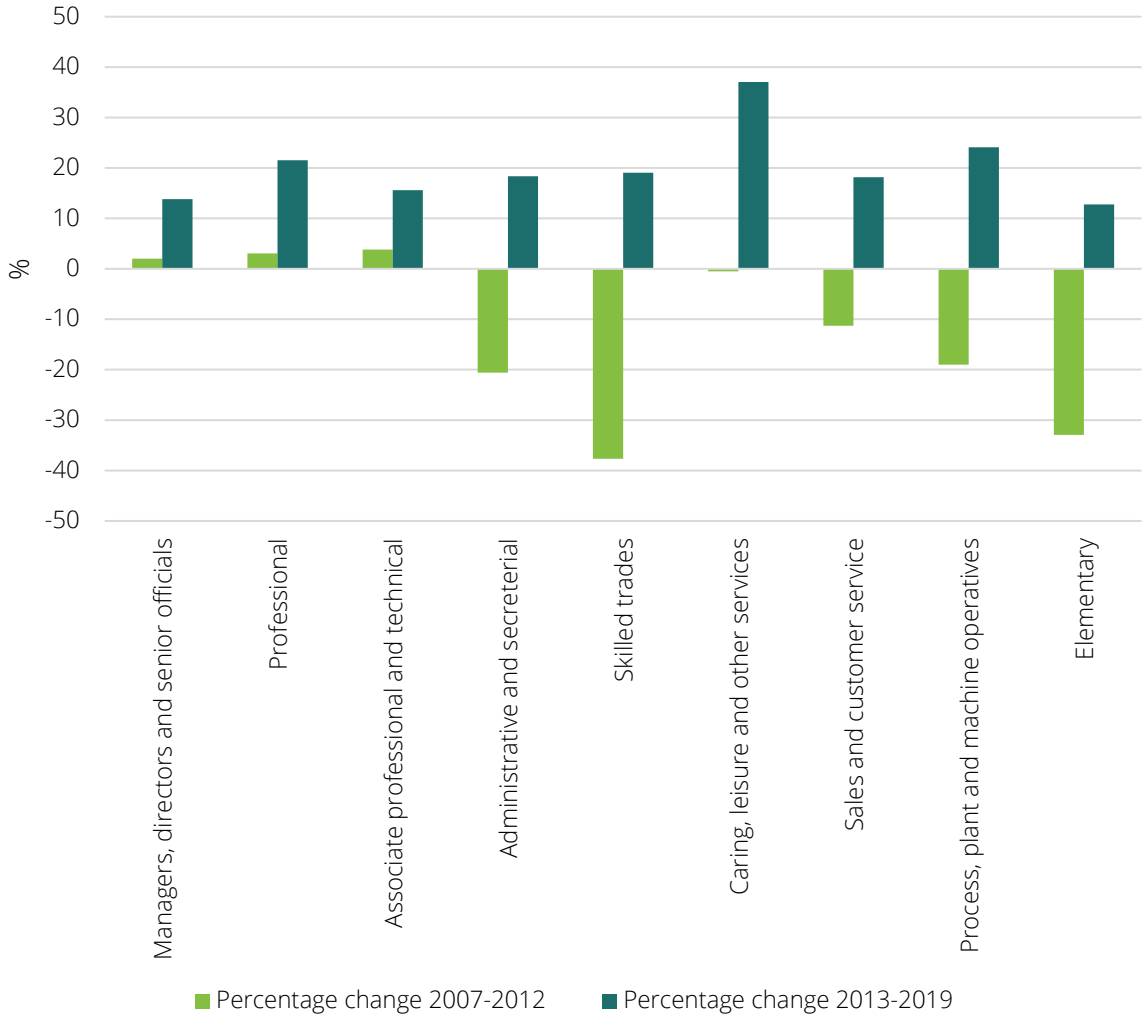
In contrast, '*Elementary'* occupations which are amongst those identified as facing the highest risks from automation technologies experienced an almost 33 per cent decline in the

number of jobs over the period 2007-2012. With the labour market recovery however these occupations have seen only an increase of 13 per cent over 2013-2019. Thus, over the period 2007 to 2019 there remained 20 per cent fewer '*Elementary'* jobs. Similarly, '*Administrative and Secretarial'* occupations identified as being at high risk from automation technologies by 2019 had not recovered the jobs lost over the period 2007-2012. The scale of this shortfall in these jobs however was much more limited, with only around 2 per cent fewer jobs in 2019 compared to 2007.

Having declined by over 37 per cent over the 2007 to 2012 period owing to the economic crisis and the distinct effect this had on the construction sector '*Skilled Trades*' occupations had still not recovered the number of jobs it lost by 2019. These occupations have been identified by Doyle and Jacobs (2018) as having between 20-35% of jobs at high risk from automation technologies, dependent upon the methodology utilised. Despite the fall-out of these occupations having been the consequence of the recession the recovery of *'Skilled trades*' occupations since 2012 has been slow and indeed was slowing in the year's most recent to 2019. By 2019, despite close to 7 years of employment growth across the economy there remained 20 per cent fewer jobs in this sector than there was in 2007. This data would suggest that whilst cyclical factors might have been behind the decline in such jobs, structural factors are likely behind the ongoing reduction in jobs in these occupations. This is perhaps not all that surprising given the Construction bubble and the fact that this sector had grew to an unsustainable size pre-2008 economic crisis.

Nevertheless, '*Process, plant, and machine operative*' occupations despite being identified by Doyle and Jacobs (2018) as facing the highest automation risks have recovered over 2013 to 2019 all and more in percentage terms of the jobs that were lost during the recessionary period.

Figure 11: Percentage change in jobs by occupation, 2007-2019



Source: CSO, Labour Force Survey.

What then can be said about how jobs have been changing in Ireland over the period 2007 to 2019 and the role which automation technologies may be having in effecting these changes. In this respect, whilst the data is certainly clear in that we have seen the sharpest growth in those sectors identified as being amongst the lowest risk of being substituted by automation technologies, the data is less clear in terms of change in job numbers in those occupations identified as facing higher risks. In this respect, whilst jobs facing the highest risks from automation technologies have seen significantly slower growth than other occupations, it is also the case that growth has been slowest in those occupations which were impacted most by the economic crisis and which for other reasons we might not expect a recovery of job numbers. For example, in the aftermath of analysis of the 2008 economic

crisis it has became conventional wisdom that employment levels in the construction sector prior to the crisis were unsustainable and so should not be expected to make a full recovery.

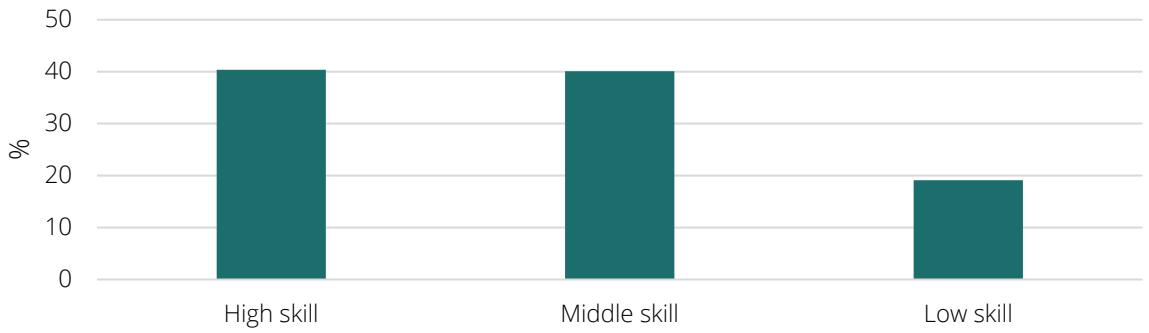
3.5 Skill-biased change

One hypothesis used to explain differences in the occupational risk of different jobs to automation technologies is commonly referred to as the 'skill-biased technological change' model (Katz and Murphy, 1992). The theoretical reasoning is that because skilled workers are more capable of adapting to technological change and having technology complement the work that they do, they are less likely to have their job replaced by machines. By the same logic, low-skilled workers are less capable of adapting to technology, are more likely to perform simple tasks, and thus are more susceptible to the risks posed by automation technologies (Acemoglu and Autor, 2011; Maeda and Yugami, 2016).

There is abundant empirical support for this thesis. Various studies demonstrate an increase in demand for high skill workers, an increase in the skills premium for higher skilled jobs, a stagnation of wages at other points on the distribution; and a widening polarisation of wages between high skilled and other workers (Crivellaro, 2014; Hanushek *et al,* 2015; Machin and van Reenan, 1998). This evidence underpins the emphasis on upskilling as a way of mitigating the risks posed by automation technologies (Nedelkoska and Quintini, 2018).

In looking through the data for Ireland what is immediately clear is the skills-biased nature of employment change in Ireland over the period 2008 to 2019. In 2019 high and middle skill jobs comprised the vast majority of employment, with low skill employment accounting for just under 20% of employment.

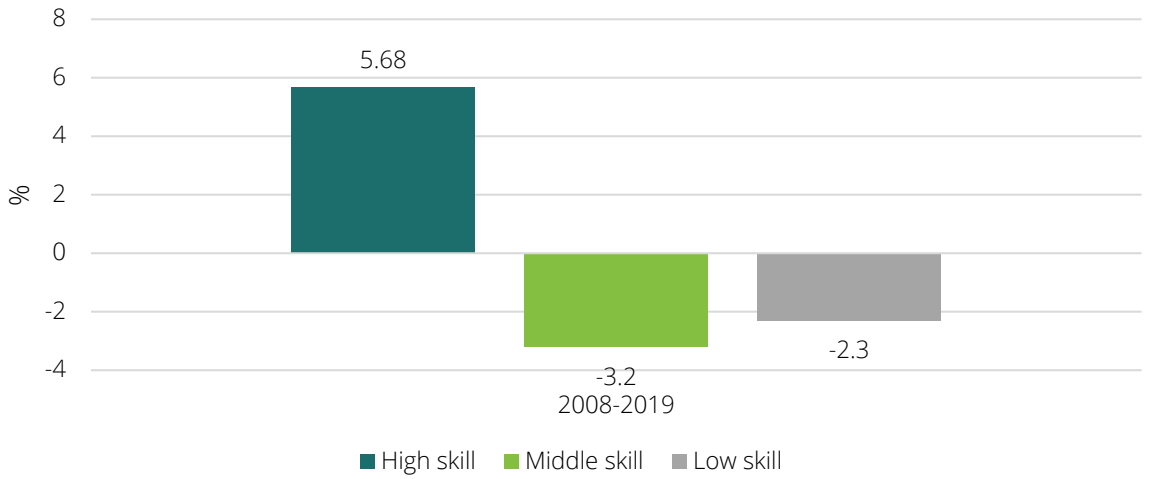
Figure 12: Employment by skills level, 2019



Source: CSO, Labour Force Survey

In terms of change over the period 2008 to 2019 the substantive increase in high skill employment is notable having seen an almost six-percentage point increase as a share of total employment over the period. In contrast middle-skill employment declined by just over 3 percentage points, whilst low skilled employment declined by over 2 percentage points. In this respect, it is interesting whilst the most notable finding is the substantive increase in high skill employment as a share of total employment, this has been at the expense of middle-skill employment more so than low-skilled employment which has not declined as much over the period.

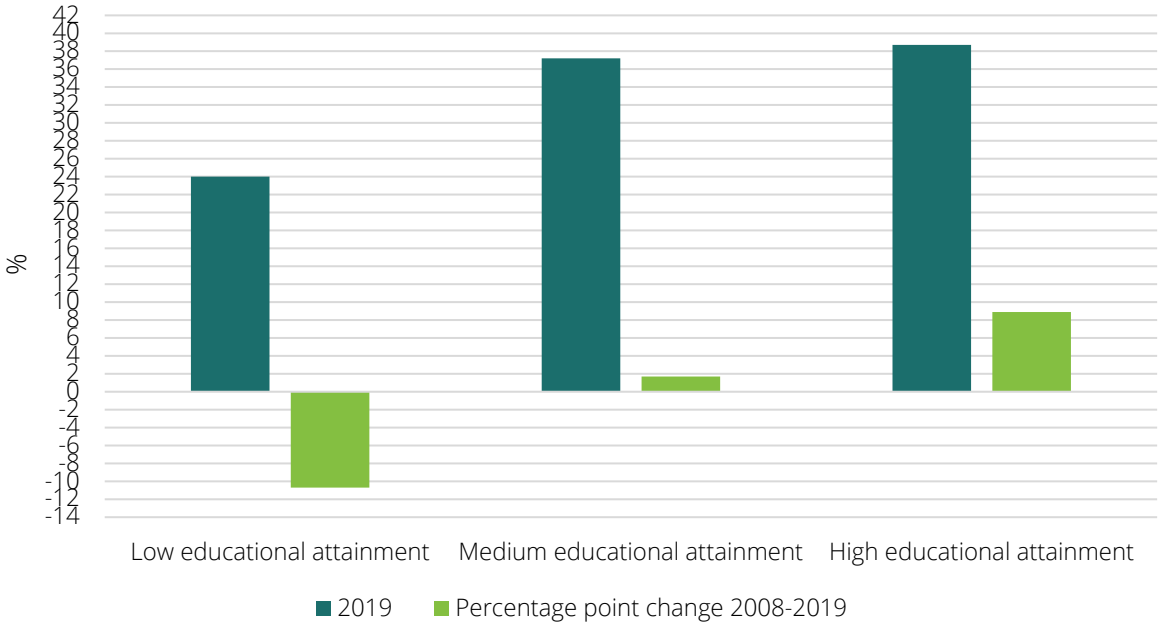
Figure 13: Percentage point change in share of working adults in each skill group 2008-2019



Note: High skill = Managers, directors, and senior officials; Professional occupations, Associate Professional and technical occupations. Medium skill = Administrative and secretarial occupations; skilled trades occupations; caring leisure and other service occupations; process plant and machine operatives. Low skill = sales and customer service occupations; elementary occupations.
Source: CSO, Labour Force Survey.

In terms of how this translates across to changes in the level of educational attainment of working adults over the period 2008 to 2019 the data shows an increase in the share of working adults with medium or high levels of educational attainment and the decline in the share with low levels of educational attainment. In 2019, close to 40% of working adults had high levels of educational attainment.

Figure 14: Percentage point change in share of working adults by level of educational attainment 2008-2019



Source: CSO, Labour Force Survey.

If current trends continue those with low-to-middle level skills or low-to-middle levels of educational attainment are at risk of being displaced from their job as the structure of our labour market is increasingly skills-biased.

Table 2: Change in employment and share of employment in sectors ranked by earnings 2008 and 2019

	Average hourly earning 2008 (Euro)	Average hourly earnings 2019 (Euro)	Percentage change numbers in employment 2008-2019	Percentage point change in share of employment 2008-2019
Education (P)	34.81	36.49	29.04	1.44
Financial, insurance and real estate activities (K,L)	30.36	34.27	2.00	-0.18
Public administration and defence (O)	27.50	26.22	26.74	0.45

Information and communication (J)	26.62	33.35	42.33	1.37
Professional, scientific, and technical activities (M)	24.71	27.71	9.98	0.24
Human health and social work activities (Q)	23.98	23.51	19.83	1.48
Industry (B to E)	20.70	23.68	-4.81	-1.36
Transportation and storage (H)	20.55	23.34	16.00	0.41
Construction (F)	20.09	21.68	-29.29	-3.12
Wholesale and retail trade (G)	16.45	19.49	-6.95	-1.76
Arts, entertainment, recreation & other service (R,S)	16.32	19.26	8.01	0.11
Administrative & support service activities (N)	15.93	19.01	15.31	0.40
Accommodation and food service activities (I)	12.55	13.41	30.89	1.48

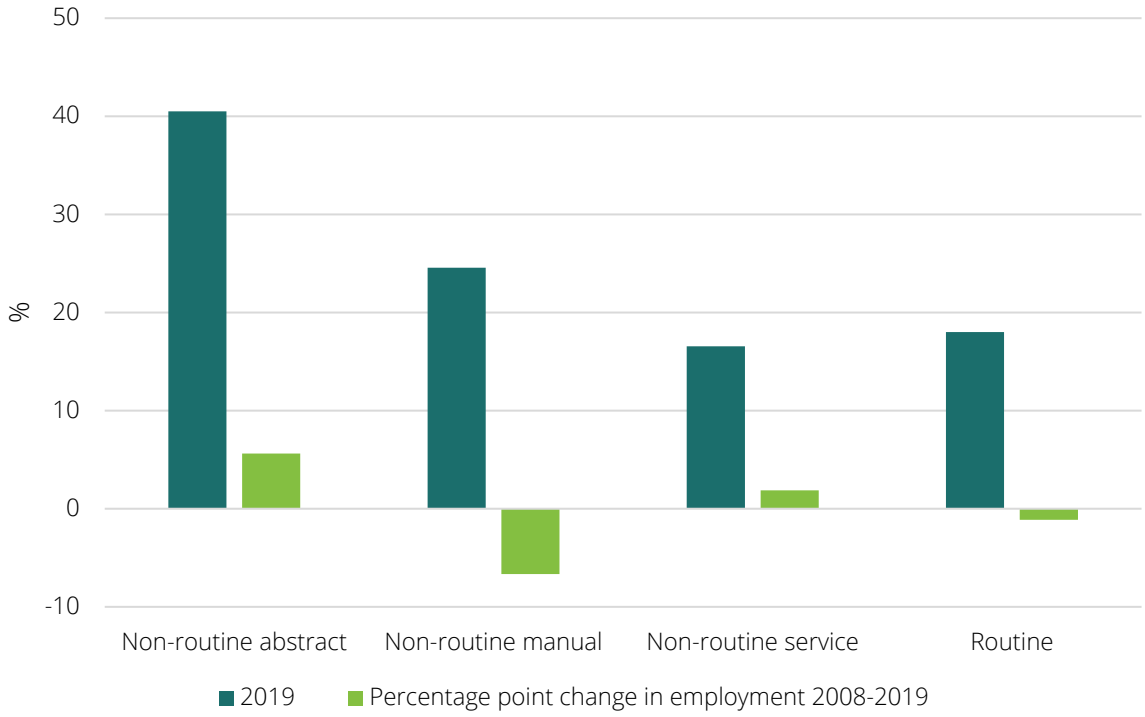
3.6 Routine biased change

An alternative theory emphasises the potential for technological change to replace occupations heavily reliant on routine, non-complex tasks that can be easily codifiable by robotic or algorithmic processes (Autor et al, 2006; Autor and Dorn, 2013; Goos et al, 2009; Acemoglu and Autor, 2011; Handel, 2012). This theory is called 'routine-biased technological change'. The basic premise behind the routine-biased technological change model is that the likelihood that your job will be substituted (wholly or partly) for by machines is related to the specific tasks involved in your job (Autor *et al,* 2003; Sebastian and Biagi, 2018). Jobs involving predominantly routine tasks tend to be at higher risk from automation technologies. On the other hand, jobs with a higher incidence of non-routine tasks tend to be at lower risk, principally because machine tend to be much less capable of undertaking these tasks. According to the routine-biased technological change hypothesis, the production process is defined in terms of job tasks. Job tasks are allocated to either workers or to capital (automation technologies) depending on: 1) the degree to which they are automatable (repetitive and replaceable by code and machines); 2) their separability from other tasks; and 3) the relative costs of using machines versus humans.

The routine-biased technological change model predicts that advances in automation technologies result in a decline in jobs with primarily routine tasks and an increase in the number of jobs whose tasks are predominantly nonroutine in nature. This theoretical model

is supported by an increasing number of authors, including Goos *et al* (2015) Autor and Dorn (2013). Their reasoning is that whilst the skills-biased technological change model provides a useful framework for understanding changes at the higher end of the skills distribution, the routine-biased technological change model provides a more accurate framework of how and the reasons why automation technologies impact workers whose jobs involve particular tasks differently.

Figure 15: Percentage share by nature of job, 2019 and Percentage point change in share of working adults by nature of job 2008-2019



Source: CSO Labour Force Survey.

The above data support the hypothesis of the routine-biased technological change model and thus suggest that automation technologies have been having a labour substituting effect on employment in Ireland over the years 2008 to 2019. In this respect, technological advances appear to be having a labour-saving effect in occupations whose tasks are predominantly routine and non-routine manual in nature. In contrast, there has been sharp increases in the number of jobs whose tasks are predominantly either non-routine abstract or non-routine service-orientated in nature. Thus, we ostensibly need not yet be concerned with the general decline in the numbers of jobs but should be concerned with the

displacement of jobs.

In this respect, whilst it is worth pointing out that the transition within our labour market towards non-routine abstract and non-routine service labour over the years 2008 to 2019 shows that the potential for routine-biased displacement has declined over this period. Nevertheless, it is worth pointing out that the scale of decline in routine occupations was limited, with 18% of workers still employed in routine occupations and 24% employed in non-routine manual occupations in 2019.

SECTION 4: WHAT EVIDENCE IS THERE FOR THE IMPACT OF THE TRANSITION TO A GREEN ECONOMY ON THE STRUCTURE OF THE IRISH LABOUR MARKET

4.1 The impact of the low carbon transition for employment in Ireland

Significant reductions in carbon emissions associated with human activity will be necessary to limit ecological damage (Intergovernmental Panel on Climate Change (IPCC), 2018). This transition will imply significant changes to lifestyles, consumption and associated economic activity. This change represents a significant structural force with major implications for labour markets. This can lead to the presumption that environmental policy and its associated changes are pitted against jobs. Despite this, indications are that efforts to limit emissions could be beneficial for labour markets.

The International Labour Organisation (ILO) (2019a) in their report to the G20, point out that business as usual policy with respect to climate change will result in substantial environmental damage with significant negative implications for labour markets, among other effects. They point out that increasing temperatures have already reduced productivity - 23 million work years were lost between 2000 and 2015 globally due to environmental hazards tied to human activity.

Increased heat stress tied to rising temperatures will reduce global work hours 2.2 per cent, the equivalent of nearly 80 million full time jobs by 2030 (ILO, 2019b). This is premised on 1.5 degrees of warming relative to pre-industrial levels by the end of the century and thus likely amounts to a conservative estimate. Globally, 40 per cent of employment relies directly on environmental services, with up to 16 per cent of jobs in the EU tied directly to the environment (ILO, 2019a).

Despite some debate as to the empirical effects of environmental policy on employment which tend to be sectorally focused (Bowen and Kuralbayeva, 2015), much of the forecast literature projects significant positive effects over the longer term, particularly in the European context (García-García, Carpintero and Buendía, 2020). Many of these positive

effects arise due to increased investment spurred by technological innovation and development, or dynamic effects (Fankhauser, Sehlleier and Stern, 2008).

The ILO (2018) in their report for the G20 nations estimate that Europe will produce an additional 500,000 jobs directly and indirectly due to environmental adaption measures. This is particularly true of investment tied to new adaptive infrastructure, which will directly increase labour demand in construction and indirectly produce or induce jobs elsewhere.

Similarly, Eurofound (2019) model the employment effects of implementing policy necessary to limit warming to 2 C and find that these measures lead to an additional 1.2 million jobs over the 12 million produced under their baseline policy scenario. These gains are unevenly distributed but positive in all cases – adherence to the Paris Agreement produces an additional 0.1 per cent employment gain over their baseline scenario in Ireland.

The European Comission (2019) predict that the pursuit of emissions reductions consistent with 1.5 C of warming generate some 1.5 to 2 million additional jobs over their baseline scenario to 2050, or between 0.6 and 0.9 per cent. These gains they predict will be concentrated in Construction, Agriculture, and Power generation.

In addition, organisations like UNEP (2011) assert that economic greening can produce net benefits in terms of decent jobs – jobs that entail a fair wage, workplace rights and protections, as well as prospects for career advance (ILO, 2020).

However, as Fankhauser, Sehlleier and Stern (2008) point out, climate policy's effect on employment is also felt over shorter- and medium-term horizons. These immediate effects can result in dislocation for workers, particularly in emissions intensive industries. Workers displaced by sustainability efforts are more likely to face longer spells in unemployment and lose industry specific skills (Vona, Marin, Consoli and Popp, 2017). Workers with specialised skills can face higher transition costs when faced with sectoral shifts such as those likely entailed by transition efforts (Lamo, Messina and Wassmer, 2011). As such, any Just Transition incorporating concern for social dimensions and equity into policy to promote

sustainability should examine these potential short-term barriers and act to mitigate them (Goldrick-Kelly and Nugent, 2019).

4.2 The low-carbon transition: Evidence for the impact of the transition to a low carbon economy to-date

4.2.1 Emissions and Output

Many authors have noted Ireland's laggard status with respect to emissions (Torney and O'Gorman, 2019; Burck *et al*., 2020; Goldrick-Kelly and Nugent, 2019). In many respects, therefore, transition and its attendant employment effects are likely in their relatively early stages. This section will examine evidence to date regarding changes in emissions and its relationship to changes in the Irish labour market.

Figure 16 displays two measures of emissions in the Republic of Ireland between 2008 and 2019 corresponding to emissions measured on a residence or territorial basis in thousands of CO_2 equivalent tonnes.[2] Resident emissions are measured using the Air emissions accounts methodology, which attributes emissions based on responsibility rather than physical location (Department of Energy and Climate Change, 2015). Therefore, emissions for which Irish residents or registered businesses are responsible are included, while foreign residents and enterprise emissions within Ireland are excluded. This methodology is designed to be more analogous to national accounting methods, allowing researchers to examine the correspondence between economic production and its associated emissions (Eurostat, 2014).

In contrast, territorial emissions comport with greenhouse gas inventory methods which measure emissions occurring within Ireland (Department of Energy and Climate Change, 2015). These emissions discount emissions attributed to residents abroad and include all emissions within the territory regardless of responsibility. These data tend to be used for

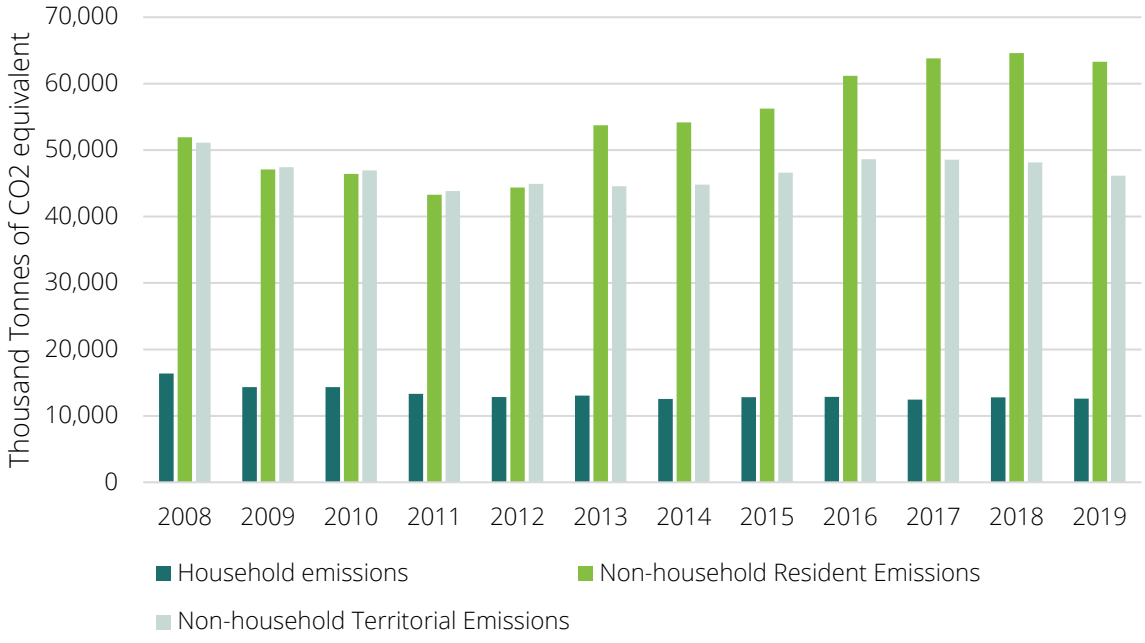
[2] Carbon dioxide (CO_2) equivalent tonnes represent a scale by which different varieties of greenhouse gas can be expressed in common units. This scale sets CO_2=1, and global warming potentials (GWP) which measure their capacity to retain heat in the atmosphere are used to express values in common units. For example, a tonne of methane, which has a GWP of 25, would be expressed as 25 CO_2 equivalent tonnes. Hereafter, emissions are expressed in this unit.

emissions reporting and set targets by international bodies.

Between 2008 and 2012, the two series show a close correspondence, varying by a maximum 1.6 per cent.[3] Both series show significant emissions reductions over the period, showing aggregate falls of between 12.1 and 14.6 per cent. However, from 2013 the series show a significant divergence, with resident emissions between 20.7 and 37.1 per cent higher than the territorial measure between 2013 and 2019.

This disjuncture in the series is primarily caused by the inclusion of "Air transport operated abroad by residents" from 2013, which adds approximately 9.8 million tonnes of CO_2 equivalent that year, growing to 17.7 million tonnes by 2019. The series also show a difference in trend. While the two series show growth following 2013, emissions growth is more modest in the territorial series and shows a maximum in 2016, falling thereafter. In contrast, resident emissions grow up until 2018, only showing a fall in the year to 2019.

Figure 16: Emissions Trend in Ireland 2008-2019

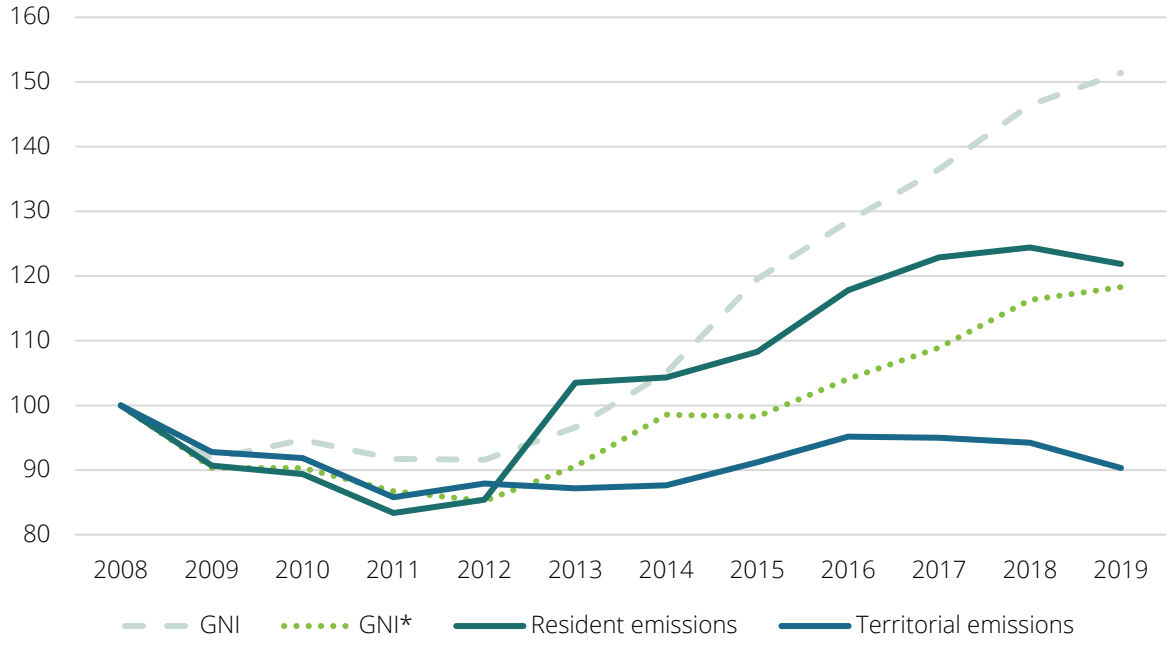


Source: Air emissions accounts totals bridging to emission inventory totals (Eurostat, 2021), Air emissions accounts by NACE Rev. 2 activity (Eurostat,2021)

[3] To ascertain emissions attributable to economic activity on a territorial basis, household emissions are subtracted from "Total emissions as reported to international conventions (UNFCC and CLRTAP)" reported in Eurostat's (2021) "Air emissions accounts totals bridging to emission inventory totals" dataset.

These data suggest that Ireland's transition from a low carbon economy is, at best, in its very early stages. Most proposals to weld employment gains to emissions reductions are also premised on severing the historic linkage between output growth and environmental impact worldwide (IPCC,2018). This *decoupling* process occurs where resource use or environmental damage grow more slowly than activity (relative decoupling) or sees overall declines where activity grows (absolute decoupling) (IRP, 2017). To remain consistent with IPCC guidance concerning remaining carbon budgets, Ireland and other states must show significantly greater levels of emissions reductions, and hence much more significant decoupling, if climate goals are to be consistent with continued economic growth (UNEP, 2020).[4]

Figure 17: Gross National Income (chain linked 2018) and Emissions Trend



Source: Air emissions accounts totals bridging to emission inventory totals (Eurostat, 2021), Air emissions accounts by NACE Rev. 2 activity (Eurostat,2021), National Income and Expenditure 1995-2019 (CSO, 2021)

4.2.2 Emissions and Employment

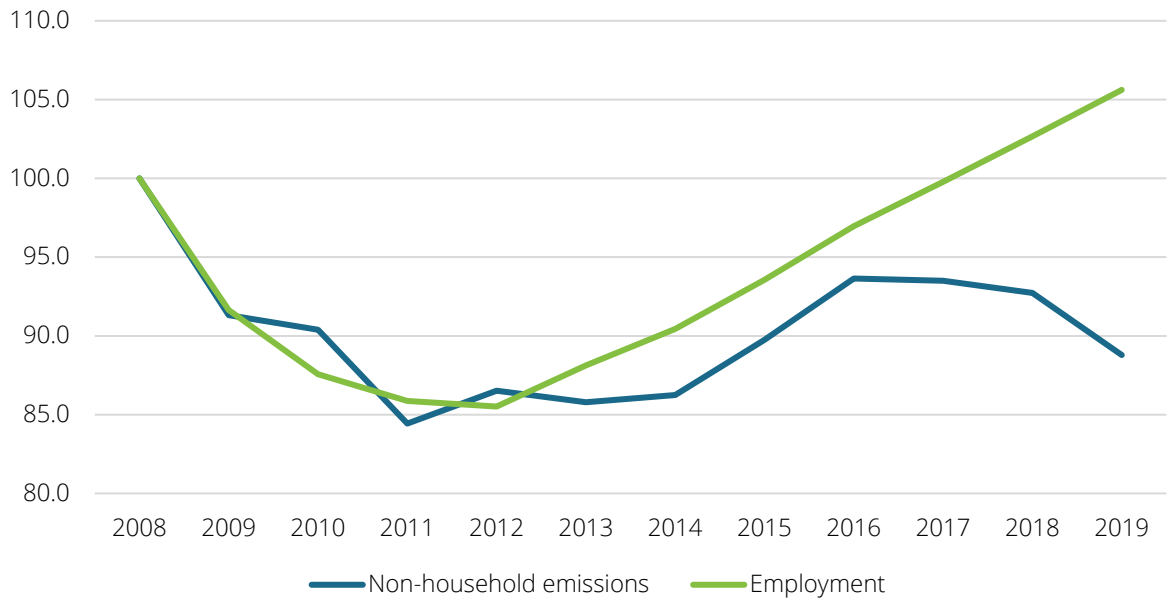
In a close analogy to output decoupling (output in this case tends to be the underlying driver of employment and environmental damage) declines in emissions can only be associated

[4] We should note at this point a lack of unanimity regarding this point. Advocates of "degrowth" assert that any economic model premised on continued growth will be at odds with environmental sustainability in numerous domains (Weiss and Cattaneo, 2017). A specific technical point relates to the difficulty maintaining sufficiently rapid decoupling in continuously expanding economies. Given Ireland's pursuit of a growth strategy, and sustained growth following the economic crash and current pandemic crisis, we examine transition according to decoupling success.

with net employment gains where reductions in average emissions intensity per person employed outpaces employment growth. Where relative or absolute decoupling is occurring, this should be reflected in a changed relationship between environmental impact (in this case emissions standardised by the heat they retain relative to carbon dioxide which is set at 1) and employment.

Figure 18 displays trends in non-household territorial carbon emissions and employment following the financial crisis in 2008. We utilise adjusted emissions accounts data which break down emissions by economic sector. Emissions accounts data are aggregated on a resident basis and include emissions attributable to residents outside the territory. As these emissions may be loosely connected to employment in Ireland, we adjust data to exclude non-territorial emissions by residents and add emissions by non-resident units within the territory.

Figure 18: Aggregate territorial non-household emissions and employment trend (2008=100)



Source: LFS Employment by sex, age and economic activity (from 2008 onwards, NACE Rev. 2) (Eurostat,2021); Air emissions accounts by NACE Rev. 2 activity (Eurostat,2021), Air emissions accounts totals bridging to emission inventory totals, author calculations

These trends appear to be characterised by three periods corresponding to close coupling between emissions and employment, relative decoupling and absolute decoupling: 2008 to 2012, 2012 to 2016 and 2016 to 2019.

The period immediately following the Financial crisis and its associated recession is associated with falls in employment that are closely mirrored by emissions reductions. Both series show rapid falls in emissions in the immediate crisis period, and reach their low points in 2011/2012. Aggregate employment fell by close to 14.5 per cent between 2008 and 2012 from just under 2.2 million employed persons to 1.88 million. This corresponds to a fall of approximately 319 thousand. Emissions fell by nearly 15.6 per cent or just over 8 million tonnes of CO2 equivalent between 2008 and its low point in 2011.

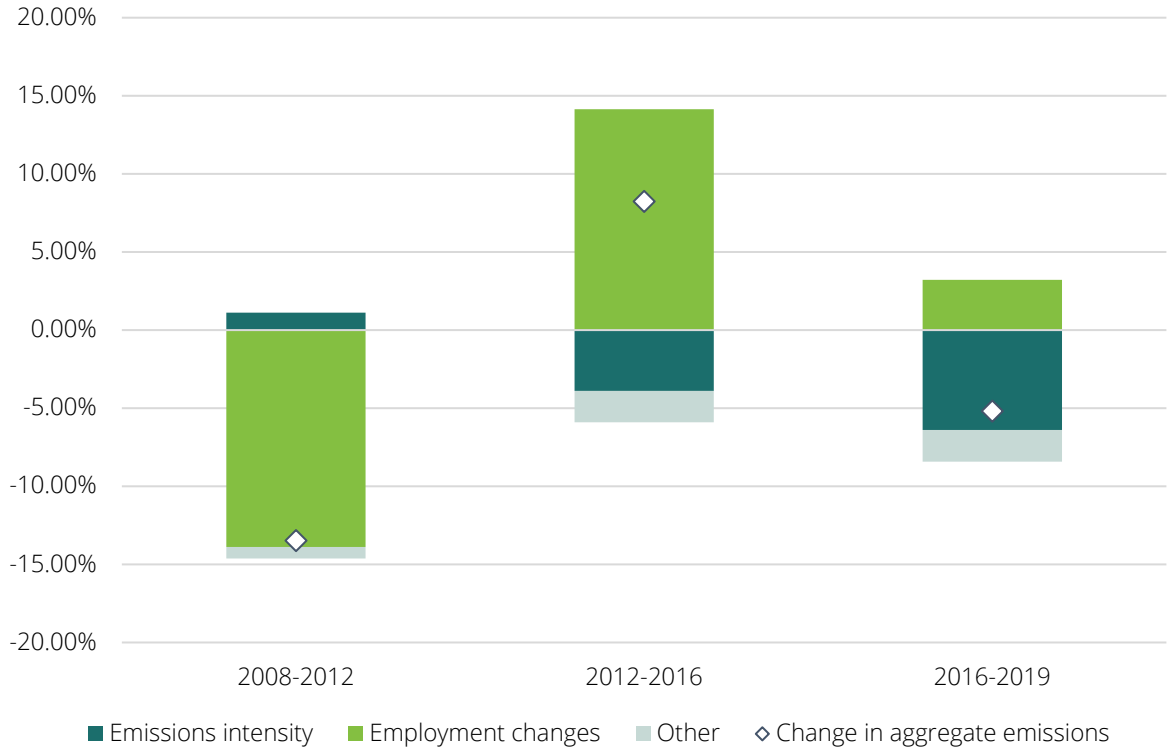
Between 2012 and 2016 both series show increases, though this process is concentrated in the years following 2014 for non-household emissions. While both series show increases, a decline in emissions intensity per job leads to a relative divergence between them – employment growth (13.4 per cent) outpaces increases in aggregate emissions (8.2 per cent).

The years following 2016 see that relative divergence become absolute. Employment grows by 8.9 per cent between 2016 and 2019. Over the same time span, non-household territorial emissions fall by 5.2 per cent.

Decoupling can also be established via decomposition methods such as the Kaya identity, which expresses emissions as a function of output, population, energy use and efficiency (Waggoner and Ausubel, 2002). While not positing a causal relationship between employment and emissions per se, an adjusted Kaya identity can be used to identify the degree to which emissions changes have been associated with falls/rises in employment or reduced impact per job (emissions per person employed).

Figure 19 decomposes changes in aggregate emissions into changes associated with increased/decreased employment, increased/decreased emissions intensity per job within sectors and shifts to or from sectors showing greater rates of change in emissions. The first two categories correspond to static analyses holding another factor constant: “employment changes” refers to emissions changes if numbers employed changed and emissions intensities were held constant, while this is reversed for “emissions changes”.

Figure 19: Decomposing emissions changes by employment and emissions per job



Source: LFS Employment by sex, age and economic activity (from 2008 onwards, NACE Rev. 2) (Eurostat,2021); Air emissions accounts by NACE Rev. 2 activity (Eurostat,2021), Air emissions accounts totals bridging to emission inventory totals, author calculations.

These decompositions support distinct phases in emissions trend explained by different factors. While emissions fell significantly in the period between 2008 and 2012, these falls can be explained by the recession that followed, which depressed economic activity and consequently led to job losses.

This phase actually saw a slight increase in emissions intensity per job. By contrast, in the initial economic recovery period between 2012 and 2016, average emissions per person employed fell, but this was outweighed by employment gains. The final phase between 2016 and 2019 is associated with significant improvements in aggregate emissions per job which outpace employment gains, leading to aggregate reductions in emissions.

4.3 Sectoral adjustments in employment and concentration of emissions

A focus on aggregate emissions can mask the significant differences in emissions associated with work in different economic sectors. As Goldrick-Kelly and Nugent (2019) note, more emissions intensive jobs will likely see more substantial changes. The most carbon intense

sector by some way was *Electricity, gas, steam and air conditioning supply* (NACE D) from 2008 to 2019. In 2008, the sector produced 1,257.5 tonnes of CO_2 equivalent per person employed in the sector, more than 50 times the economy wide average of 23.6 tonnes (Table 5). This accounted for 28.1 per cent of territorial non-household emissions that year, the second largest aggregate contributor and only 0.5 per cent of employment (Figure 20). While remaining over 30 times as intensive as the economy average in 2019, this sector was the largest single contributor to emissions reductions over the period, showing falls of over 6 million tonnes CO_2 equivalent between 2008 and 2016 exceeding the aggregate fall over the span while showing gains in employment terms of 18.1 per cent or some 2,100 additional jobs. This was likely tied to a shift away from fossil fuel intensive electricity generation in the form of coal and peat and increased generation through renewable sources (SEAI, 2020). This sector also appears to be the driving force behind the observed disconnection between employment growth and emissions in aggregate between 2016 and 2019.

Transportation and storage, *Manufacturing* and *Mining and quarrying* were the other major contributors to emissions declines showing falls of 224,500, 572,200 and 159,700 tonnes of CO_2 equivalent respectively. While they remained over the emissions per job average for the economy as a whole, each saw reductions in emissions per person employed. Despite these declines, the *Transportation and storage* and *Manufacturing* increased their share of aggregate non-household territorial emissions from 6.6 to 7.0 per cent and 15.5 to 16.2 per cent respectively between 2008 and 2019 due to slower than average falls in sectoral emissions. Employment in *Transportation and storage* grew significantly, by about 16 per cent or 14,600 moving from 4.1 to 4.6 per cent of the labour market. In contrast, *Manufacturing* shed 10,800 jobs between 2008 and 2019, the immediate post crisis falls outweighed job gain in the recovery period after 2012. As a result, its employment share fell from 12.1 to 10.9 per cent.

Table 3: Most Emissions Intensive sectors 2008 & 2019

Sector	Intensity per job 2008 (tonnes of CO_2 equivalent)	Intensity per job 2019 (tonnes of CO_2 equivalent)	Employment Change (thousands)	Emissions change (thousands tonnes of CO_2 equivalent)
NACE D	1257.5	620.9	2.1	-6,080.5
NACE A	166.6	197.9	-13.2	1,018.3
NACE E	95.3	144.6	-1.1	510.9
NACE H	37.6	30.3	14.6	-224.5
NACE C	30.4	29.4	-10.8	-572.2
(NACE B	27.5	23.7	-4.8	-159.7
Non-intensive sectors	3.7	3.5	135.6	192.8
Total	**23.6**	**19.9**	**123.5**	**-5,825.7**

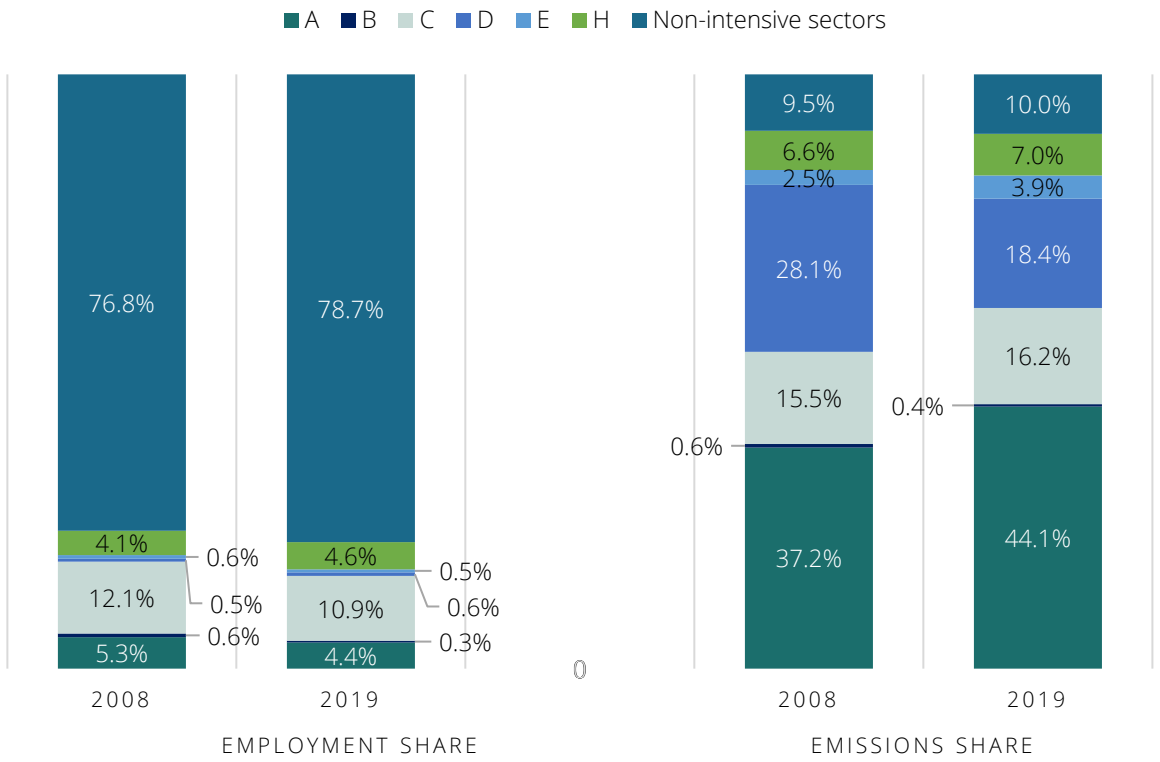
Source: LFS Employment by sex, age and economic activity (from 2008 onwards, NACE Rev. 2) (Eurostat,2021); Air emissions accounts by NACE Rev. 2 activity (Eurostat,2021), Air emissions accounts totals bridging to emission inventory totals, author calculations.

Other sectors, in contrast, showed emissions increases between 2008 and 2019. The biggest increases were seen in the *Agriculture, forestry and fishing* which grew by 5.3 per cent or over 1 million tonnes of CO_2 equivalent. This increase was attributable to the *Crop and animal production, hunting and related service activities* which contributes more than 99 per cent of aggregate sectoral emissions. At the same time, employment fell by 13,200, leading to a significant increase in emissions per job from 166.6 tonnes per person employed to 197.9 tonnes. This increased the sector's share of non-household territorial emissions from 37.2 to 44.1 per cent.

The other major contributor to increased emissions was *Water supply; sewerage, waste management and remediation activities*. This sector emitted an additional 510,900 tonnes of CO_2 equivalent in 2019 relative to 2008 while showing employment declines of 1,100. This led to a significant increase in emissions intensity from 95.3 tonnes to 144.6 tonnes per person employed and an increase in the sector's share of emissions from 2.5 to 3.9 per cent. Non-emissions intensive sectors – so defined by their relatively low rates of emissions per person employed relative to the national average – had a relatively small emissions profile in aggregate, despite some growth in emissions (192,800 tonnes of CO_2 equivalent) and a consequent increase in emissions share from 9.5 to 10 per cent. However, these sectors

comprised the substantial majority of overall employment in 2008 and 2019. Employment growth in these sectors exceeded that seen in aggregate, leading to an increase in their overall employment share from 76.8 to 78.7 per cent.

Figure 20: Breakdown of emissions and employment by sector



Source: LFS Employment by sex, age and economic activity (from 2008 onwards, NACE Rev. 2) (Eurostat,2021); Air emissions accounts by NACE Rev. 2 activity (Eurostat,2021), Air emissions accounts totals bridging to emission inventory totals, author calculations.

4.4 The green sector in Ireland

The *Environmental Goods and Services Sector* - a measure of the "green economy" – has shown significant growth in Ireland over the past few years.[5] Between 2013 and 2017, the sector more than doubled, from 16,171 to 39,733 full-time equivalent workers. As shown below, most of this growth was attributable to growth within *Construction* (NACE F), *Manufacturing* (NACE C) and *Real Estate Activities* (NACE L) where no EGSS jobs were captured in 2013 but which had 12,619, 3,498 and 3,255 EGSS positions respectively in 2017.

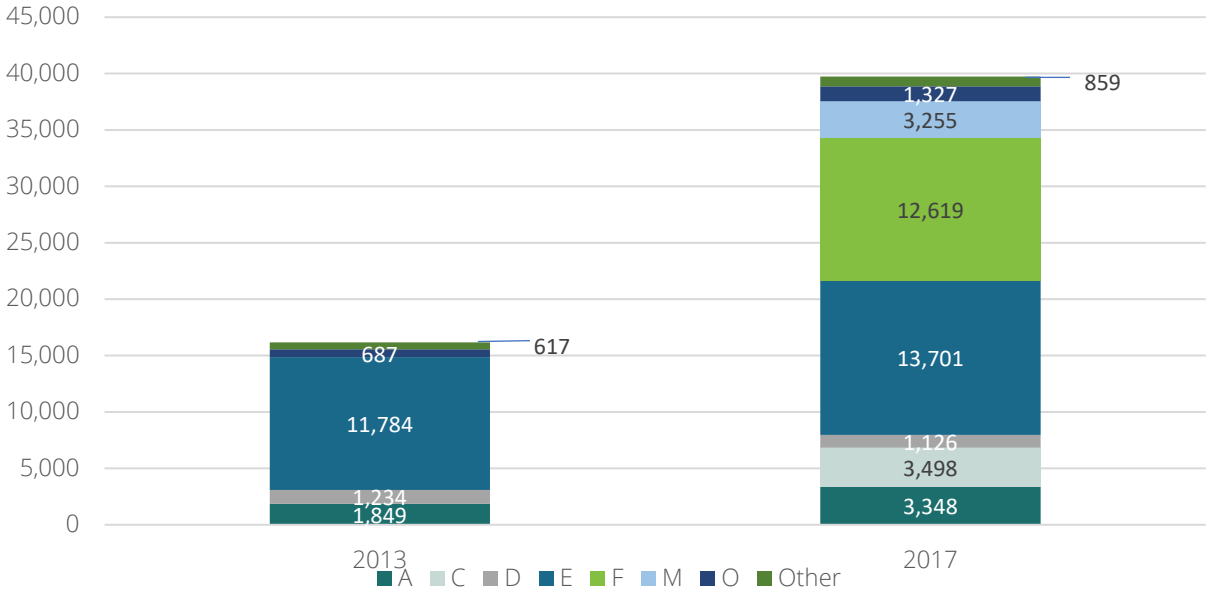
[5] EGSS identifies producers of goods and services with an environmental protection or management purpose as their primary objective (Eurostat, 2009).

In both years The *Water supply; sewerage, waste management and remediation activities* (NACE E) represented the largest single contributor to the EGSS sector and showed significant growth of 16.3 per cent in absolute terms. Interestingly, this sector increased its emissions over the same period. The amalgamated category Industry, which includes this sector alongside others, grew significantly as a proportion of aggregate employment from 4.7 per cent to 8.3 per cent.

Similarly, EGSS employment within the NACE category *Agriculture, forestry and fishing* (NACE A) grew by over 81 per cent from 1,849 to 3,348 while increasing as proportion of aggregate employment (1.9 per cent to 3.3 per cent) despite falls in overall employment observed in within the wider sector over the same time span.

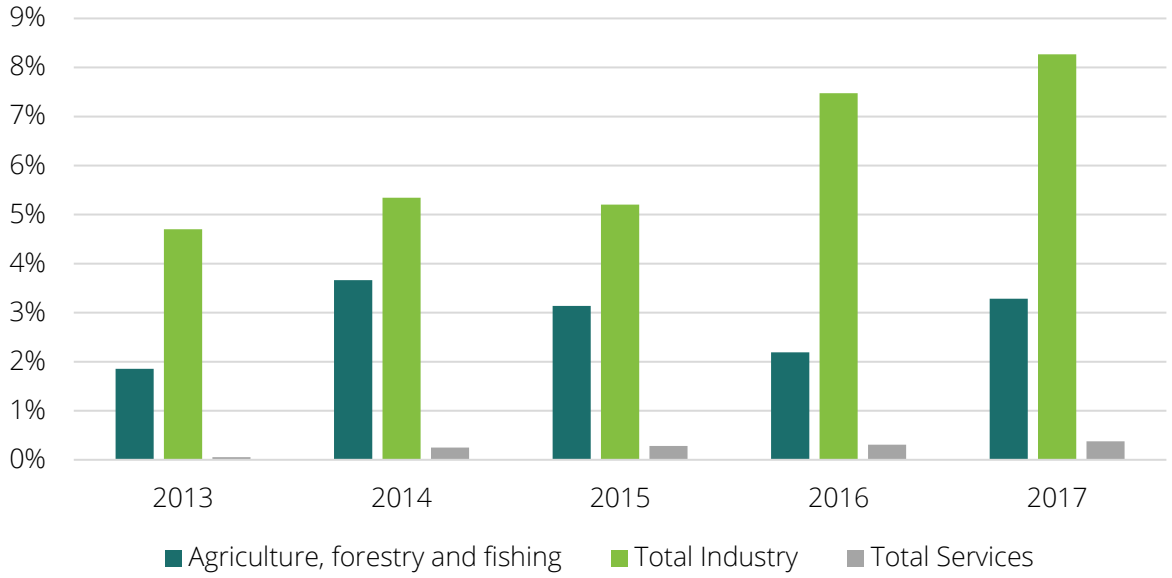
At the same time, the broad *Service*s sector (NACE sectors G-U) saw some growth over the period from less than 0.1 per cent of aggregate employment to 0.4 per cent in 2017. This implies that EGSS employment outpaced wider sectoral growth. However, despite this relative growth, in 2017, the EGSS sector remained relatively marginal within wider employment in the composite category, despite *Service*s making up the vast majority of employment in Ireland.

Figure 21: Environmental Goods and Services Sector Composition by NACE Sector



Source: Employment in the environmental goods and services sector (Eurostat, 2021)

Figure 22: Environmental Goods and Services Sector Ireland as a proportion of aggregate employment by broad NACE sector



Source: Employment in the environmental goods and services sector (Eurostat,2021), Labour Force Survey (CSO,2021)
Note: Industry represents a composite of several NACE sectors: *Mining and quarrying*, *Manufacturing*, *Electricity, gas, steam and air conditioning supply*, *Water supply; sewerage, waste management and remediation activities* and *Construction* or NACE sectors B-F respectively. *Services* incorporates sectors G-U. See Appendix.

However, other identification methodologies would likely produce far higher estimates of green job numbers in Ireland. The EGSS methodology – and the discontinued Green Goods and Services Sector (GGSS) formerly produced by the Bureau of Labour statistics in the United States - define jobs by combining the environmental properties of a given industry with associated work activities (Consoli, Marin, Marzucchi and Vona, 2016).

In contrast the Occupational Information Network (O*NET) dataset developed by the US Department of Labour uses an occupational approach. O*NET includes occupational data including work tasks, education, necessary experience and work context.

As Table 4 shows, the choice of methodology can substantially affect estimates of green sector size. Irish specific O*NET data is unavailable to the best of the authors' knowledge.

Table 4: Estimates of Green Jobs for varying methodologies

Region	Methodology	Green Jobs estimate	Source
United States	GGSS	3.4 million or 2.6% of employment (2011)	Chadwick, Dewolf, Fett and Viegas (2013)
United States	O*NET framework (restricted)*	9.8-12.3% employment (2011/2012)	Consoli, Marin, Marzucchi and Vona (2016)
United States	O*NET framework	19.4% directly and indirectly green	Bowen, Kuralbayeva and Tipoe (2018)
European Union	EGSS	4.15 million Full-time equivalents or c. 2.3-2.4% of employment (2017)**	Eurostat (2021)
European Union	O*NET framework	87.6 million or 40% of employment (2016)	European Commission (2019)

Note: * See Appendix. ** Full-time equivalent refers to adjusted data designed to reflect employment levels incorporating hours worked. A full-time worker is standardised as 1 FTE, while part-time workers are presented as some fraction based on hours relative to the full-time average. In this case, In the absence of EU FTE estimates, full-time employment is added to 0.5 part-time employed numbers.

4.5 What can be said about the labour market and our green transition?

Clearly, the majority of territorial non-household emissions in Ireland are attributable to specific sectors which do not have the same footprint in employment terms. Other emissions methodologies can produce even greater degrees of emission concentration (Goldrick-Kelly and Nugent, 2019).

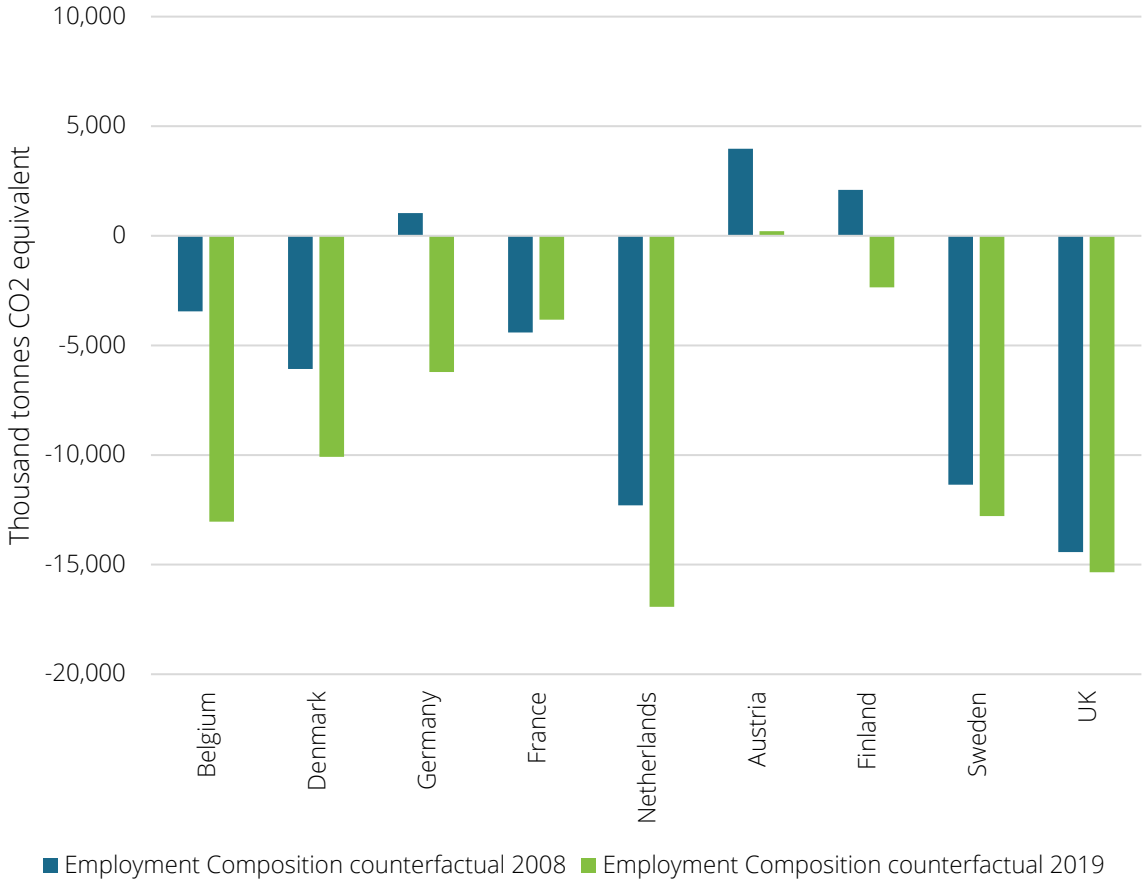
However, in relative terms, Irish employment is biased in composition terms to economic sectors with higher emissions intensities relative to many comparable states.[6] This can be demonstrated by simulating the effect of divvying Ireland's employed population according to the sectoral shares recorded in comparators (Figure 23).

[6] Comparable states here refers to current and former members of the European Union with populations greater than 1 million and similar levels of GDP per capita (McDonnell and Goldrick-Kelly, 2017)

In 2008, holding emissions per person employed constant, Ireland would have shown significant emissions reductions if its employment composition matched six of nine comparators with the exceptions of Germany, Austria and Finland. Greater counterfactual emissions (approximately 1.0, 4.0 and 2.1 million tonnes of CO_2 equivalent respectively) were predominantly generated by the greater weight of *Manufacturing* and *Electricity, gas, steam and air conditioning supply* in employment terms within these countries. In most cases, shifting employment shares to match comparators would have generated significant reductions in emissions, all else equal in 2008. The biggest emissions offsets would have been generated by matching employment shares in UK, Netherlands and Sweden, which would have generated reductions of 14.4 (27.8 per cent), 12.3 (23.7 per cent) and 11.4 million tonnes (21.9 per cent) CO_2 equivalent respectively.

In most cases, these counterfactuals generate greater emissions losses by 2019, despite Ireland's progress concerning aggregate emissions between 2008 and 2019. For five of the nine cases, emissions declines amount to more than 10 million tonnes of CO_2 equivalent, or more than a fifth of non-household territorial emissions. By 2019, only Austria retained an employment profile that would have generated marginally greater emissions (0.5 per cent or 208,000 tonnes CO_2 equivalent) in Ireland. The biggest sectoral contributor to these counterfactual reductions was the *Agriculture, forestry and fishing* sector, which contributed between 3 and 16.1 million tonnes CO_2 equivalent. In seven of the nine comparators (Belgium, Denmark, Germany, France, Austria, Finland and the UK), counterfactual reductions from declining employment in the sector more than exceeded offset totals. This analysis suggests that in employment terms, *Agriculture, forestry and fishing* represents the largest structural emissions challenge.

Figure 23: Counterfactual estimates of changes in Ireland's non-household territorial emissions given comparator employment shares



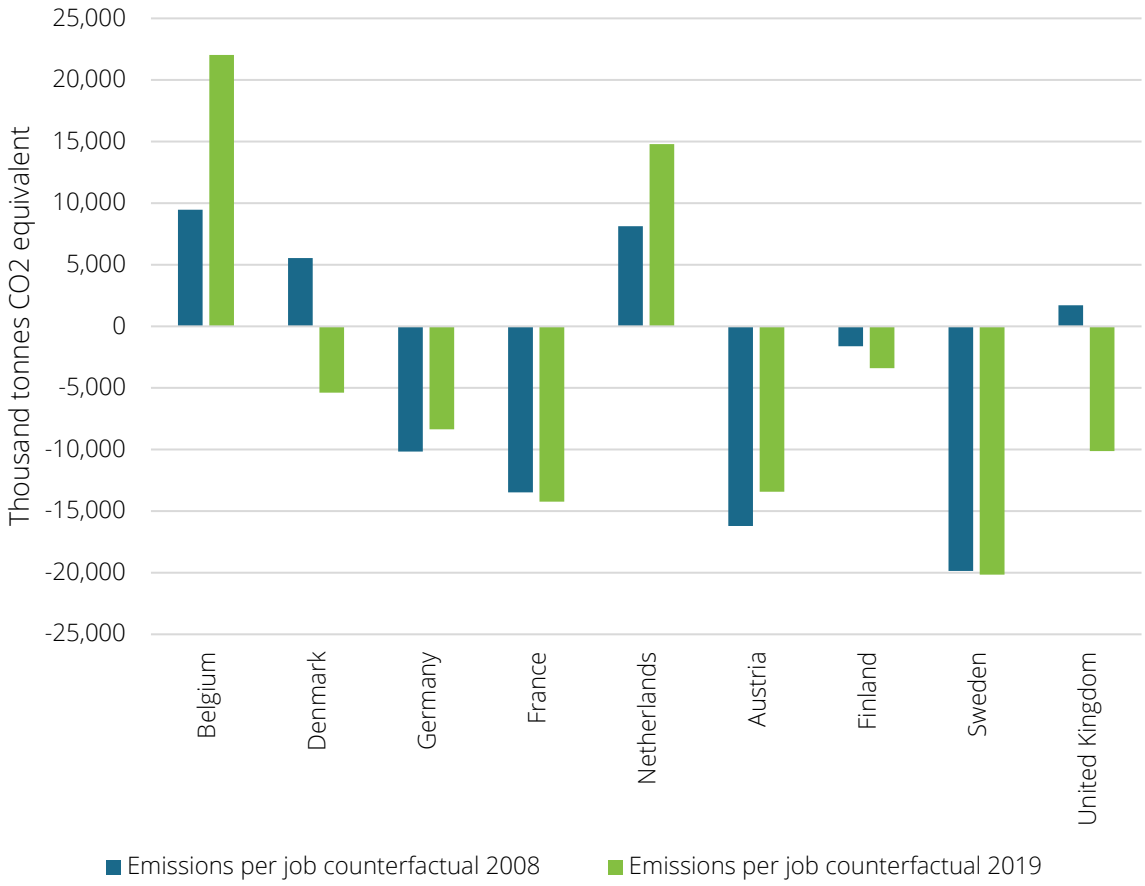
Source: LFS Employment by sex, age and economic activity (from 2008 onwards, NACE Rev. 2) (Eurostat,2021); Air emissions accounts by NACE Rev. 2 activity (Eurostat,2021), Air emissions accounts totals bridging to emission inventory totals, author calculations.

On the other hand, posing the counterfactual in terms of emissions per jobs offers a different picture (Figure 24). Keeping employment constant and attributing comparator emissions per person employed improves ROI's standing in relation to some comparators such as Belgium and the Netherlands, whose emissions per job would have led to significantly more emissions than we measured in 2008 or 2019. However, several comparators show counterfactual reductions exceeding 10 million tonnes of CO_2 equivalent: The UK, Austria and France. Reductions exceeded 20 million tonnes of CO_2 equivalent if Irish employment composition remained the same and emissions per person employed adjusted to Swedish sectoral levels.

These reductions were mainly driven by counterfactual emissions falls in *Agriculture, forestry and fishing* and *Electricity, gas, steam and air conditioning supply*. While subject to country

specific factors that may be more or less amenable to intervention, these reductions may be indicative of significant transition potential that targets how these sectors operate even where employment levels remain the same.

Figure 24: Counterfactual estimates of changes in Ireland's non-household territorial emissions given comparator emissions per person employed



Source: LFS Employment by sex, age and economic activity (from 2008 onwards, NACE Rev. 2) (Eurostat,2021); Air emissions accounts by NACE Rev. 2 activity (Eurostat,2021), Air emissions accounts totals bridging to emission inventory totals, author calculations.

SECTION 5: CONCLUSION AND IMPLICATIONS

5.1 Conclusions

In this paper, we examine the degree to which different theoretical variations of two major structural forces shaping labour markets, in the form of automation/technological change and the low carbon transition, have had measurable effects on the labour market in the Republic of Ireland over the period from the 2008 global economic crisis to the current pandemic period.

In the case of automation, the evidence for change is somewhat mixed. Trends in aggregate employment and unemployment – growth in the former and sustained reductions in the latter - in the Republic of Ireland between 2007 and 2019 are not consistent with pessimistic projections of mass unemployment generated by technological advance. Evidence of labour substitution is also not evident in the data for hours worked, which have recovered following the crisis period 2008-2012. However, the labour market has seen an apparent structural shift to increased part-time work, and a decline in labour market participation driven in large part by declines in participation by men (despite lingering differentials in participation in relation to women). These trends may reflect impediments to labour market participation and intersect with experiences of precarity since the 2008 crisis (Nugent, Pembroke and Taft, 2019).

The sectors facing relatively low automation risk appeared to fare best over the course of the recession. However, many at risk sectors saw significant growth following an initial significant loss during the 2008 crisis period, suggesting that advances in and utilisation of automation technologies did not necessarily bias employment recovery away from these jobs. Similarly, in occupation terms, low risk occupations showed significant growth in the recovery period, but sectors such as Caring, leisure and other services (identified by Doyle and Jacobs (2018) as facing the lowest automation risk) grew much more relatively. Other at-risk sectors grew but had not seen recovery to their former levels in relative terms.

The evidence is clearer with respect to skills and routine biased change. Employment in Ireland has become increasingly skewed towards higher skilled work and away from middle and low skilled employment, paralleling a trend towards a more educated workforce. Employment also appears to have been biased to non-routine abstract and service work, consistent with labour substitution theories positing greater displacement where work had higher proportions of routine tasks which are more readily automatable.

Where the green transition is concerned, the available evidence suggests that such a structural shift is more prospective than currently in evidence. In the Irish case, the data suggest that the Republic of Ireland may have begun a process of decoupling economic activity and employment from emissions, although this may depend on how one assigns emissions occurring outside of Ireland's borders. Other measures of emissions show less progress, and observed emissions reductions do not match those demanded by the scientific evidence (Burck et al., 2020; UNEP, 2020).

Ireland also appears to be showing growth in terms of "green employment" according to more restrictive industry basedindustry-based definitions of green jobs, and other occupation/skills basedskills-based definition would likely show a more significant employment profile. Emissions in Ireland are relatively concentrated in sectoral/employment terms, with 90 per cent of emissions associated with just over a fifth of employment.

Progress in emissions intensive sectors seems to be concentrated in the Electricity, gas, steam and air conditioning supply sector, which though still a significant emitter, has led emissions reductions between 2008 and 2019. Agriculture, forestry and fishing remains the problem sector in emissions terms, showing an increase in aggregate emissions and carbon intensity per person employed.

A comparison with other comparable states suggests that our employment structure drives some of our laggard status in emissions terms, with hypothetical adjustments to our employment profile showing significant consequent reductions in emissions (all else equal) that have increased over time. Nevertheless, an alternative counterfactual where

employment in Ireland remained as is and emissions per job matched other states would also result in significant emissions reductions.

5.2 Implications

As we relay over the course of the paper, the most negative predictions as to the employment implications of automation and green transition processes, namely that both trends will/would induce net losses in employment does not seem to be borne out by the empirical evidence or prospective literature.

On the other hand, a closer examination of the data and findings as to the effect of automation and green transition on the labour market suggest that these shifts may impact some sections of the labour market, and in turn, some workers, more than others. These impacts have considerable scope to play out from automation and we are just now beginning to face these challenges in the transition to a low carbon economy. In the latter case, despite some definitions of "green jobs" showing significant present scope, our carbon situation (and relative lack of progress) suggests that these sectors will too face significant challenges if we are to meet climate goals. In some senses, the literature on transitions based on current data may be overly sanguine.

Employment trends reflect a bias towards higher skill and less routine work which may prove disruptive for displaced workers who may find a relatively hostile labour market as a result. The available literature suggests this could be true of workers displaced by technological change as well as those in emissions intensive or non-green jobs.

The separate analyses undertaken here both, for example, suggest that persons in Agriculture, forestry and fishing face challenges from both automation and the necessity of emissions reductions. The sector has been identified as at high risk for automation from both a skillsskill and occupation basedoccupation-based perspective. The sector also has a relatively low proportion of green jobs both as measured in industry-based terms and as imputed by occupation-based estimates. The sector also appears to be the primary blockage to emissions reductions on a territorial basis, showing persistently high levels of emissions in

aggregate and increasing emissions per person employed in the sector. Further research as to transition difficulties faced by this and other at-risk sectors could be beneficial to craft sector specific responses to these challenges.

However, in many senses, these issues and others suggest that, while specific in terms of their precise impacts, these major structural transitions may show a great deal of overlap in terms of risk and managing common problems of transition difficulty. Alternative configurations of social protection and activation support can ease transition difficulty for workers facing displacement, alongside a proactive approach to planning incorporating workers and their representatives (Mercier, 2020; Ní Lochlainn,2020; Goldrick-Kelly and Nugent, 2019). A Just Transition framework could be extended to broader structural changes to ensure that the costs and potential benefits of wider labour market shifts are shared.

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Appendix A

NACE Code	Description
A	Agriculture, forestry and fishing
B	Mining and quarrying
C	Manufacturing
D	Electricity, gas, steam and air conditioning supp
E	Water supply, sewerage, waste management and remediation activities
F	Construction
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
H	Transportation and storage
I	Accommodation and food service activities
J	Information and communication
K	Financial and insurance activities
L	Real estate activities
M	Professional, scientific and technical activities
N	Administrative and support service activities
O	Public administration and defence; compulsory social security
P	Education
Q	Human health and social work activities
R	Arts, entertainment and recreation
S	Other service activities
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U	Activities of extraterritorial organisations and bodies

Source: Reproduced from Eurostat (2008)

Appendix B

The O*NET framework produces a relatively expansive definition of green jobs which incorporates occupations affected by "greening" that can be broken into three subcategories:

1. Green increased demand (Green ID) comprise current occupations that are forecast to show high rates of employment growth due to economic greening.
2. Green Enhanced Skills (Green ES) are current jobs that are expected to significantly change in terms of the task profile.
3. Green New and Emerging (Green NE) refer to jobs which emerge in response to the needs of the green economy.

Consoli *et al* (2016) restrict their estimates of the green sector to the Green ES and Green NE categories , while Bowen *et al* (2018) include the Green ID sector.

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