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‘Untapped potential’? Linking regional economic futures and the prospects for demographic recovery in sparsely populated Scotland

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Contents

Tables

Figures

Key messages

This report presents the results of a refined model which evaluates how employment change could affect population levels and demographic structures across Scotland, focusing on sparsely populated areas (SPAs) which have been identified as vulnerable to depopulation. The analysis identified *potential populations* which assume no barriers to labour migration.

It is very possible that Scotland's SPAs have potential for demographic recovery - in terms of population levels, and for at least some subregions - which is not being realised. When future migration is tied to regional employment changes under a business as usual scenario, potential population levels indicate that the depopulation previously forecast for the SPAs is reversed. Sparsely populated parts of Orkney and northern Scotland have the most positive trends within the SPAs, while prospects for SPAs in the south-west are more pessimistic.

Projected population growth in the SPAs does not lead to more sustainable and balanced population structures, which may be more difficult to achieve.

A second net zero scenario, including the possible impacts of reducing emissions on employment levels in different industries, has a strongly positive impact on potential populations in the SPAs and in other regions, although this is subject to higher uncertainty, and a likely optimism bias.

These findings are subject to uncertainty, including assumptions of the household characteristics and age structures of migrants. Additionally, subregion-scale projections should not be assumed to apply to all communities within them. However, the results improve the understanding of the feasibility of repopulation within sparsely populated areas.

1. Background: demographic challenges in Scotland's sparsely populated areas

The demographic challenges faced by sparsely populated areas, and by some other regions in Scotland have become widely acknowledged. The population of Scotland's SPAs – places where it is estimated that less than 10,000 people lived within 30 minutes' travel in 2011 - has been projected to fall by 18.6% from 2018-43 (Hopkins and Piras, 2020a). National Records of Scotland (NRS) (2020a) have also projected population declines for fourteen council areas by 2028, including in three of the five

council areas where a majority of the population lives in remote areas[1], and in five out of seven councils where over a quarter of the population are resident in remote areas. This concern is reflected in the Scottish Government's publication of a national population strategy (Scottish Government, 2021a) which highlights sustainable population levels, sustainable population structures (in terms of age), and geographical balance in population distribution as major demographic challenges for Scotland. Additionally, the first strategic objective of the National Islands Plan (Scottish Government, 2019) is "*To address population decline and ensure a healthy, balanced population profile*".

As a whole, the SPAs in Scotland suffer from the impacts of unfavourable age structures which will inevitably lead to population loss unless supported by increased migration (Copus and Hopkins, 2018). However, the issue of rural depopulation is not specific to Scotland: approximately 60% of European regions outside of 'Predominantly urban regions' are shrinking, and it is also recognised that depopulation can result from different combinations of spatial, demographic and economic characteristics (Copus et al., 2020).

The essential role of migration in supporting communities in sparsely populated areas, and indeed population levels in Scotland as a whole (National Records of Scotland, 2022) raises questions over how this uncertain and complex spatial process should be estimated and fed into demographic projections. Different types of economic-demographic models exist, with a broad premise that economic growth drives migration (George et al., 2004). This note presents results from a refined model which evaluates the implications of regional economic futures for the demography of SPAs in Scotland, which are considered as particularly vulnerable to depopulation. The projections described in this note do not constitute *likely* future populations, but instead form *potential* populations: the population levels and demographic structures which could be observed in different places in sparsely populated Scotland (and elsewhere) in a reasonable and regionally-detailed economic scenario for the 2018-43 period. The trends in these *potential populations* could identify variation in the feasibility of repopulation of sparsely populated areas of Scotland.

[1] The Scottish Government's Urban Rural Classification defines 'remote' areas as small towns and rural areas over half an hour's drive away from urban areas. Population distributions in council areas sourced from Scottish Government Geographical Information Science & Analysis Team, Rural and Environment Science and Analytical Services Division (2018) (Table 5.2: page 20)

2. Could economic development support balanced population growth in sparsely populated areas? Introducing the economic-demographic approach

Given the importance of migration to future population growth in Scotland, it is unfortunate that it is highly difficult to predict, as it is influenced by numerous factors and events (Castelli, 2018). Migration data is also not readily available (due to the location of administrative boundaries) for sparsely populated areas which are vulnerable to depopulation.

The migration estimates used by NRS within their most recent sub-national projections are based on past data (National Records of Scotland, 2020b), and detailed data from NRS on net migration (age-, sex-, and council area-specific) has been previously used in population projections for Scotland's SPAs (Hopkins and Piras, 2020a). However, there are arguably two reasons why alternative estimates of migration could be considered. Firstly, the major socio-economic shocks of Brexit, the COVID-19 pandemic, and implications of the war in Ukraine could shift migration rates and patterns, with evidence of a post-Brexit decline in migration from the EU to Scotland (Scottish Government, 2021b) being evidence of this. Secondly, the SPAs are diverse, in terms of their spatial distribution across the mainland and islands, and also in their relative economic characteristics and opportunities. The latter include the contribution of different types of industries to economic value added and employment, trends in these activities (the growth and decline of different industries), and the strength of links to other areas (including residents commuting to another place for work). These factors are likely to vary across space and create inequalities in development, affecting in turn the size and distribution of the future labour force. We argue that there is considerable value in assessing the potential implications of these changes for future populations in sparsely populated areas, by developing subregional estimates of migration based on economic development.

In 2020, an economic-demographic foresight method was trialled: this created a whole Scotland scenario of future employment change (by industry sector) for the period 2018-43 in and generated net migration rates - and their detailed breakdown by age and sex - for 25 subregions. Fundamentally, the model identifies, for each five-year subperiod, the labour requirement created by the evolution of employment in each subregion, and the proportion of this demand that cannot be met by the local workforce (accounting for its turnover). This proportion is assumed to be met by immigrant employees, allocated (in residence) between different subregions based on dynamically-evolving economic links between subregions: the model is concerned

with where potential migrants could live, therefore people arrive and settle where there is a demand for labour (either locally or in nearby regions based on commuting patterns). However, the model does not distinguish the sources of these potential migrants: where people were born, or where they moved from. The resulting net migration rates for each subregion (and their structures) account for these employees and other members of their households. If shrinking total employment is expected in a subregion, then the number of immigrant employees (and their household members) for that subregion is negative. It is important to note that assumptions about the structure and size of households (including the children, older people and other people who accompany labour migrants) are based on Scotland-wide data for residents. These are applied consistently for all subregions, but as these assumptions impact upon projected population structures (as do our assumption that migrants' age structures reflect those of the subregion's population), the population structures resulting from the modelling should be assessed with caution. Additionally, in reality, the households of current or recent migrants may differ from those of Scottish residents as a whole.

Thus, we assume that in each subregion the labour supply always aligns with the local demand, and that if the labour demand declines, the people who lose their jobs leave the subregion[2]. The migration rates calculated as above were incorporated into a population projection process, which also captures the evolution of detailed population structures through births, aging and deaths (Hopkins and Piras, 2020b). The first version of the model produced unrealistically high net rates of migration since it used single Scotland-wide estimates of employment evolution, which are likely to be heavily influenced by major economic centres in larger cities: a very different context to the economies of sparsely populated areas. The population forecasts summarised in this note are based on an improved and refined model which used more detailed regional estimates of future employment change which are projected to occur given a business as usual development scenario. In addition, given the urgency of achieving net zero emissions, we have generated a second scenario which combines the regional forecasts with an additional estimate of the impacts of decarbonisation on different industries: this is used to examine the sensitivity of our model to further change.

The economic-demographic foresight modelling generates population projections in five year steps for 25 subregions covering the whole of Scotland. in this note we focus on the picture within the SPAs for the 2018-43 period. These subregions were

[2] Further model refinements could introduce constraints such as house availability and cost, thus allowing for mismatches between demand and supply.

defined using small areas (Data Zones) for the purposes of this analysis, and were drawn based on the SPAs definition, local authority boundaries, and Travel to Work Areas (for subregions in the very large council areas of Highland and Argyll and Bute). It is important to note that population trends described in this report and modelling outputs do not identify variability in outcomes below the subregion level. For example, subregions or regions where population decline is being experienced or is projected for the future are likely to contain communities which are growing, and/or which have potential to grow.

3. Business as usual regional economic futures: employment change in different industries

Although the Census publishes the most detailed, and most complete, public data on residents' employment, the long time period between Censuses limits the usefulness of this information for identifying how future employment might change. In this analysis, a detailed annual time series of estimated employment within different industries was constructed using Annual Population Survey data. Although publicly available employment totals are rounded and are survey-based, the Annual Population Survey and its contributor surveys provide sub-national information and are recommended by the Office for National Statistics as a source of employment data[3]. Moreover, the annual resolution and availability of data from 2004 onwards provide a high volume of data well suited to modelling trends. In the first version of the model, which used Scotland-level employment figures by sector, employment totals by sector for 2019-28 were modelled[4] and then used to generate estimated rates of employment change across 2018-43. However, regional level employment estimates proved too unstable to be modelled using the same approach, or other time series modelling strategies, especially for future projections. Therefore, in the version of the model presented here, each subregion- and sector-specific time series for 2004-18 was used to extrapolate a linear trend which was assumed to continue until 2043. Based on this trend, rates of employment change for each sector, subregion, and five-year period were calculated. In those cases where the coefficient for the linear trend was not significant (at the 10% level), the employment was assumed to remain stable during the period. In a few cases where the trend was negative, zero employment was set as a floor to avoid negative values in further away periods.

[3] https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/methodologies/annualpopulationsurveyapsqmi

[4] The method used was vector autoregression

4. How might net zero affect employment?

The Scottish Government have a target of achieving net zero carbon emissions by 2045 (Scottish Government, 2020). Achieving net zero requires changes which "…are transformational, not gradual and incremental" (House of Lords Industry and Regulators Committee, 2022). The impacts of decarbonisation on regional economic development and employment patterns are uncertain, not least because jobs in some 'green' sectors may be dependent on stages of technological development (Connolly et al., 2016). Furthermore, at the European level, the industry sectors responsible for the vast majority of carbon emissions support only a small proportion of employment (OECD, 2012), implying that significant decarbonisation may not directly affect most of the economy.

The net zero scenario consists of the regional employment changes from the business as usual scenario, adjusted by sector-specific employment changes applied to all subregions. The latter were derived from an analysis of EU-level employment change by industry sector (2020-30) assuming a cut in emissions of 50-55% associated with the European Green Deal (Cedefop, 2021). These were used to calculate estimated employment changes in Scotland (from 2018-28) within macro-sectors. Based on the assumption of successful economic restructuring (and creation of additional green jobs), our final net zero scenario suggests very positive impacts of carbon reduction on employment. Almost all industries grow, with rapid expansion of employment in utilities, water and waste management. Employment is expected to sharply fall within the land-based and extractive industries, and decline marginally in manufacturing.

Table 1: Changes in employment applied in the net zero scenario (in addition to regional employment changes)

Macro-sector*	**Five-year multiplier for total employment in macro-sector****
AB (Agriculture, forestry and fishing; mining and quarrying)	0.86
DE (Utilities; water and waste management)	1.18
C (Manufacturing)	0.99
F (Construction)	1.04
G (Wholesale and retail plus vehicle repair)	1.03
I (Accommodation and food service)	1.06
HJ (Transportation and storage; information and communication)	1.04
KLMN (Financial and insurance; real estate; professional/scientific/technical; admin and support)	1.04
OPQ (Public sector; education; health and social work)	1.04
RS (Arts, entertainment and recreation; other services)	1.02
TU (Other)	1.04

**Macro-sector names derived from the UK Standard Industrial Classification (SIC); **Values above 1 indicate increases in employment, values below 1 indicate decreases.*

5. Regional overview and subregional variation: projected population change (2018-43) given business as usual

In the following paragraphs, in addition to total populations (and changes in total populations over time), we refer to the following indicators of demographic change:

Working age population: all people aged 15-64

Dependency ratio: the number of children (aged 0-14) and older people (aged 65 and over) per 100 people of working age

Old age dependency ratio: the number of older people (aged 65 and over) per 100 people of working age

These definitions are not tied to actual working ages or employment activity, but are based on the resolution of population data.

Table 2: Demographic change from 2018-43 under business as usual regional economic development

Indicator	SPAs	Not in SPAs (Outside mainly urban council areas)	Not in SPAs (Mainly urban council areas)
Total population (2018)	126,471	1,619,719	3,691,910
Population change (2018-43)	+6.5%	+4.1%	+13.5%
Working age population (2018)	74,920	1,006,726	2,464,599
Working age population change (2018-43)	-0.7%	-1.5%	+7.8%
Dependency ratio (2018)	68.8 people	60.9 people	49.8 people
Dependency ratio change (2018-43)	+12.4 people	+9.3 people	+7.9 people
Old age dependency ratio (2018)	46.0 people	35.3 people	25.8 people
Old age dependency ratio change (2018-43)	+9.0 people	+9.0 people	+9.2 people

The population characteristics at the starting point of 2018 emphasise the distinctive and less balanced demographic profile of the SPAs, as there are high numbers of dependents (children and older people) relative to the size of the working age population in the SPAs, compared with other regions (Table 2). **However, following projected migration rates generated by the business as usual scenario, the depopulation which has previously been forecast for the SPAs** (Hopkins and Piras, 2020a) **and for many remote council areas** (National Records of Scotland, 2020a) **is reversed**. The population of SPAs is projected to grow 6.5% by 2043, a faster rate of growth than in the non-SPAs outside urban centres. The number of working age residents in the SPAs is projected to decline slightly, but the respective trend in the more rural region outside the SPAs is similar. Mainly urban councils are projected to experience considerable population growth, including in the working age population, by 2043.

In addition to changes in population totals, population structures are also expected to evolve, and in the SPAs, there are projected to be 12.4 more children and older people for every 100 working age residents by 2043. Populations outside the SPAs are also expected to become more unbalanced, but to a lesser extent. Surprisingly, the changes in old age dependency ratios for the three regions are very similar, with around nine more older residents per 100 people of working age in the SPAs and in both areas covering the rest of Scotland. Taken together, these indicators suggest that **business as usual economic development will create a more unbalanced population structure in the SPAs, but that increasing numbers of older people are not the only driver of this.** Confirming this, the older population (aged 65 and over) in the SPAs is projected to grow at a slower rate (+18.7%) than it does outside the SPAs in mainly urban councils (+46.2%) and in the rest of Scotland (+23.4%). Additionally, the population of children is projected to grow (+14.0%) in the SPAs, while it will only grow slightly in urban centres (+2.0%) and decline fractionally in the rest of Scotland (-0.4%).

The inter-regional variability in the optimism of the business as usual population projections across Scotland, and the within-SPAs variation in this, are particularly notable (Figure 1). **Under the business as usual scenario, six out of nine subregions in the SPAs are projected to experience population growth**, with the population of 'Orkney Islands – SPA' projected to grow by almost a third (+32.5%) and sparsely populated subregions in northern Scotland ('Highland – SPA', 'Moray and Aberdeenshire – SPA', 'Perth and Kinross and Stirling – SPA') projected to expand by more than 15% each. Sparsely populated areas of the Western Isles (+6.4%) and Shetland Isles (+3.3%) may experience slower rates of population growth, but **there is a more pessimistic projection for the south west of Scotland**: with the total population expected to fall by nearly ten per cent (-9.8%) in 'Argyll and Bute – SPA', by slightly more in 'Southern Scotland – SPA' (-12.1%), and by over twenty percent (-20.8%) in 'North Ayrshire – SPA' (the Isle of Arran). The working age population projections are less positive than the total population changes for all subregions in the SPAs, but growth is still projected in five out of nine subregions, with the highest increase in 'Orkney Islands – SPA' (+20.5%); the largest decline is projected for 'North Ayrshire – SPA' (-20.4%).

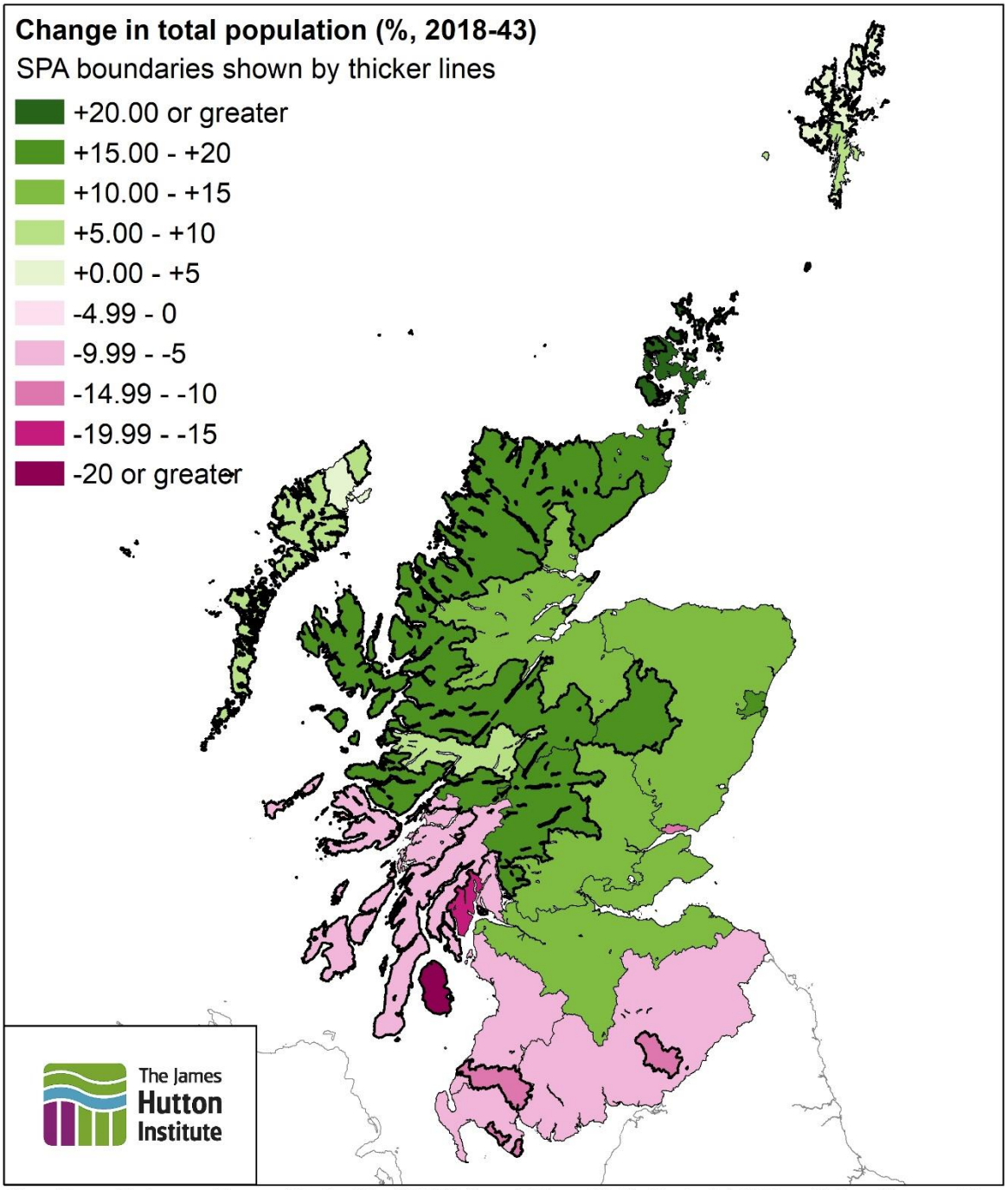
A core finding is that projected population growth, following the business as usual scenario, is not linked to the development of more sustainable population structures. This can be inferred from the pattern of total population change and the changes in dependency ratios for the three summary regions (Table 2), but also by projections for all 25 subregions in Scotland. There are very strong, significant

positive correlations between the dependency ratios in 2018 and their projected values in 2043, but the population structures in 2018 are not significantly correlated with forecast population change over the next 25 years[5]. **Projected population change is however significantly positively correlated with change in the dependency ratio and old age dependency ratio[6], indicating that more positive population change is likely to be associated with a transition to a less sustainable population structure**, given current low fertility rates and high life expectancy. For instance, 'Orkney Islands – SPA' is projected to grow faster than any other part of the SPAs, but relative numbers of dependents (compared with the size of the working age population) also increase to a greater extent than any other part of the SPAs. It should be acknowledged that projected population structures (including population distributions across age bands and dependency ratios) are heavily influenced by the model's assumptions related to migrants, including their household structures and age distributions (Section 2).

[5] 25 subregions, Pearson's correlations. Dependency ratios in 2018 and 2043: $r = 0.90$, $p < 0.001$; Old age dependency ratios in 2018 and 2043: $r = 0.91$, $p < 0.001$; Dependency ratio in 2018 and Total population change (%): $r = -0.25$, $p = 0.223$; Old age dependency ratio in 2018 and Total population change (%): $r = -0.25$, $p = 0.224$

[6] 25 subregions, Pearson's correlations. Change in total population, 2018-43 (%) and Change in dependency ratio, 2018-43 (people): $r = 0.53$, $p = 0.007$; Change in total population, 2018-43 (%) and Change in old age dependency ratio, 2018-43 (people): $r = 0.66$, $p < 0.001$

Figure 1: Projected population change (2018-43) at the subregion level



Coastlines: Ordnance Survey Strategi®; GISCO Coastal lines 2016: Scale 1:1 Million: © EuroGeographics for the administrative boundaries (reprojected to British National Grid). Subregion and SPA boundaries: derived from simplified Data Zone Boundaries (raw data: GI-SAT (Geographic Information Science and Analysis Team), Scottish Government: Data Zone Boundaries 2011. Copyright Scottish Government, contains Ordnance Survey data © Crown copyright and database right (2022))

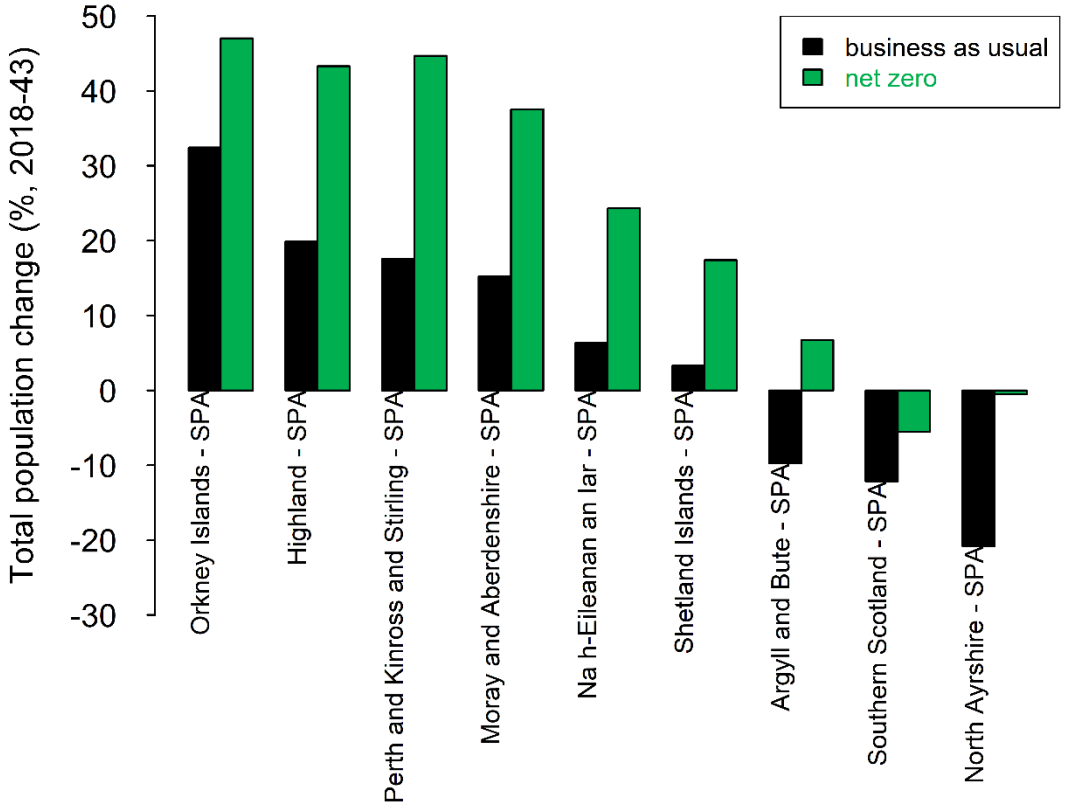
6. How does net zero affect populations across Scotland and in the SPAs?

A second version of the model analysed the demographic implications of regional employment changes given the business as usual scenario, plus the potential implications of economic restructuring to achieve net zero on employment in different industries (Table 1). **Decarbonisation is projected to have a noticeably positive effect on population levels and structures within all areas of Scotland, including the SPAs** (Table 3). Under net zero, the population of SPAs is forecast to increase by 26.1%, a considerably larger increase than that following the business as usual scenario. In other regions outside the SPAs, the level of projected population change is considerably more positive under net zero, with the mainly urban councils seeing the largest positive effect. Decarbonisation is also projected to lead to smaller increases in dependency ratios in all three regions compared to the 'business as usual' scenario, although the SPAs have the largest increase in this under both scenarios. Within the SPAs, the level of optimism of population projections at the subregion level was distributed in a similar way for both scenarios, with consistently more positive trends in the net zero scenario. Notably, the sparsely populated parts of Southern Scotland and North Ayrshire are projected to lose population in both scenarios (Figure 2).

Table 3: Projected demographic change (2018-43) in the business as usual and net zero employment scenarios

Indicator	Scenario	SPAs	Not in SPAs (Outside mainly urban council areas)	Not in SPAs (Mainly urban council areas)
Total population change	business as usual	+6.5%	+4.1%	+13.5%
	net zero	+26.1%	+22.8%	+36.2%
Dependency ratio change	business as usual	+12.4 people	+9.3 people	+7.9 people
	net zero	+9.8 people	+7.7 people	+7.4 people

Figure 2: Subregion-level variation in projected population change (2018-43) within the SPAs.



7. Interpretation and implications

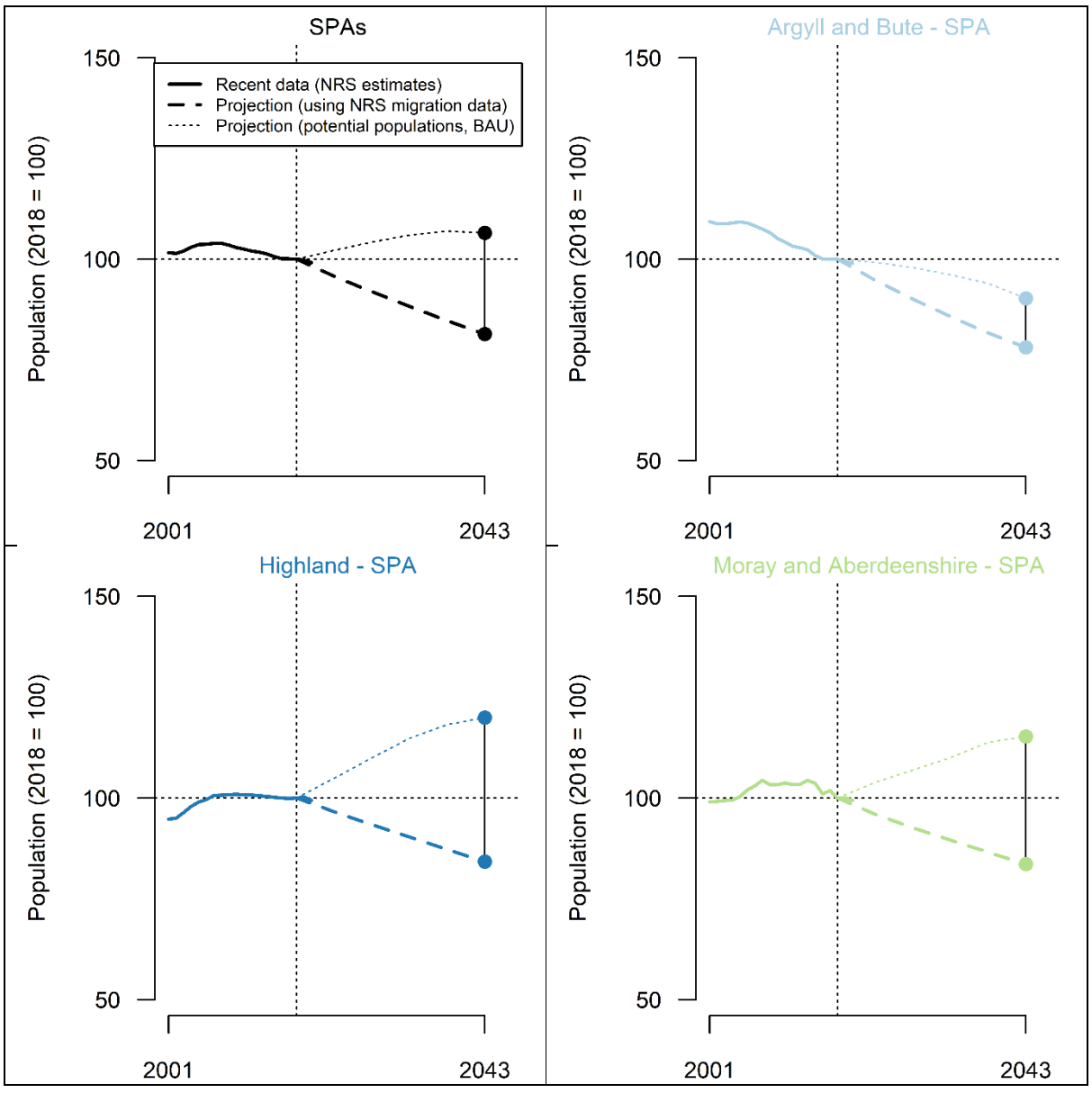
Economic-demographic foresight was developed by the researchers in 2020 as a model structure and analysis to investigate the implications of potential employment changes for populations across Scotland. It focuses on sparsely populated areas, addressing concerns about population loss from these areas, based on demographic age structures and recent migration patterns (Copus and Hopkins, 2018). The strong focus on economic development was informed by the diversity of economic activities in the SPAs, and their multiple networks of links with other parts of Scotland. The exploratory analysis (Hopkins and Piras, 2020b) acknowledged the unsuitability of applying nationwide employment trends to areas which are often characterised by remote towns and scattered small settlements. However, the analysis suggested that

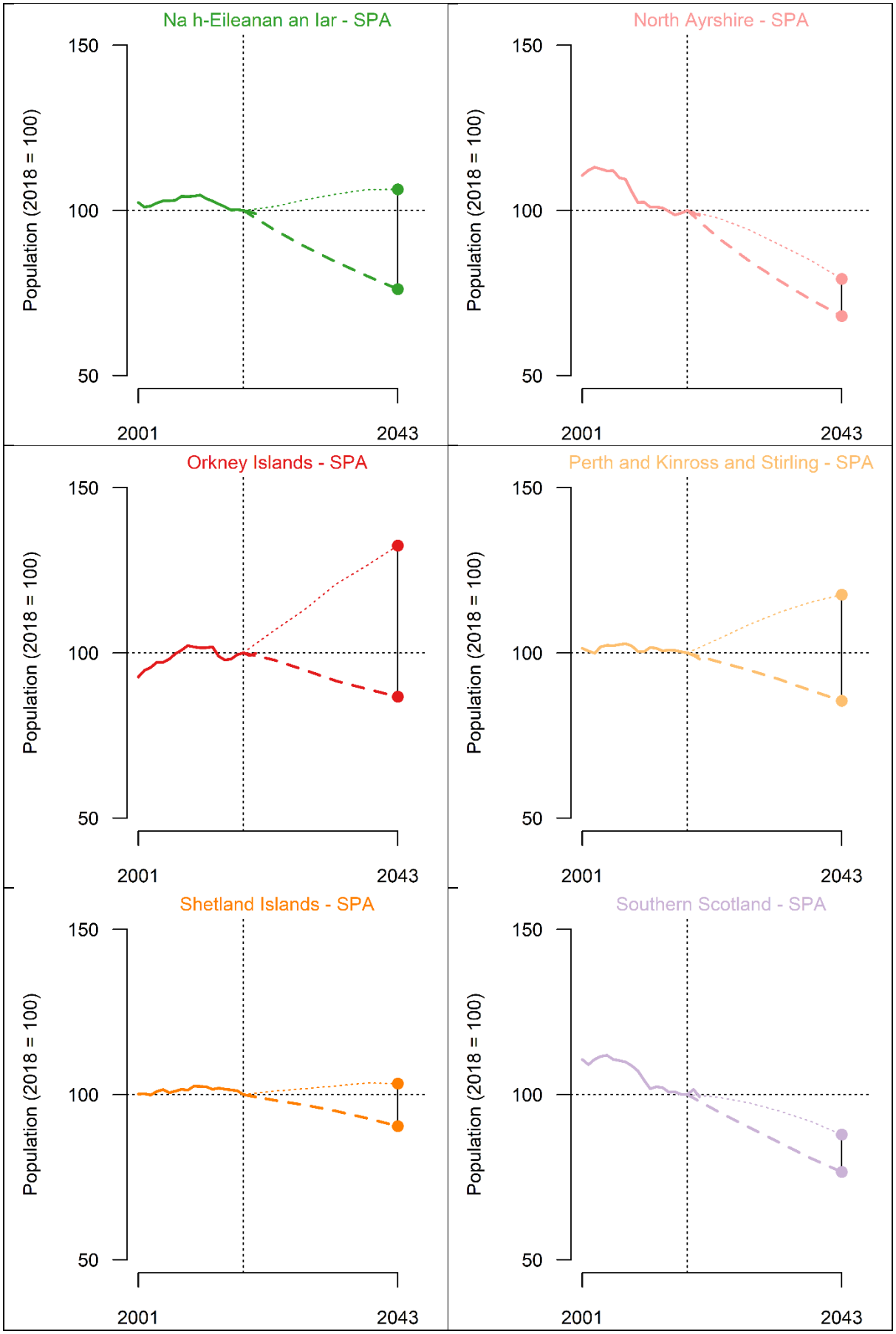
"...enabling sparsely populated areas of Scotland to access and participate in the benefits of economic development - wherever this occurs - is crucial to supporting population levels", and that attributes of population projections and economic characteristics could be used to inform tailored interventions in different sparsely populated locations in a place-specific (Iammarino et al., 2019) manner. Improved regional employment modelling has generated more realistic forecasts of potential populations compared to the previous model using Scotland-wide employment change, and while the underlying data, modelling process, and their fit to custom geographies are subject to uncertainties, **the results enhance understanding of the opportunity for repopulation within sparsely populated areas**.

The potential populations which could live in sparsely populated places, described in this note, are based on the assumption that migration into or out of regions automatically occurs in response to changing employment patterns: labour supply always aligns to local level demand. The real-world barriers to migration - not least housing affordability, personal commitments, skills mismatches to available employment, salary differences between subregions and changing government policies on external migration – do not apply. Additionally, the characteristics of migrants' households and their age structures are assumed to reflect those of Scottish and local (subregion) residents, respectively: these assumptions (and their limitations) will affect projected populations. The subregion scale of the analysis described will also mask underlying variation in population trends and projections at the community level. **However, at the subregion (intra-regional) level, comparing the projected demographic trend based on potential populations to depopulation risks inferred from recent population data, or population projections using alternative migration assumptions, could provide a stronger indication of the scale of demographic challenges, the feasibility of repopulation in different places, and potentially the level of policy intervention required.** Figure 3 illustrates these comparisons for the SPAs as a whole and for the nine subregions. The two projections (for 2018-43) shown are potential populations (based on regional employment change in the business as usual scenario, assuming no barriers to migration and full labour availability for growing industries) and projections where the future evolution of migration is based on recent trends (National Records of Scotland, 2020b; projections published in Hopkins and Piras, 2020a). The former can be considered an unlikely best case scenario for future population levels, while the latter present a more realistic and data-grounded projection.

Figure 3: Recent population trends (2001-20) and projected populations and potential populations (2018-43) for the SPAs and subregions.

Note: all graphs are at the same scale and indicate (background dotted lines) the start of the projections in 2018, and the 2018 population level (indexed to 100). The points and vertical solid lines illustrate the difference between projected populations and projected potential populations in 2043.




Na h-Eileanan an Iar - SPA
North Ayrshire - SPA
Orkney Islands - SPA
Perth and Kinross and Stirling - SPA
Shetland Islands - SPA
Southern Scotland - SPA
Population (2018 = 100)
150
100
50
2001
2043

In six subregions, depopulation is forecast in the more realistic projected populations, but potential population levels in 2043 show growth from 2018. **Reversing depopulation may be more achievable in parts of the SPAs where potential populations show higher rates of growth, and/or where removing limitations to migration and labour flows makes a bigger impact on population projections, indicated by the difference in the 2043 population levels** (represented by the points on Figure 3). Therefore, there appears to be a greater degree of optimism in 'Highland - SPA', 'Moray and Aberdeenshire - SPA' and 'Orkney Islands - SPA'[7]. In 'Perth and Kinross – SPA' the metrics noted above are also positive; however, recent population trends in this subregion (from 2001-20) show a population decline of over 3%. Across sparsely populated parts of remoter islands ('Na h-Eileanan an Iar – SPA', 'Shetland Islands – SPA'), the visualised indicators on Figure 3 suggest greater challenges in achieving population stability or growth. Lastly, it is notable that depopulation is forecast in three subregions ('Argyll and Bute - SPA', 'North Ayrshire - SPA' and 'Southern Scotland - SPA') in both projections: including in the 'best case' potential populations. The removal of barriers to migration and any limitations to labour supply does not achieve population growth in these areas, and the relatively small differences between the more realistic projected populations and potential populations in these subregions in 2043[8] suggests limited scope to limit population loss (a continuation of past population trends in these subregions) without considerable action.

Across all sparsely populated areas, these actions could align with previous recommendations of place-based interventions to support easier in-migration to these places, or enhanced connectivity to other regions (Hopkins and Piras, 2020b) as a means of "levelling up straightforward access to home-based and flexible working" (Hopkins and Piras, 2020b: 14). The COVID-19 pandemic has had very uneven impacts on different types of jobs, with remote working becoming commonplace in high skilled professional roles: ongoing blended working arrangements could support workers living further away from employers, but it is also argued that rural areas and smaller cities and towns may not benefit from the shift to online work (Florida et al., 2021). Resident surveys have the potential to identify the degree to which key structural issues (low housing availability, internet

[7] In addition to the differences shown on the graphs (displayed relative to 2018 population levels) In 'Orkney Islands – SPA' the 'realistic' projected population in 2043 was only 65.5% of the potential population in the same year.

[8] In addition to the differences shown on the graphs (displayed relative to 2018 population levels) in 'Argyll and Bute – SPA' the 'realistic' projected population in 2043 was 86.5% of the potential population. In 'North Ayrshire – SPA' and 'Southern Scotland – SPA', the respective figures were 85.8% and 87.2%.

connectivity and access to services) noted previously (Hopkins and Piras, 2020b) affect different places within sparsely populated regions, and their extent across the region as a whole: the latter could identify the governance level required for action. For example, The National Islands Plan Survey (2021) collected salient and recent data on island residents' views on these issues, as well as perceptions of local job opportunities and intentions to remain on the island in the short term: with notable differences in responses across different groups of islands and age groups identified in the full survey analysis (Wilson et al., 2021).

While acknowledging the uncertainty and limitations which remain in the modelling and its data inputs, projected potential populations suggest that it is very possible that Scotland's SPAs have potential for demographic recovery - in terms of population levels, and for at least some subregions - which is not being realised. The applied business as usual regional development scenario generates population growth of six and a half percent in the SPAs from 2018-43. The spatial pattern of projected population change across Scotland suggests that there is a regional influence on population trends, and that sparsity (as currently defined) has a smaller effect than other place-specific conditions. This may be an artefact of the council area resolution of some data inputs (e.g. employment data and demographic processes), but it is notable that 'Highland – SPA' has a higher rate of projected population growth than the non-sparsely populated subregions around Inverness, Fort William and Thurso and Wick; 'Na h-Eileanan an Iar – SPA' is projected to out-perform the non-sparse area near Stornoway; and although 'Argyll and Bute – SPA' is forecast to lose almost 10% of its population by 2043, the Dunoon area (not sparsely populated) is expected to lose over 16% of its people in the same period. The SPAs' subregions in the south and west of Scotland have the most pessimistic projections, but population declines are also expected in non-sparse subregions in close proximity to these. The contrast in population trends expected in the sparsely populated parts of island local authorities (Orkney, Shetland and Na h-Eileanan an Iar) emphasise the diversity in similar types of area. The results also found that a net zero scenario leads to more positive population growth in the SPAs and other regions, although this scenario assumes a positive effect of emission reduction on the economy and that this goal is successfully achieved: therefore, the comparison between the business as usual and net zero scenarios is subject to high uncertainty.

While regional employment changes could benefit population levels in the SPAs, it is interesting that the projected effect on population structure is decoupled from this, as the number of dependents per 100 people of working age increases faster in the SPAs than it does in other regions. This potential picture of unbalanced

population growth is supported by correlations between dependency ratios and total population change, considering all subregions. These findings – and others related to population structures - are caveated by the impact of the model's assumptions of household sizes and compositions, and migrant ages, on these structures. This measure may imply that achieving more balanced demographic profiles in sparsely populated areas is more difficult - potentially requiring longer time periods or targeted interventions - compared with supporting population levels alone. More practically, the projected changes to population structure in the SPAs (growing numbers of older residents and children, but with a slight decline in the working age population) could lead to a challenge of diversifying service provision to broader demographic needs.

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Appendix: acknowledgements and data sources

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Hopkins and Piras (2020a) contains details of data sources used previously to define the SPA and population and economic data used in this analysis.

Regional employment scenario calculated from data sourced from: ONS Annual Population Survey (ONS Crown Copyright Reserved [from Nomis]); Census 2011 Table QS605SC (© Crown copyright. Data supplied by National Records of Scotland).

Net zero scenario (Scotland-wide multipliers) calculated from data sourced from: Table A.1 (p48-50 in Cedefop (2021); Eurostat National accounts employment data by industry (up to NACE A*64) [nama_10_a64_e] (Last update 26.01.22, Extracted on 07.02.22); Census 2011 Table CT0144 (ONS Crown Copyright Reserved [from Nomis]); Office for National Statistics (no date) UK Standard Industrial Classification (SIC) Hierarchy. Available at https://onsdigital.github.io/dp-classification-tools/standard-industrial-classification/ONS_SIC_hierarchy_view.html; ONS Annual Population Survey (ONS Crown Copyright Reserved [from Nomis]).

Past population trends shown on graphs in Figure 3 calculated from National Records of Scotland Estimated population at 30 June by 2011 Data Zone area, council area and year, Scotland, 2001-2020, Persons (© Crown Copyright 2021). © Crown copyright. Data supplied by National Records of Scotland.

Data analysis used R (R Core Team, 2020), RStudio (RStudio Team, 2020), MATLAB, Stata. R Packages used include 'readxl' (Wickham and Bryan, 2019). Map created using ArcGIS. Colour scheme on map and graphs (Figure 3) based on Colorbrewer (https://colorbrewer2.org/, © Cynthia Brewer, Mark Harrower and The Pennsylvania State University)

Some R code used adapted from that at https://statisticsglobe.com/r-write-read-multiple-csv-files-for-loop