

A fair, just and long-lasting recovery for all: Forecasting and nowcasting in West Yorkshire

Briefing Note

Place Based Economic Recovery, Regeneration and Resilience Network

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SUMMARY POINTS

West Yorkshire's regional output

A quick recovery after the initial impact of the Covid-19 pandemic

- Yorkshire and The Humber's annual GVA has declined by 11.6 percent from 2019 to 2020— the largest output contraction since the 2008 global financial crisis.
- The region's economy has gradually recovered, reaching 92.87% of its pre-pandemic size.
- Annualised GVA growth rates have decreased by 10 percent in 2020 Q4 and 2021 Q1— the largest decrease since late 1980s. Then the rates have increased from a 5.5 percent change in 2021 Q3 to a 6.8 percent change in 2021 Q4—the highest positive annualised growth rate since late 1980s.

... But not as quick as other English regions that have strong reliance on digital, science and technology, healthcare and services sectors

West Yorkshire is forecast to reach 99% of pre-pandemic 2019 size in 2022

West Yorkshire as a system

- Better public transport and digital connectivity is concentrated in city and town centres, less affordable homes in suburban areas.
- More affordable homes than the English average to attract homes and businesses to region
- High demand for future 'green' jobs than other English regions → better prepare local workforce with right skills in demand.
- Increasing car traffic demand raises concern over road energy consumption.

Socioeconomic components of regional output

As the incorporation of the headline GVA statistic is insufficient, a compositional understanding of the drivers of output figures is, in fact, vital toward a consideration of the stability of an inclusive economy, and so is the movement of its socioeconomic components.

- Higher levels of investments in improved transport connectivity and in local workforce's skills and training increase regional GVA.
- Skills and training of local workforce reduces unemployment levels.
- Higher unemployment levels are linked to less dependence on cars, which may suggest an otherwise increase in demand for public transport in certain areas of the region.
- A strategic action regarding education and transport connectivity in the present make homes become more affordable in the future. Increased housing prices due to rising

demand likely correlated with increasing demand for local labour may attract workers from commutable, neighbouring areas if transportation infrastructure allows.

EXECUTIVE SUMMARY

An increasing concern of national and regional policymaking in response to the Covid-19 pandemic is provision of timely data on real-time economic performance and underlying activities throughout different parts of the nation and regions to give a complete signal about a fair, just, and long-lasting recovery plan for all. This briefing note outlines the economic recovery plan of the West Yorkshire region as a direct response to a request by West Yorkshire Combined Authority. The economic recovery plan has naturally evolved from a necessary immediate response to the Covid-19 pandemic to a broader re-imagining of developing a sustainable, fair and inclusive economy. This evolution brings with it a necessity to reconceptualise the aims and approaches of economic forecasting in West Yorkshire and the measurement of success.

Through a series of recommendations, this document presents a proposal to create a dynamic systems-based model over many social and environmental aspects to fully understand the West Yorkshire's inclusive economy and to provide the most updates of the region's economic nowcasts and forecasts. This proposal is conducive to West Yorkshire policy professionals, empowering them to adjust the nation's economic recovery plan to the region's emergent aspects and policy interactions with an ultimate goal of ensuring fair, just opportunities for all, especially disconnected parts and underrepresented social communities of the economy.

The three areas of focus emerge to support a sustainable, fair and resilient recovery of West Yorkshire:

First, the regional economy points to the role of timely data on real-time economic performance, economic nowcasts and forecasts to introduce profound economic changes, direct revaluations, and impact economic policy decisions. Data releases by the Office for National Statistics (ONS) and internal nowcasting to generate the regional annual output are due with a significant delay and far too late to make real-time decisions. Thus, in this analysis, we provide nowcasts, using most timely Regional Short Term Indicators (RSTI) releases with insights on the region's economy.

Second, the regional economy is better understood as a dynamic system with inclusive and sustainable economic aims. There necessitates available resources and comprehensive assessment of social and environmental values—such as transport and digital connectivity, housing affordability, skills of local workforce, business performance, transition to net-zero emissions—at local geographic areas to understand how the region's social economic system work and to indicate its disconnected parts that should be paid more attention to achieve the fairness and inclusiveness strategy.

Third, the incorporation of foundational measures relating to environmental and socioeconomic values into the region's economic output will further allow for a forensic view

of the components of the West Yorkshire economy as well as its top-level statistics, resulting in a dynamic and responsive recovery policy for all. Considering wider environment and social impacts as well as understanding regional advantages in local workforce, infrastructure and innovative ecosystems help set immediate priorities for investments and policy interventions today and secure a more resilient economy in the future.

INTRODUCTION

Post Covid, following the Johnson government's (at least stated) ambition to 'Level Up' regional differences and inequality are becoming an increasing concern in national policy making (McCann, 2020). In order to meet this ambition and to evaluate different policies, "reliable and consistent data measuring the economic performance of the regions are required" (Koop et al., 2020). The West-Yorkshire Economic Recovery Plan is focussed on "supporting jobs for people in resilient businesses, on helping people get the skills they need to get jobs, and on the infrastructure so people can access opportunities" (WY Recovery Plan 2021) and the latest version of the plan "moves the focus from rescuing the economy to building resilience and securing a fair, just and lasting recovery for everyone"¹ or "moves the focus from rescuing the region's economy to re-imagining and building resilience"².

The economic recovery plan has naturally evolved from a necessary immediate response to Covid-19 pandemic to a broader re-imagining of developing a sustainable, fair and inclusive economy. This evolution brings with it a necessity to reconceptualise the aims and approaches of economic forecasting in West Yorkshire and the measurement of success.

The movement from recovery to regeneration and resilience requires a rethinking of economic measurement and measures of success. This consideration of a wider economy away from static recovery focussed economics to a broader consideration of an economy working for all in West Yorkshire requires:

1. The conceptualisation of the economy as a dynamic complex system.
2. The inclusion of wellbeing, welfare and inclusivity in forecasting and measurement.
3. The incorporation of innovative forecasting and nowcasting techniques.
4. A data driven approach with the harnessing and incorporation of local data.

Additionally, there is an imperative to recognise the limitations of standard data sources for an analysis of a regional economy pivoting toward inclusivity. Whilst a command of these sources remains vital for numerous purposes, not in the least for working with national government and associated funding programmes the numerous standard data sources lag behind in presenting a picture of inclusion, wellbeing and effects within the region. Economic Recovery Plan's (ERP's) focus on a fair, just and lasting recovery *for all*, requires a deeper level of analysis as well as continuous monitoring.

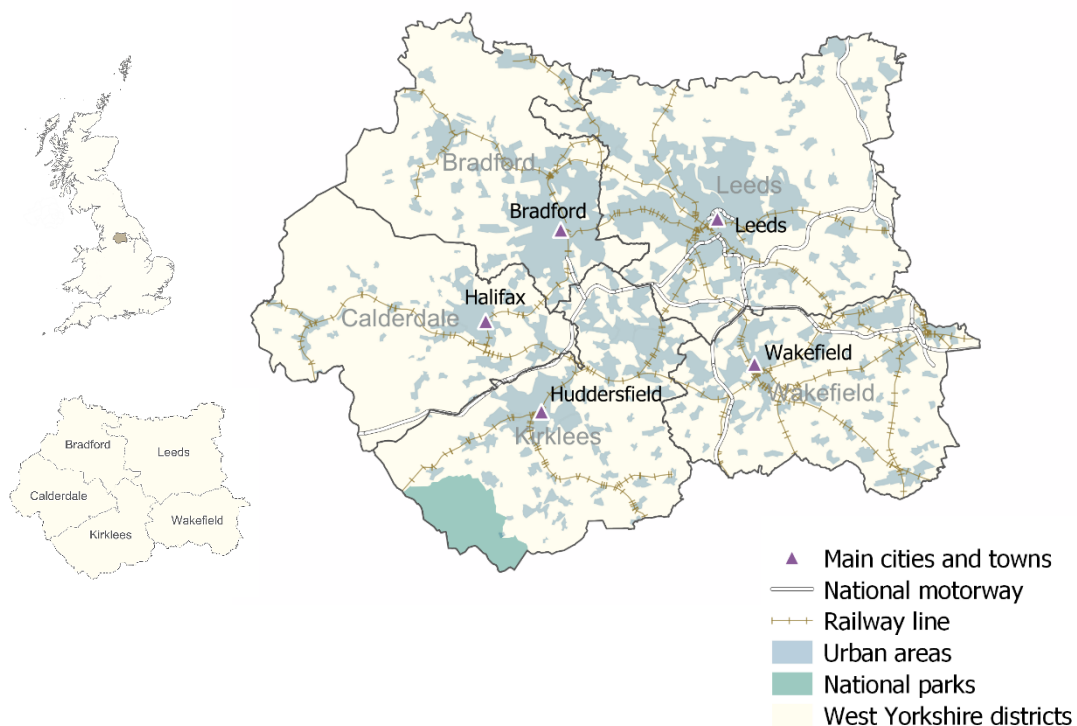
Economic forecasting, nowcasting and measures of success should include the more timely Office of National Statistics (ONS) releases. In particular the Regional Short-Term Indicators (RSTIs) releases as well as an internal nowcasting to generate regional Gross Value Added

¹ <https://www.thebusinessdesk.com/yorkshire/news/2081309-refreshed-economic-recovery-plan-revealed>

² <https://www.the-lep.com/all-news-and-blogs/economic-data-shows-west-yorkshire-recovery-gaining-momentum/>

(GVA) statistics from the UK as a whole ONS GVA statistics released quarterly and far sooner than their annual regional counterpart. Crucially however, this data must be supplemented with foundational insight on the region’s economy, insight into the specific movements and progress each decile of the region’s populace. It is a key foundational concern that the poorest decile have had barely any income growth over the last 20 years (Harnold et al., 2021), is the group with broadly the greatest policy concern for employment, skills, wellbeing. Yet, this picture is lost with broad overview statistics and needs greater incorporation into analysis. This foundational measure is a key indicator of economic health and should have a greater prominence in analysis.

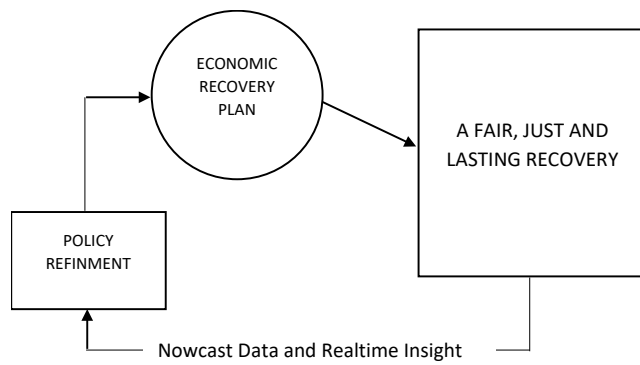
WEST YORKSHIRE MAP



Source: Office for National Statistics licensed under the Open Government Licence v.3.0. Contains OS data © Crown copyright [2022].

The Economic Recovery Plan bases its forecasting on publications from the National Institute of Economic and Social Research (NIESR) and the Office of Budget Responsibility (OBR) with recognition of the difficulties of regional forecasting and a consideration of unknown variables related to the ongoing pandemic (for instance the need for future lockdowns).

More timely economic forecasts of the composition of West Yorkshire output will empower West-Yorkshire policy professionals to adjust the ERP to looming events and emergent aspects of the interactions of policy and the economy. The incorporation of foundational measures into the nowcasts will further allow for a forensic view of the components of the West Yorkshire economy as well as its top-level statistics, resulting in a dynamic and responsive recovery policy for all:



To combat the Covid uncertainty and unknown effects of looming economic events, Economic Policy must be quasi-continuous with adjustment required based on nowcasted data and real time insight in order to forestall recovery for small portions of the economy and rather ensure an equal distribution.

NOWCASTING REGIONAL OUTPUT

“One cannot reliably base policy today on regional output data that are two years out of date”
(Koop et al 2020).

Nowcasting for real-time economic policy decisions

The Economic Recovery Plan bases its forecasting on publications from the National Institute of Economic and Social Research (NIESR) and the Office of Budget Responsibility (OBR) with recognition of the difficulties of regional forecasting and a consideration of unknown variables related to the ongoing pandemic (for instance the need for future lockdowns). Ultimately however, whilst regional modelling can be improved and the Covid related uncertainty tamed through additional data and sophisticated techniques. The majority of published forecasts broadly concur with an overall increase in UK economic activity in 2021 (e.g. NISER +6.8%, OBR +4%, IMF +4%, BCC +7.1%, KPMG +6.6%). The UK economy is recovering speedily but the promised growth is distributed unequally with considerable regional disparities. Timely data on real-time regional economic performance (e.g., nowcasts) is becoming crucial for local policymakers to introduce profound economic changes, direct revaluations, and impact economic policy decisions.

At the time of writing (March 2022), West Yorkshire’s annual output—gross value added (GVA)—for 2020 and 2021 is yet to be released and due to be in end 2022—which is a significant delay for over a year and far too late to make real-time decisions. Thus, nowcasting these years is necessarily important for policymakers to give a complete signal about underlying economic activities in real-time. That said, GVA historical data for West Yorkshire is only available yearly, which can otherwise withhold the nowcast accuracy as the nowcasts progressively become more accurate at higher frequent data. Thus, West Yorkshire’s nowcasts for the 2020-2021 period are assumed to closely move with these for Yorkshire and The Humber—the historical data of which is available in quarterly frequency. Yorkshire and The Humber’s quarterly output data has been released up to 2021 Q2, which is only a 6-month lag. Most subsections of nowcasting therefore pay attention to Yorkshire and The Humber’s output and its growth rates with nowcasts for West Yorkshire revealed in the subsection ‘Forecast 2022-2030’.

Following Koop et al. (2020), we use mixed-frequency Vector Autoregression (VAR) model to nowcast Yorkshire and The Humber’s GVA estimates for the last two quarters of 2021. See A1 in the Appendix for more details of model and variables used.

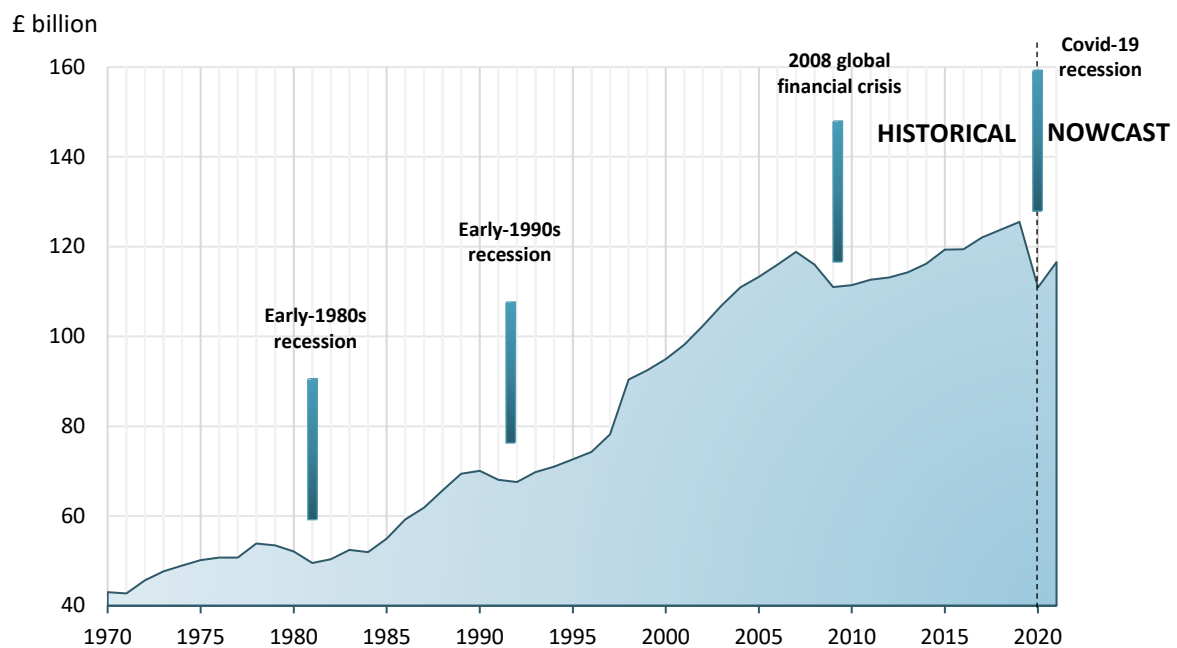
A quick recovery after the initial impact of the Covid-19 pandemic

Key points:

- Yorkshire and The Humber's annual GVA has declined by 11.6 percent from 2019 to 2020—the largest output contraction since the 2008 global financial crisis.
- The region's economy has gradually recovered, reaching 92.87% of its pre-pandemic 2019 size.
- Annualised GVA growth rates have decreased by 10 percent in 2020 Q4 and 2021 Q1—the largest decrease since late 1980s.
- There has been an increase from a 5.5 percent change in 2021 Q3 to a 6.8 percent change in 2021 Q4—the highest positive annualised growth rate since late 1980s.

Yorkshire and The Humber's annual GVA has declined by 11.6 percent from £125.5 billion in 2019 to nearly £111 billion in 2020, reflecting the initial impact of the Covid-19 pandemic on the region's economy.³ According to historical data on the region's output by ONS, as shown in Figure 1, this economic shock represents the largest output contraction since the 2008 global financial crisis. While unavoidably faring worse during 2020, the region's economy has gradually recovered throughout the following year and has reached £116.5 billion which amounts to 92.87% of its pre-pandemic 2019 size as shown in the short-term economic nowcast for 2021 in Figure 1.

FIGURE 1: YORKSHIRE AND THE HUMBER'S ANNUAL GVA IN 2018 CONSTANT PRICES, 1970-2021

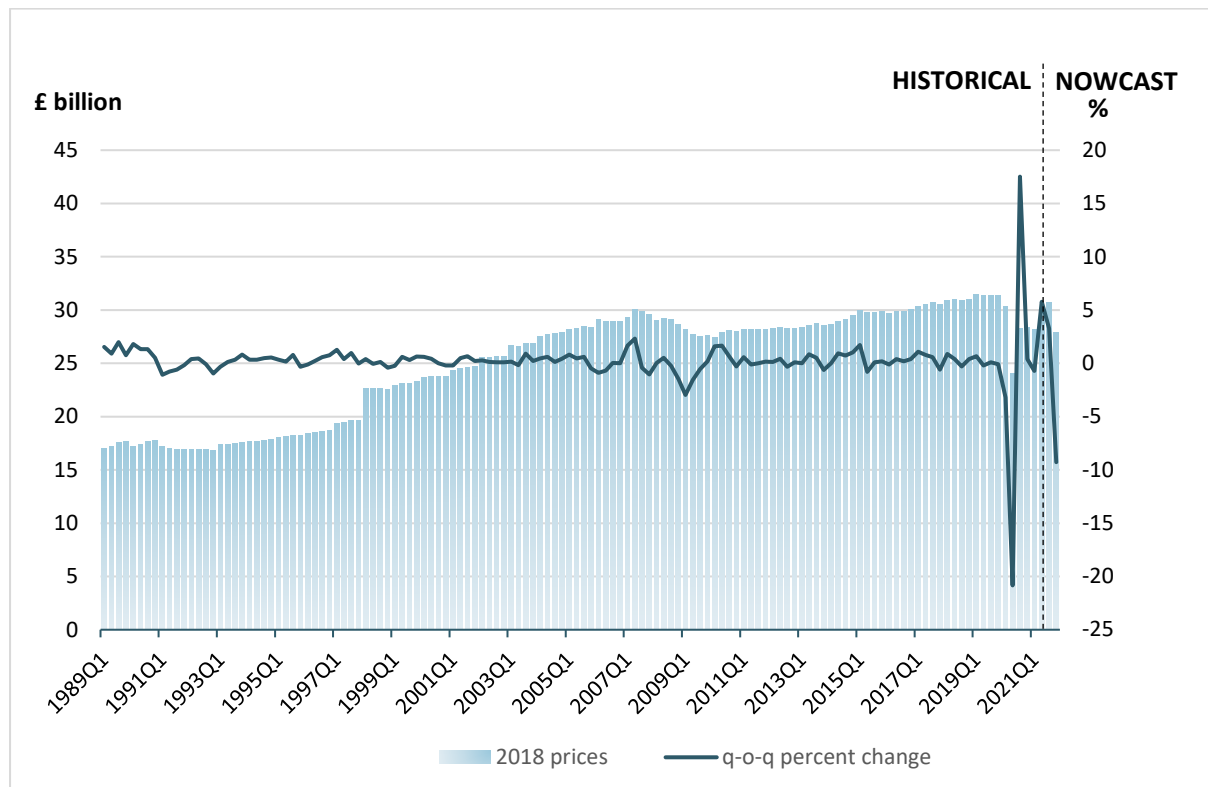


Source: ONS and authors' estimation.

³ In this analysis, GVA is measured in real terms (i.e., inflation-adjusted).

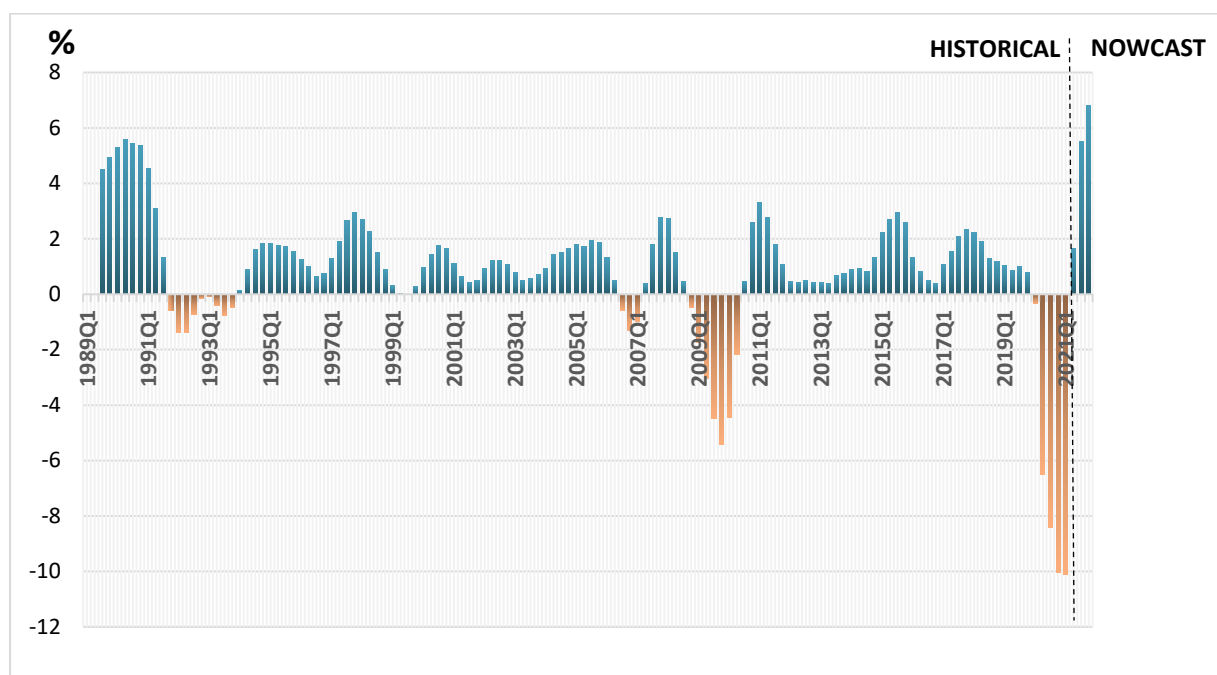
To capture more dynamic patterns of output, we turn to quarterly GVA levels and corresponding quarter-on-quarter growth rates. As seen in Figure 2, Yorkshire and The Humber region has experienced a rapid shortfall by over 20 percent in first half of 2020 – the largest quarter-on-quarter decline since late 1980s, followed by a rapid yet unstable recovery in subsequent quarters in 2020 and in first quarter of 2021. In none of the subsequent quarters has the region’s GVA reached pre-pandemic levels with the quarterly growth rates decreasing from 15 percent in 2020 Q3 to a sub-zero rate in the following quarter. This could be largely due to uncertainty in Covid-19 new variants as well as national and regional restrictions. Particularly, in 2020 Q3, first lockdown restrictions were eased with introduction of Eat Out to Help Out scheme; in 2020 Q4, second national lockdown was introduced; in 2021 Q1, third national lockdown to cope with new Alpha variant surge.

FIGURE 2: GVA QUARTER-ON-QUARTER PERCENT CHANGE, YORKSHIRE AND THE HUMBER



Source: ONS and authors’ estimation.

FIGURE 3: ANNUALISED ESTIMATES BASED ON GVA QUARTER-ON-QUARTER PERCENT CHANGE, YORKSHIRE AND THE HUMBER



Source: ONS and authors' estimation.

For comparative purposes, annualised estimates are present in Figure 3.⁴ The annualised estimates in entire 2020 and 2021 Q1 for Yorkshire and The Humber region shows strong negative growth rates, which is the largest decrease since late 1980s. Particularly, the region has the lowest growth rates at minus 10 percent in two consecutive quarters 2020 Q4 and 2021 Q1 prior to a slow recovery in following quarters. The nowcast model for two last quarters of 2021 shows that the region has been experiencing a gradual recovery, increasing from a 5.5 percent change in 2021 Q3 to a 6.8 percent change in 2021 Q4—the highest positive annualised growth rate since late 1980s.

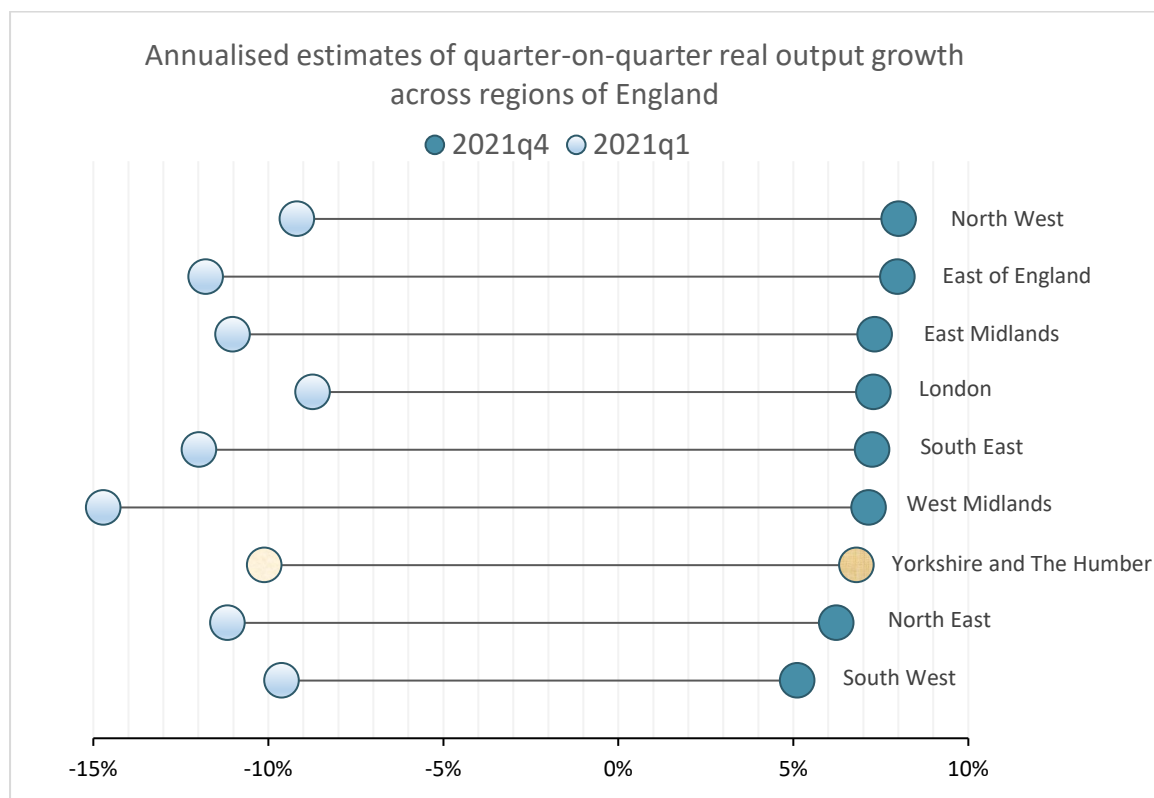
But not as quick as other English regions

These shortfall and recovery patterns of the Yorkshire and The Humber's GVA appear to be smaller than other regions of England. The region's annualised growth rate for 2021 Q1, as shown in Figure 4, is rather smaller than a majority of regions of England, and so is its nowcast for 2021 Q4. The smaller shortfall in early 2021 was expected to experience otherwise stronger resilience in the 2021 post-pandemic recovery period than larger affected regions. This is further confirmed by changes in GVA levels. The region's output has shown to perform

⁴ The annualised growth rates help facilitate seasonality changes of various quarters while quarterly data fails to do so. The annualised estimates of quarterly growth rates take the form: $\Delta GVA_A_t = \frac{1}{4}\Delta GVA_Q_t + \frac{1}{2}\Delta GVA_Q_{t-1} + \frac{3}{4}\Delta GVA_Q_{t-2} + \Delta GVA_Q_{t-3} + \frac{3}{4}\Delta GVA_Q_{t-4} + \frac{1}{2}\Delta GVA_Q_{t-5} + \frac{1}{4}\Delta GVA_Q_{t-6}$ Where ΔGVA_A_t is Yorkshire and The Humber's annualised GVA growth rate based on quarterly GVA growth rate at quarter t (ΔGVA_Q_t) and its lags, considering weights of previous quarters.

fairly during the initial effects of the pandemic with GVA in 2020 lowering to 88.4% relative to their 2019 output size. Compared to Yorkshire and The Humber, East of England and West Midlands have been more affected in 2020 with their output levels have lowered to 87.6% and 84.6%, respectively (See Table 1).⁵ However, they have quickly gained ground to outperform the Yorkshire region and also the capital London in 2021 with East of England already reaching its pre-pandemic size—the second fastest regional recovery among nine English regions. Their quick recovery is largely driven by greater reliance on healthcare sector than other regions.⁶ Indeed, Birmingham and Solihull in West Midlands is the area with the highest percentage (nearly 7 percent) of local people working in NHS provider organisations across English areas, whereas the numbers for Cambridgeshire and Peterborough, and Norfolk areas in East of England are also relatively high at 5.19 and 5.32 percent, respectively (Maguire, 2020). Other regions such as London and North West have quickly followed East Midlands and East of England during 2021. Following EY (2022), London and Manchester in North West has quickly bounced back due to their strong reliance on digital, science and technology, and services sectors which were temporarily affected during initial stage of pandemic but helps the cities remain resilient long-term.

FIGURE 4: ANNUALISED OUTPUT GROWTH OF ENGLISH REGIONS, 2021Q1-2021Q4, RANKED BY 2021Q4 PERFORMANCE



Source: Authors’ estimation.

⁵ West Midlands’s automotive manufacturers have been affected by pandemic-hit disruption in global supply chain.

⁶ EY (2022) finds that regions reliant on healthcare sector fared better during the pandemic.

TABLE 1: ANNUAL GVA OF ENGLISH REGIONS, RANKED BY 2021 PERFORMANCE (2019=100)

Region	2020	2021
South West	88.8%	102.2%
East of England	87.6%	102.1%
West Midlands	84.6%	96.7%
London	91.1%	96.6%
North West	89.6%	95.3%
Yorkshire and The Humber	88.4%	92.9%
North East	87.9%	92.2%
East Midlands	87.7%	91.9%
South East	86.9%	91.6%

Source: Authors' estimation.

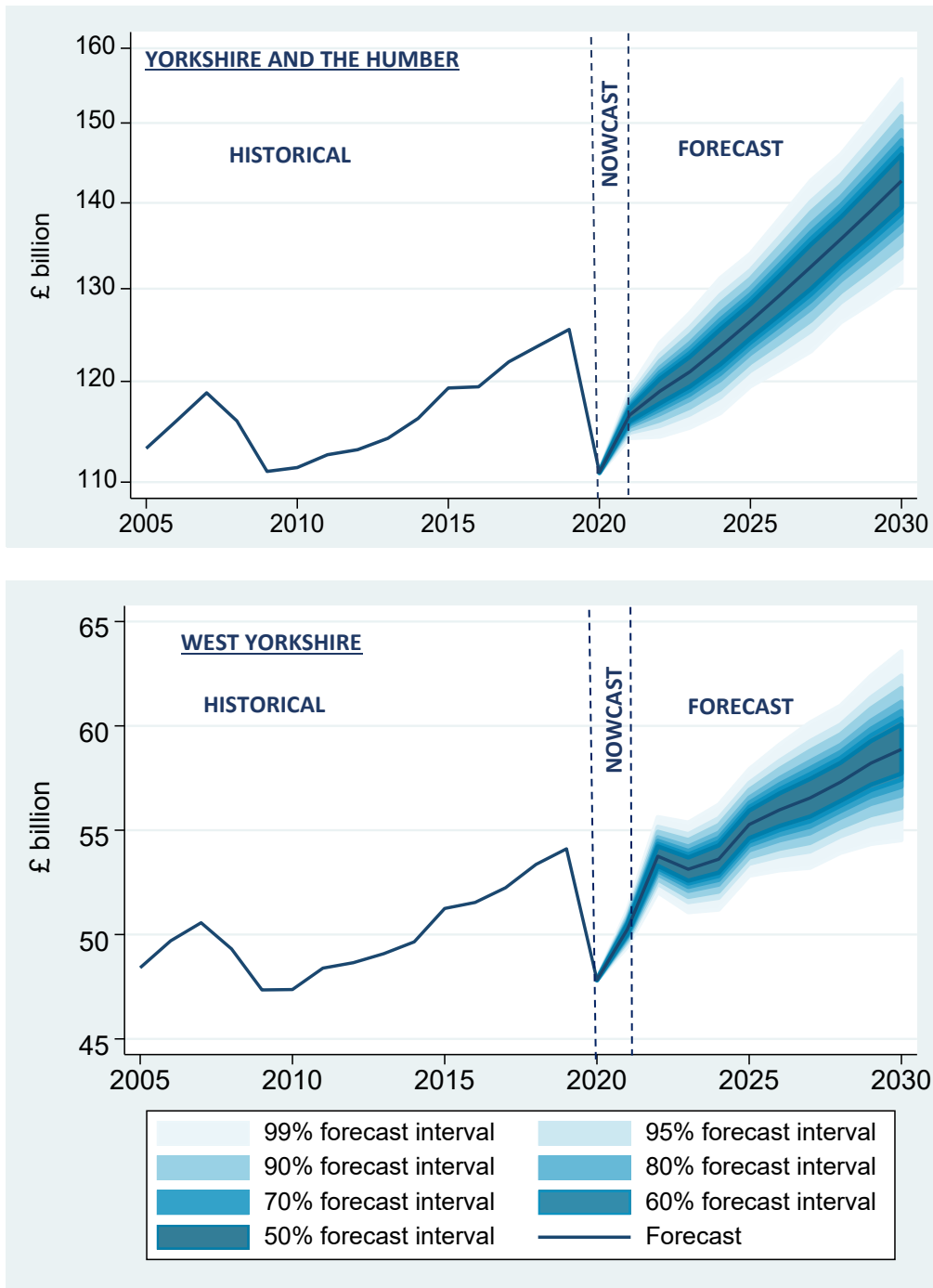
The pandemic has contributed to narrow the gap between the Yorkshire and The Humber and other UK regions short-term, but that gap appears to be set to widen again during the post-pandemic recovery period. This is because deep-rooted regional imbalance still exists with the pandemic inducing long-lasting implications in more balanced, sustainable, and inclusive growth along with acceleration in digitalisation, science and technology. Thus, having right, balanced focus on the region's sectoral strength and specialism and on fast-growing, output-improving sectors in coming years is therefore a must to achieve better recovery medium-term and to gain higher long-term, sustained economic growth for Yorkshire and The Humber.

Forecast 2022-2030

As the region Yorkshire and the Humber has yet to reach its pre-pandemic size with considerable regional disparities in early recovery periods, we further outline the pace of growth to gain a broader picture of how the region's economy will progress towards 2030.⁷ We perform out-of-sample forecasts from 2022 to 2030 with historical annual outputs from 1970s to 2020 and 2021 nowcast obtained in the previous subsection. Our forecasting practice is performed recursively towards 2030.

⁷ The forecasts are based on projections of the region's working age population projections published in ONS.

FIGURE 5: GVA WITH 2022-2030 FORECASTS, YORKSHIRE AND THE HUMBER AND WEST YORKSHIRE



Source: ONS and authors' own calculation. **Note:** Data is in 2018 prices.

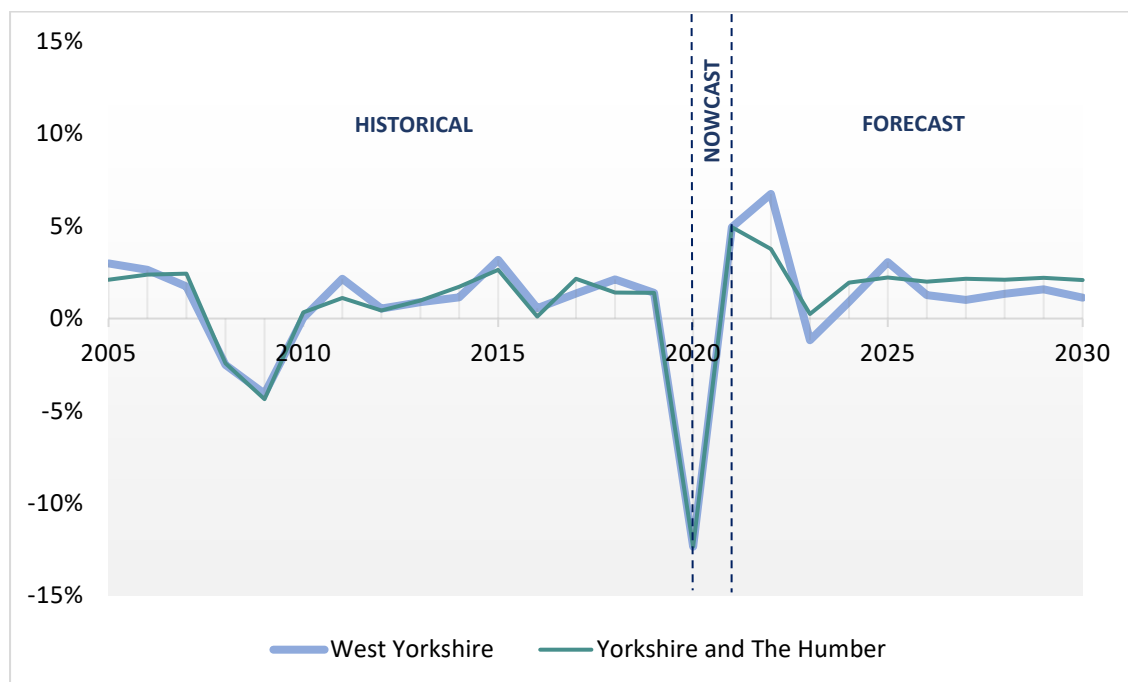
with a range of forecast intervals of root mean squared forecast errors (RMSE). As shown in Figure 5, the region's output is forecast to grow average 2% per year between 2022 and 2025 with expectation to regain its pre-pandemic GVA level during 2025. The region is then on course for slightly higher growth rates at 2.1% per year during 2026-2030.

We also perform out-of-sample forecasts in the same time period for West Yorkshire in Figure 5 (See Note in Figure 6 for details of nowcasts and forecasts estimated). GVA growth rates of

West Yorkshire remain rather strong in post-pandemic period 2022-2025 at 2.38% on average. Markedly, the region is forecast to reach 99% of pre-pandemic 2019 size in 2022 with a 50% forecast interval and higher. However, the growth rates are set to decline to 1.26 on average, respectively, over the following period 2026-2030.

The dynamic change in growth rates of West Yorkshire throughout historical, nowcast, and forecast periods is further shown in Figure 6. Having said that earlier, nowcasts for West Yorkshire for the 2020-2021 period are assumed to closely move with these for Yorkshire and The Humber, which is largely based on the fact that historical data of these regions often strongly co-moved. Similarly, GVA growth rates for West Yorkshire move rather in line with Yorkshire and the Humber during forecast periods, albeit at slightly higher rates for 2022 and 2025. In this way, there necessitates a strategic policy for a long-term growth of West Yorkshire to catch up with other regions in Yorkshire and The Humber and also other regions of England.

FIGURE 6: GVA GROWTH RATES WITH 2022-2030 FORECASTS, YORKSHIRE AND THE HUMBER AND WEST YORKSHIRE



Source: ONS and authors' own calculation.

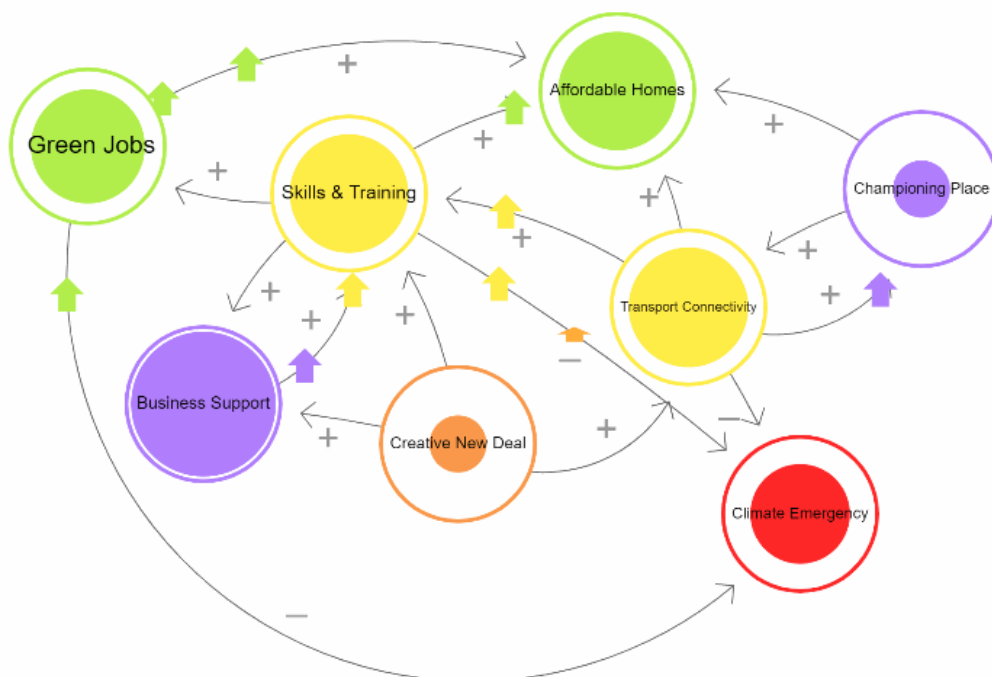
Note: Nowcasts of Yorkshire and The Humber's GVA growth rates for 2020 and 2021 are in a year-on-year term and calculated based on annual GVA estimates from the nowcasting model by Koop et al. (2020). Nowcasts for West Yorkshire for the 2020-2021 period are assumed to closely move with these for Yorkshire and The Humber. This assumption is based on historical data dated back to 1998 and historical estimates for the period 1988-1998. Forecasts for these regions are estimated based on growth rates of working age population projections in Yorkshire and The Humber, given the available data on population projections for the broad region only and the closely moving population rates (although unreported) of these three regions throughout historical data dated back to 1991.

WEST YORKSHIRE'S ECONOMY AS A SYSTEM

The interlinking relationships and emergent properties of the policies within the Economic Recovery Plan necessitates the consideration of the West Yorkshire Economy not as a series of siloed policy areas and isolated economic markets but as a wholly intertwined system. For instance, Land-Value Uplifts have numerous effects through the system and should not be considered an isolated or end outcome of a policy. Likewise the stagnation of the poorest decile reverberates throughout the system effecting numerous layers and groups. Equally the design of successful policy which focus on equal and inclusive growth benefits from an understanding of the interlinking systematic relationships observed within West Yorkshire.

We propose the creation of a dynamic systems-based model to fully understand the West-Yorkshire economy, allowing a consideration of the interactions of groups, organisations, policy and markets. Within this system the creation of standalone success measures allows for not only specifically targeted policy, but an understanding of how various interventions can interact to avoid pitfalls and generate meaningful inclusive growth.

FIGURE 7: A DYNAMIC SYSTEMS-BASED MODEL



The above simulation demonstrates a long-term connectivity between the policy areas and the relationship between the fair and just recovery policy and the lasting recovery interventions.

This model follows the economic growth measurement that has evolved over time. In its origin, the main focus was on short-term financial values such as physical capital investment. Following economic recessions and academic criticism, the focus has recently shifted from

using a single metric of financial values to multiple metrics of economic, social and environmental values for a long-term sustained economic impact.

The two aspects of social and environment values are crucial for overall economic impact, especially in post-pandemic recovery interventions. First, ensuring long-term economic growth necessitates improving social aspects related to people, households and communities. The Covid-19 pandemic has made long-lasting impacts on many social aspects of lives such as reduced health conditions, job losses, putting low-income households and vulnerable groups at risk. Thus, ensuring long-term economic growth in post-pandemic periods is closely linked to improving people's lives, making more equal investments among social groups and communities to close the social gap that may threaten future prosperity, and create employment opportunities for all. Preparing people with future of work and upskilling the local workforce through access to relevant education and training can ensure workforce quality needed for long-term regional economy that is experiencing rapid advances in technology and digitalisation as recent trends—nationally and globally. Second, tackling environmental challenges is necessary to build a resilient, sustainable economy. Economic benefits of tackling climate change are many: positive effects on people's health with resultant increase in productivity and efficiency at work; reduced damage caused by extreme weather events that influence people's lives and businesses' production; new economic and industrial opportunities. As tackling climate change has been a megatrend globally and reaching net-zero emissions by 2050 has been a mission for the UK in particular, adding environmental factors to evaluate regional economic growth is a must to understand the region's policies in place for this matter and identify advantages early on.

To develop a meaningful representation of connectivity between above-mentioned policy areas, we view the system both at the spatial small-area level and at the regional level.

The system at the spatial small-area level

In this subsection, we show spatial differences at the local, small-area level between city and town centres and suburban areas of West Yorkshire districts. Due to limited data availability at this level, we are only able to focus on three policy areas: public transport connectivity, housing affordability, and digital connectivity. These three areas, however, are gaining more importance in building a champion place to work and live alike, especially in post-pandemic periods.

Better public transport access in city and town centres

We start off with public transport connectivity. Ensuring better accessibility to public transport, such as buses and trains, brings fair opportunities of travel for everyone regardless of wealth. Introducing concessionary fares for vulnerable groups including seniors and people with disabilities fosters travelling for at-risk groups; reducing journey times, improving punctuality, increasing the number of services and routes increase usage of public transport

for all travellers.⁸ The latter targets the comfort and values of journey times by public transport relative to that of private vehicles such as private cars. Values of journey time by public transport do not only include in-vehicle journey time, but also walk time and wait time (Wardman, 2004). Thus, punctual services and reduced journey time contribute to higher use of public transport. (Department for Transport, 2018)

The journey times by public transport to local key services are, however, place-based. Figure 8a shows that local residents living in city and town centres of West Yorkshire benefit most from accessible, established transport networks with many places having shorter journey times to all 8 key services than regional average (shaded in blue and dark blue). By contrast, in suburban areas where homes and businesses are spread out, local residents' journeys to workplace at busier towns or cities or to key services take more time than average (shaded in light yellow or yellow-green). This place-based transport connectivity suggests an increase of services and routes to remote areas to ensure residents there can live and travel to work comfortably.

⁸ Introducing concessionary fares for youth, elderly and disable people travelling on local buses (Department for Transport, 2018).

FIGURE 8: WEST YORKSHIRE'S PUBLIC TRANSPORT CONNECTIVITY, BROADBAND COVERAGE, HOUSING AFFORDABILITY AT DIFFERENT SPATIAL SCALES

Figure 8a

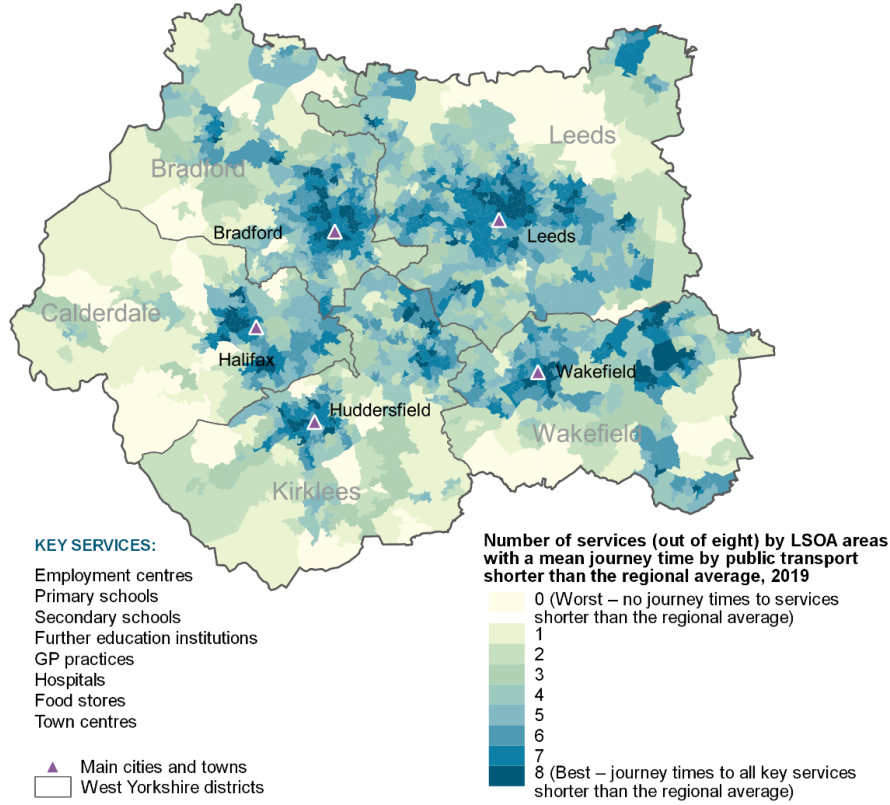


Figure 8b

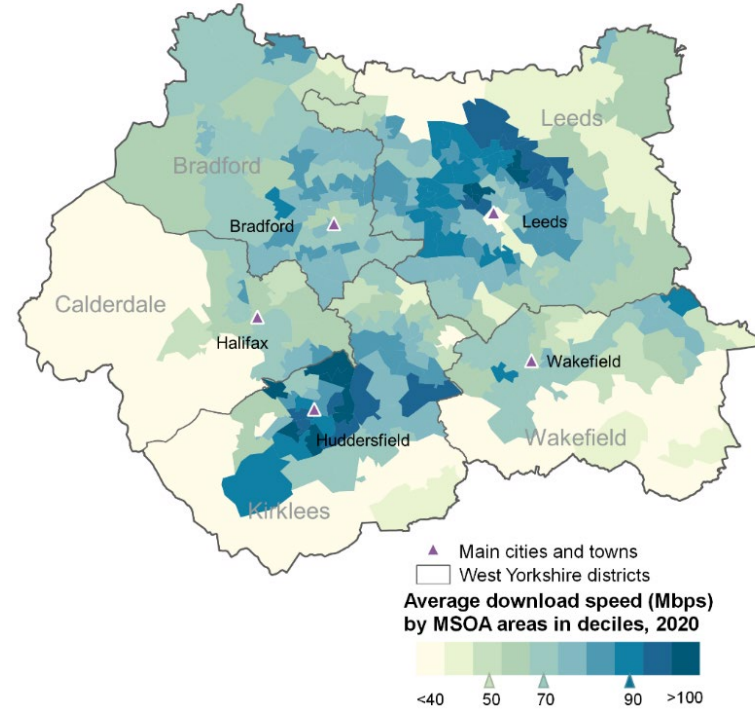


FIGURE 8: WEST YORKSHIRE’S PUBLIC TRANSPORT CONNECTIVITY, BROADBAND COVERAGE, HOUSING AFFORDABILITY AT DIFFERENT SPATIAL SCALES (CONTINUED)

Figure 8c

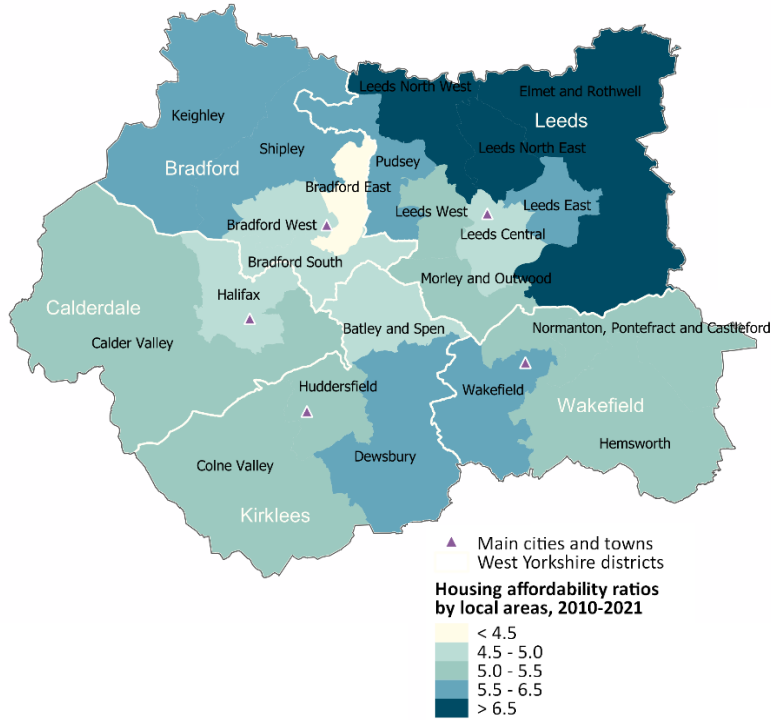
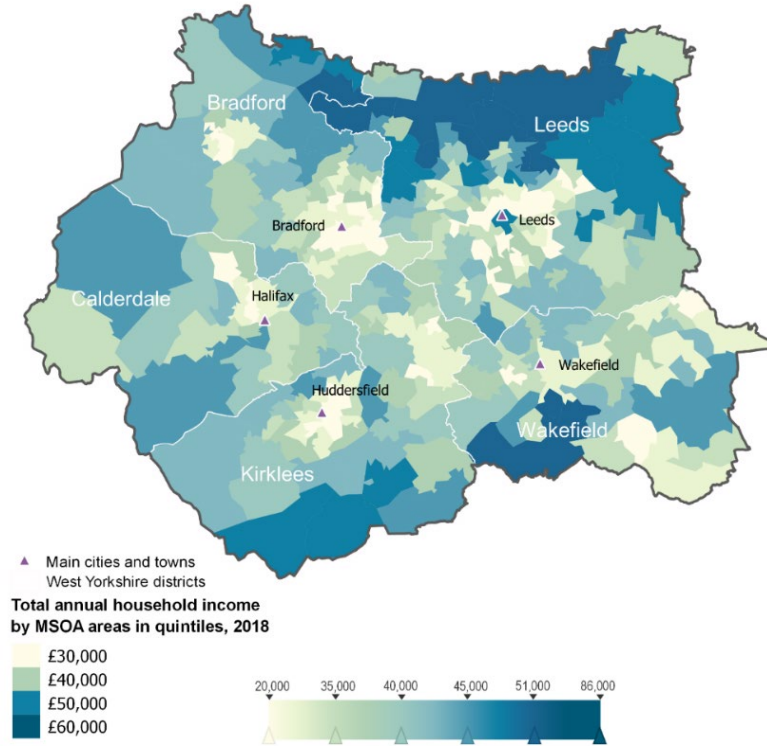


Figure 8d



Source: Department for Transport, ONS, NOMIS, Ofcom and authors’ own calculation⁹
Office for National Statistics licensed under the Open Government Licence v.3.0.
Contains OS data © Crown copyright [2022].

⁹ Middle Layer Super Output Areas (MSOAs) and Lower Layer Super Output Areas (LSOAs) are super-output-area boundaries constructed using 2011 Census data and constrained by postcodes as building blocks. MSOAs in West Yorkshire have an average of 7,800 residents, while LSOAs are smaller boundaries with an average of 1,700 residents. Local areas refer to broader boundaries of Westminster parliamentary constituencies.

Future interventions for improved transport infrastructure in the regional context

Suburban areas of West Yorkshire districts could have been much better connected by public transport with more integrated public transport services for stronger local transport links.¹⁰ Longer journey times by public transport from and to the outer suburbs contribute to dependence on private cars, which is traditionally not perceived as a big transport issue but not politically supportive either because spaces reserved to car users can limit ability of non-car modes accessible for all (Mattioli et al., 2020).

Regarding faster journey times, new transport infrastructure such as high-speed rail serves for the purpose. High-speed rail links have potential to create radical changes in accessibility to other regions, opening up new markets for local industries and making wider long-term economic impacts of local economies (Chen and Vickerman, 2017, Haynes, 1997). West Yorkshire could benefit from the future high-speed rail links (HS2) that is originally set to reduce journey times between London and Leeds by 15% from 2 hours and 13 minutes to 1 hour and 53 minutes. However, the proposed railway route to Leeds has been scrapped under further investigation, which means that local residents and businesses may forgo industrial opportunities with other regions.

Less affordable homes in suburban areas

We continue to study the housing affordability which is identified as a social concern and encompasses many economic issues such as transport connectivity (Cao and Hickman, 2018), earnings and employment opportunities (Fingleton et al., 2018).¹¹ Figure 8c reveals housing affordability, however, at a different spatial scale from public transport connectivity. Housing affordability ratios are measured by dividing median house prices by median earnings of Westminster parliamentary constituencies for the 2010-2021 period and then taking averages.

Overall, we find unevenly distributed levels of housing affordability throughout West Yorkshire. Among these areas, Bradford East has the lowest average affordability ratio score of 4.1. In contrast, areas with highest housing affordability ratios of between 6.5 and 7 are concentrated in north and east parts of Leeds, including Leeds North East, Leeds North West and Elmet and Rothwell areas. High levels of unaffordability are particularly concentrated on West Yorkshire suburban areas where there is a higher level of concentration of households with higher incomes (Figure 8d). Such households living in more peripheral locations appear

¹⁰ Generally, journey times of local residents in West Yorkshire to several key services by public transport or walking were reduced between 2017 and 2019, according to ONS. Travelling times to town centres, secondary schools, and primary schools were declined by 0.9%, 0.6% and 2.7%, respectively, on average. Mean journey times to food stores were significantly cut by 35% with a small 4% increase in the number of food stores. More importantly, local residents go to work with 35% less commuting times on average.

¹¹ See Cao and Hickman (2018) for example of housing affordability and car dependence for London spatial analysis.

to derive higher utility from more floor space (as in the Alonso-Muth-Mills model) or accessibility to natural amenities (as in the hedonic model), which may offset transportation costs to workplace or city/town centres (Fingleton et al., 2018).

The relationship between housing affordability and other policy areas

Costs of housing and transportation as well as accessibility to local amenities and employment centres are amongst determinants for residential and employment location choices—both within and across cities and towns (Gibbons et al., 2014, White, 1988). The UK example by Gibbons et al. (2014) shows that differences in housing markets across cities in the UK lead to that workers are willing to accept lower earnings to live in areas with a higher level of local amenities. A residential location within a city or a town becomes attractive if it is close to city/town or major employment centres and thereby requires short commutes and travel times. In this way, a relevant policy in response to changes in housing prices can improve liveability of residents and also attract talents to the region.¹²

More digital inclusion in city and town centres

High-speed internet access through broadband and mobile services can further facilitate economic growth by connecting ideas and information, fostering partnerships and entrepreneurial ecosystems, and matching employment opportunities (Czernich et al., 2011, McCoy et al., 2018, Sussan and Acs, 2017). The demand for faster, more reliable broadband and mobile services has been ever-increasing during the pandemic as the change to work and study from home has led to continued dependence on digital services for work, education, healthcare and entertainment (Ofcom, 2021). As work-from-home becomes a norm, people who are looking for a great place to live also require the place to be well-connected to work. To retain talents in the region for local businesses, improved broadband and mobile infrastructure and increased usage are ways to bring more homes as well as businesses to the region, making the region as a champion place of digitalisation to work and live alike.

West Yorkshire is demonstrating a promising region with recognised capabilities in digital infrastructure relative to UK local areas; however, it is rather place-based. Figure 8b shows that average download speed in centres of Leeds and Huddersfield are higher than other city and town centres in West Yorkshire, falling into top deciles in ranking across small local areas in the UK. Majority of areas in Calderdale has quite low average broadband speed, and so is Wakefield.

¹² Housing prices are determined by supply and demand in the housing market. New housing supply, if more provision of affordable homes, helps tackle the problem of housing unaffordability; otherwise, it is more likely associated with more expensive houses and higher earnings. Where there is little new (or inelastic) supply yet rising demand of housing, house prices can grow faster than earnings, which leads to unaffordability issues.

This can be well explained by gigabit-capable coverage and decent broadband coverage as in Figure 13 and Figure 14 in the Appendix A2, respectively.¹³ A majority of places in suburban areas of Calderdale and Wakefield have low gigabit-capable coverage (Figure 13) and have over 15% of homes and offices with decent broadband (Figure 14). In contrast, Leeds, Bradford and Huddersfield appear to have better digital inclusion with many places in urban areas having full gigabit coverage (Figure 13) and a small percentage of premises with broadband speed under 10 Mbps (Figure 14).

Post-pandemic recovery plan for digital access in the region:

Continuing to improve overall digital infrastructure and further facilitating laggard places without broadband access to have at least decent services are key to ensure fair, just digital inclusion for long-term regional economic growth. The current Wakefield gigabit voucher scheme by Wakefield Council and West Yorkshire Combined Authority seems instructive—funding of up to £2,500 per residence and £7000 per business to install gigabit broadband.¹⁴ Building an increasingly digital economy is a must in the periods after the pandemic which has also signalled the equal importance of connectivity for all to participate in the digital society. Such digital inclusion, along with availability of supportive entrepreneurial, innovative ecosystems and high regional human capital help attract more businesses to areas that lack of decent digital connectivity cannot do otherwise (McCoy et al., 2018). In this way, national and local investments in digital infrastructure and inclusivity help to push West Yorkshire towards a productive and prosperous economy.

The system at the regional level

In this subsection, we evaluate the system at the broader region level, citing several policy areas: transport connectivity, housing affordability, skills and training, tackling climate change and green job opportunities, business support and creative industries.

Increasing car traffic and the impact on environment

We start off with transport connectivity issues over the demand of car vehicles that local residents in West Yorkshire travel in daily lives and the impact of fuel consumed by these vehicles on the environment in pre-pandemic periods. Figure 9a shows that there is a marked difference across West Yorkshire districts between 2010-2020: Leeds (Calderdale) has the highest (lowest) demand for car vehicle transport including buses, cars, and motorcycles. The car vehicle traffic in Leeds reached 2.5 times as high as the volume of Bradford, Kirklees, and Wakefield and over 4 times relative to that of Calderdale. Although there was a rapid decline in car vehicle traffic across districts due to the impact of pandemic that led to lockdowns and

¹³ As in the definition by Ofcom, gigabit coverage refers to services that use fibre-optic cables to connect the network between the provider and end users' home and office or use coaxial cables with DOCSIS 3.1 technology.

¹⁴<https://www.westyorks-ca.gov.uk/projects/superfast-west-yorkshire-and-york-broadband/voucher-schemes/>

working-from-home, the relative traffic volumes across districts remained similar with pre-pandemic periods. In this way, the level of energy consumed by car vehicles in Leeds is expected to be significantly higher than that of remaining districts. However, the percent change of corresponding energy consumption in Leeds during 2020-2019 is surprisingly lower than that of Bradford and Wakefield—two districts that have much lower car vehicle traffic than Leeds (See Figure 9b). Energy used by car vehicles in Calderdale is reported with a slight change between 2010 and 2019 perhaps due to the low traffic of car vehicles in this district.

In post-pandemic recovery periods, Campaign for Better Transport (2020) suggests a transport-led recovery plan against three goals: transition to zero emission vehicles; improve public transport connectivity for communities; embed sustainable transport choices (e.g., walking and cycling) to improve people’s health and lives. Considering wider environmental impacts of transport, including public transportation, leads to a more resilient future economy.

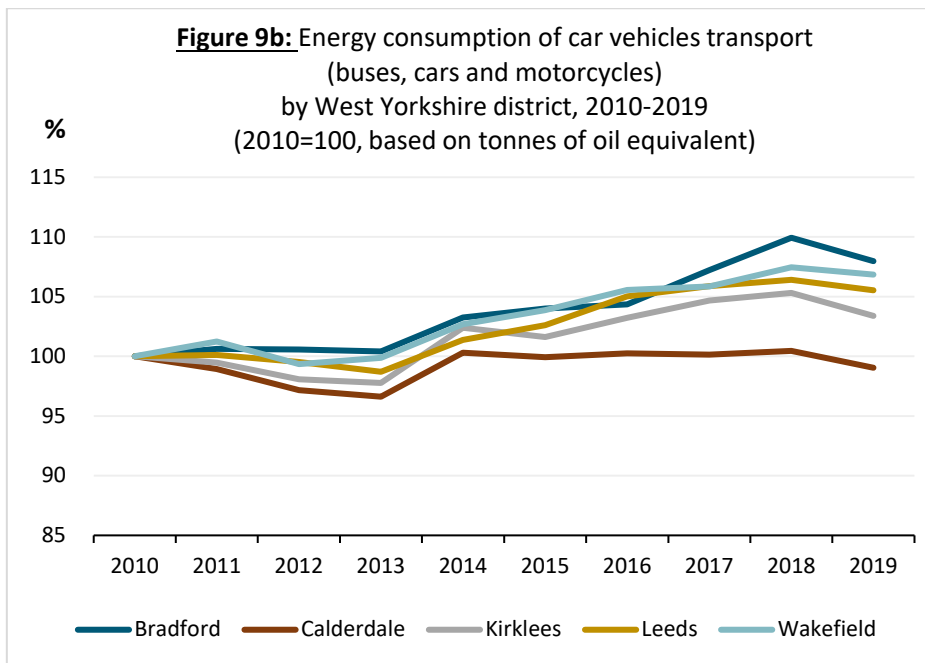
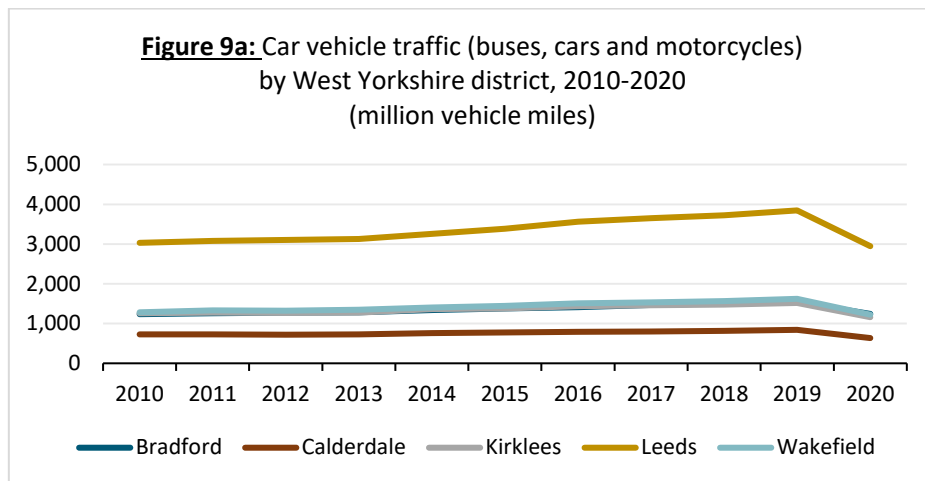
More affordable homes than the English average

As the transportation issues share socio-spatial patterns with housing demand, there necessitates a broader look at the regional level to evaluate competitive advantages relative to other regions. To better understand housing affordability of West Yorkshire, we look at Figure 10a for levels of housing affordability across West Yorkshire districts relative to a broader region of Yorkshire and The Humber and England on average. The housing affordability ratios of all districts have increased since 2005 with Leeds experiencing highest ratios across years. As of 2021, median house prices in Leeds are roughly 7 times higher than median earnings, the highest level recorded to date, while Bradford’s ratios have remained rather stable. Apart from Leeds, houses in other districts are relatively affordable relative to the averages of Yorkshire and The Humber and England, where the gap is increasing across years.

This may suggest that housing affordability is not as a big concern as other cities where housing affordability ratios are relatively high, but may impact on the local economy due to interlinked issues (i.e., employment and transport connectivity) that are closely correlated with housing market.¹⁵ A policy concern at the regional level is that increased housing prices due to rising demand likely correlated with increasing demand for local labour may attract workers from commutable, neighbouring areas if transportation infrastructure allows (Haynes, 1997, Fingleton et al., 2018).

¹⁵ Cao and Hickman (2018) show that the housing affordability ratios in London were often between 6 and 10 in 2011, with expectations of increased ratios over the last decade.

FIGURE 9: CAR VEHICLE TRAFFIC AND ENERGY CONSUMPTION, WEST YORKSHIRE, 2010-2020



Source: Department for Transport and authors' own calculation

A narrower gap of skilled workforce with the national average

Improving local workforce's skills is central to levelling up the region by satisfying the employers' demand with job-ready skills. Figure 10b shows the percentage of local workforce holding higher education qualifications.¹⁶ Among West Yorkshire towns and cities, Leeds shows a marked difference relative to remaining areas. The number for Leeds is always above Yorkshire and Humber average, although most of time it is lower than Great Britain average with reduced gaps over the last 5 years. Wakefield and Bradford are two areas with the lowest percentage of local workforce holding higher education qualifications, but the percentage is

¹⁶ Higher education qualifications refer to national vocational qualifications Level 4 and above, including foundation degrees, bachelors' degrees, postgraduate qualifications, etc.

increasing over time. The regional disparities in skills of local workforce may partially explain output disparities across towns and cities in West Yorkshire.

High demand for future 'green' jobs

The West Yorkshire has introduced the climate and environment plan to transit the region to a net-zero carbon, climate-resilient economy by 2038, going faster than the national target by 2050. As part of national strategy, the transition involves in changing many low-emissions sectors including buildings, transport, power, water systems, and urban planning. Significant progress of the transition is to be made by 2030 as such changing entire public building retrofit, accelerating installation of energy efficient lighting and heating systems for homes and business premises, transportation shifting to rail and cycle freight.¹⁷ This quick transition poses a challenge to current and future jobs of the region's economy.

On the one hand, the transition could affect 235,000 current jobs, half of which are highly-skilled jobs and in high demand and the other half of which require upskilling and support, according to the report by West Yorkshire Combined Authority (2021).

On the other hand, this radical transition brings many 'green' job opportunities for the local workforce.¹⁸ This is because of a zero-carbon economy offers market opportunities for new low-carbon technologies, goods and services that businesses compete to design, produce and sell to customers. Although the regional data is yet available, we find data for England, which represents pace of change in 'green' jobs across English regions. In 2020, English businesses active in low carbon and renewable energy economy employed 171,100 employees, an increase of 3.2 percent relative to 2019. Large businesses – with 250 and more employees – saw an increase of 3% in 'green' job opportunities between 2019 and 2020.¹⁹ The 'green' jobs in England are estimated to increase 4 times between 2020 and 2030 and another 1.7 times increase between 2030 and 2050, according to Local Government Association.²⁰ Yorkshire and The Humber region is estimated to bring the second highest 'green' jobs opportunities among English regions, only behind North West in 2030 and 2050 (See Figure 10c). To achieve the transition target, the local authority needs to understand the local workforce's skill gaps emerging within low-emissions sectors, providing relevant training in upskilling or reskilling the workforce with the right skills in demand to ensure the net-zero transition made at the pace and as planned.

¹⁷ The transition to tackle the climate change, as argued by Stern (2008), would cost 1% of global GDP per year, which otherwise loses 5% per year by 2050 if no action were taken.

¹⁸ By 'green' jobs, ONS refers to jobs in low carbon and renewable energy sector.

¹⁹ <https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2020>

²⁰ <https://lginform.local.gov.uk/>

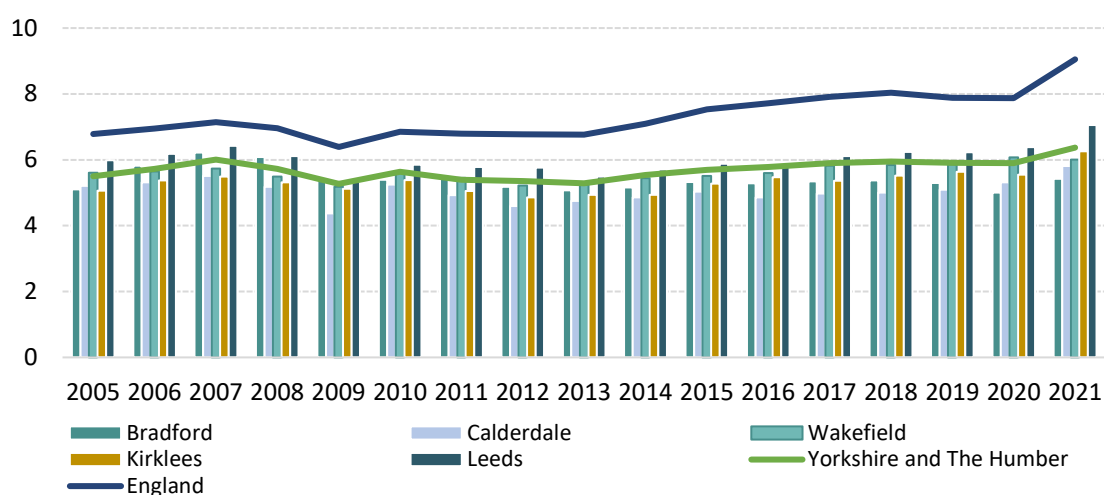
Better business support in technological and creative industries

Citing the national and regional goals towards the ‘build back better’ plan, West Yorkshire is committed to supporting and incentivising the development of creative ideas and technologies. The region has established itself as home to the medical technology innovation centre in lasting partnerships with local universities, industry businesses, NHS healthcare providers, and local authorities.²¹ As digital and cutting-edge technologies become ever-increasingly pre-eminent, local leaders could be aligned with business leaders and researchers for specialist expertise or financial investment where necessary. Additionally, the region’s Creative New Deal empowers and animates local talents, helping struggling towns to find the right balance of economic, social and cultural regeneration.

FIGURE 10: WEST YORKSHIRE’S HOUSING AFFORDABILITY, EDUCATIONAL QUALIFICATIONS, FUTURE GREEN JOBS

Figure 10a: Housing affordability ratios by local authority district, 2005 - 2021

(Ratios of median house price to median gross annual residence-based earnings)



²¹ Shaping a stronger network with the world-leading Cambridge-Oxford-London Golden Triangle or innovative hubs in other cities (i.e., Birmingham, Glasgow) helps deliver the national ambition of wider innovative activities.

Figure 10b: Higher education qualifications by local authority, 2005-2020

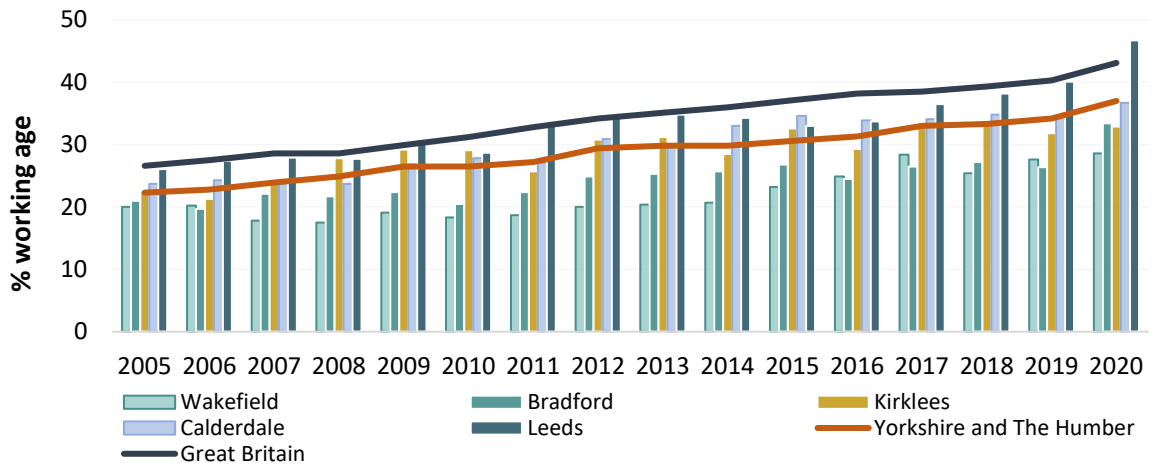
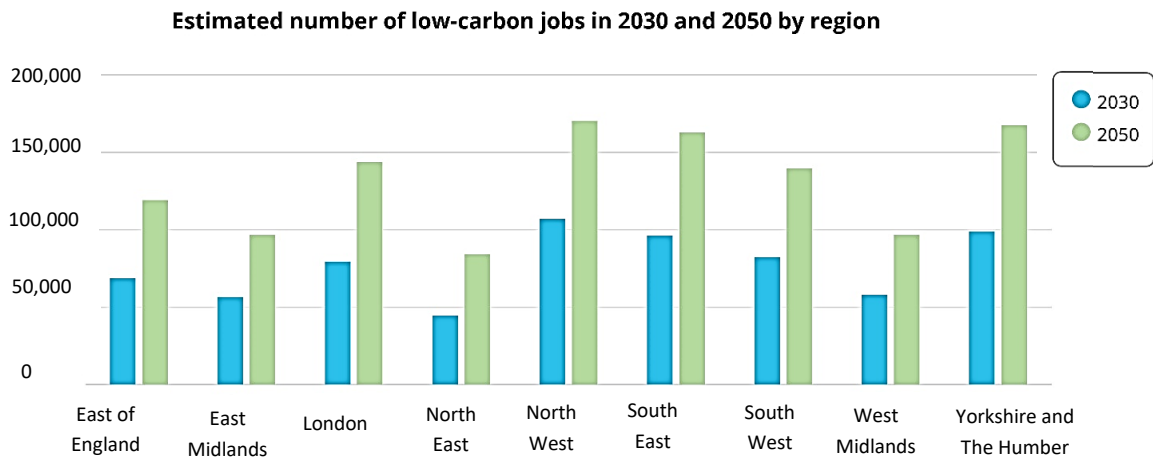


Figure 10c: Estimated number of 'green' jobs in 2030 and 2050 by English region



Source: ONS, Nomis, Local Government Association

SOCIOECONOMIC COMPONENTS OF REGIONAL OUTPUT

The objectives of a fair and just recovery for all and of a long-lasting or sustainable recovery are not particularly encompassed with the OBR focus on regional GVA. Nowcast and forecast UK Growth and regional GVA figures hide the true face of the economic recovery. Within these nowcasts and forecasts lie profound economic changes, looming crises and revaluations with the potential to withhold the forecast growth from the people who need it.

There are a myriad of reasons why regional economic activity differs, for instance geography and history; skills and demographics; regional specialisations and so on. The unique features of the West Yorkshire economy need to be identified and incorporated into a nowcasting approach in order to fully realise its insight. Given the embrace of a systems approach and a focus on a fair and just recovery, the incorporation of the headline GVA statistic is insufficient. A compositional understanding of the drivers of this figure is, in fact, vital toward a consideration of the stability of an inclusive economy.

To further understand the composition of West Yorkshire's output figures and the movement of its components, we perform impulse response functions on the West Yorkshire region, capturing the dynamic impacts within the proposed system of several sustainable, inclusive economic areas.²² We use annual data of output growth (GVA), skills and training (skilled workers with qualifications of higher education certificates and above), business support (claimant count rate), housing affordability (ratio of median house price to median gross annual earnings), transport connectivity (car traffic) and its impact on environment (energy consumption of cars) between 2005 and 2021.²³ A single VAR model with one lag is estimated, from which we estimate two sets of impulse-response functions (IRF) for a 10-year period with each representing different considerations as follows.

Measuring economic growth with the addition of its composition

In the first set of impulse-response functions, we highlight the effects of a one-standard-deviation shock to each sustainable, socioeconomic factor mentioned-above on West Yorkshire's output growth. Results are shown in Figure 11. A one-standard-deviation increase in claimant count rate leads to a 0.01 percentage point decline in output growth in the 1st period, followed by decreasing declines over the entire response period. The region's output growth is also sensitive to a contemporaneous shock of higher levels of car traffic on road

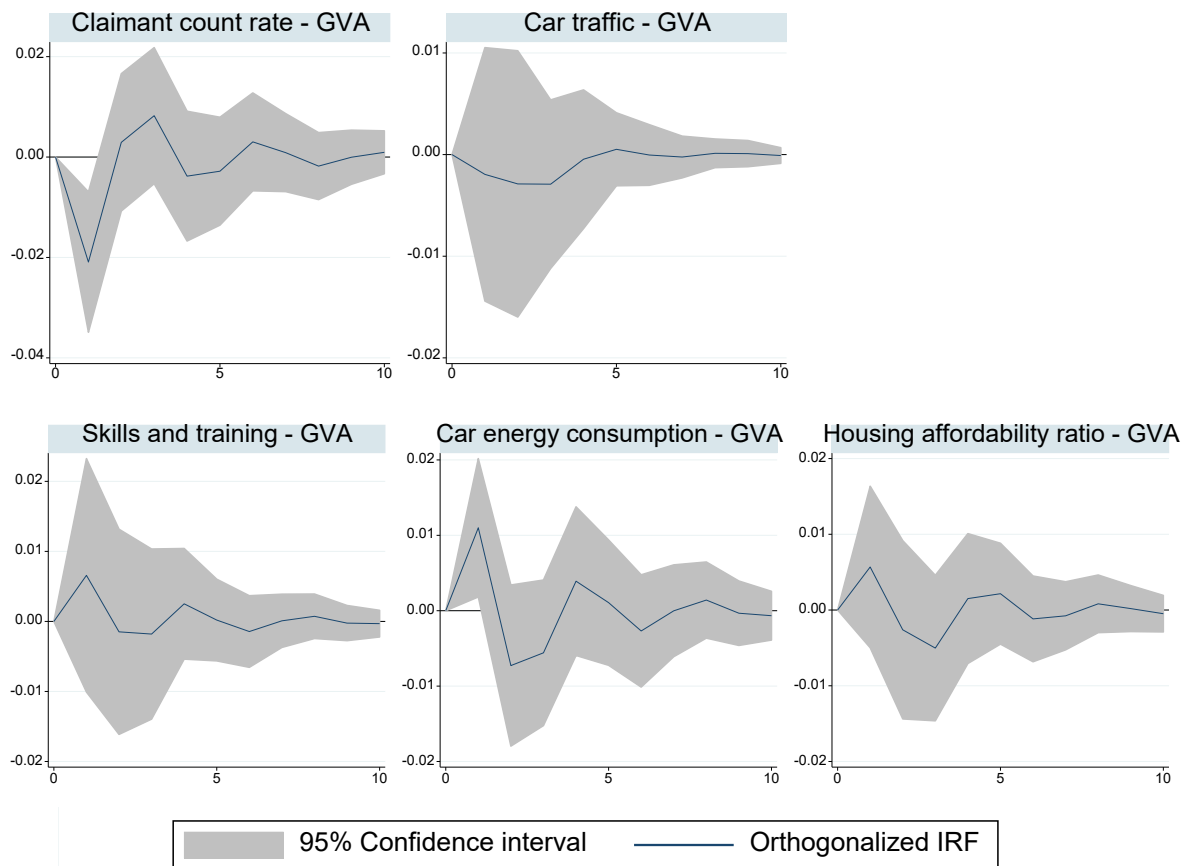
²² Impulse response functions (IRF) show the effects of contemporaneous shocks of one variable on another variable, studying how long the effects last and the degree to which the effects persist.

²³ We use the nowcast estimate obtained for West Yorkshire's output growth in the previous subsection along with its historical annual data from ONS. We also use data on NVQ4+ qualifications, claimant count rate, housing affordability ratio from ONS and Nomis for examined periods. Transport connectivity data from 2005 to 2020 is from Department of Transport with estimated data for 2021 based on rate of change from national data. All variables are measured on percentage points through transformation into log and first-differenced forms.

with a decline persisting for 3 consecutive periods before a gradual recovery. Shocks of other variables in the system show quite opposite patterns in the first 5 periods – see figures in the 2nd row of Figure 11. Output growth variably increases with higher levels of skilled workers, road energy consumption by cars, and unaffordable homes in the 1st period before declining in the next two periods and recovering in the 5th year of response.

These findings suggest that a measure of economic growth should include its composition related to socioeconomic policy areas, and further confirms higher levels of investments in improved transport connectivity and in local workforce’s skills and training. First, investing in education and training has long been proved to enhance economic growth, especially in post-pandemic recovery periods. Skilled

FIGURE 11: GVA AND ITS SOCIOECONOMIC COMPOSITION



Source: Authors’ estimation

employees have great capabilities to help businesses overcome difficult situations: quickly adapt to change, identify new products to target new markets, be resilient (F.Froy et al., 2012). Equipping the right number of people with appropriate skills in demand for high-growing sectors can help the regional economy to return to the pre-recession growth and to thrive (Sevinc et al., 2020). Second, better transport connectivity provides transformational opportunities for local residents and businesses to increase wealth and unlock their potential,

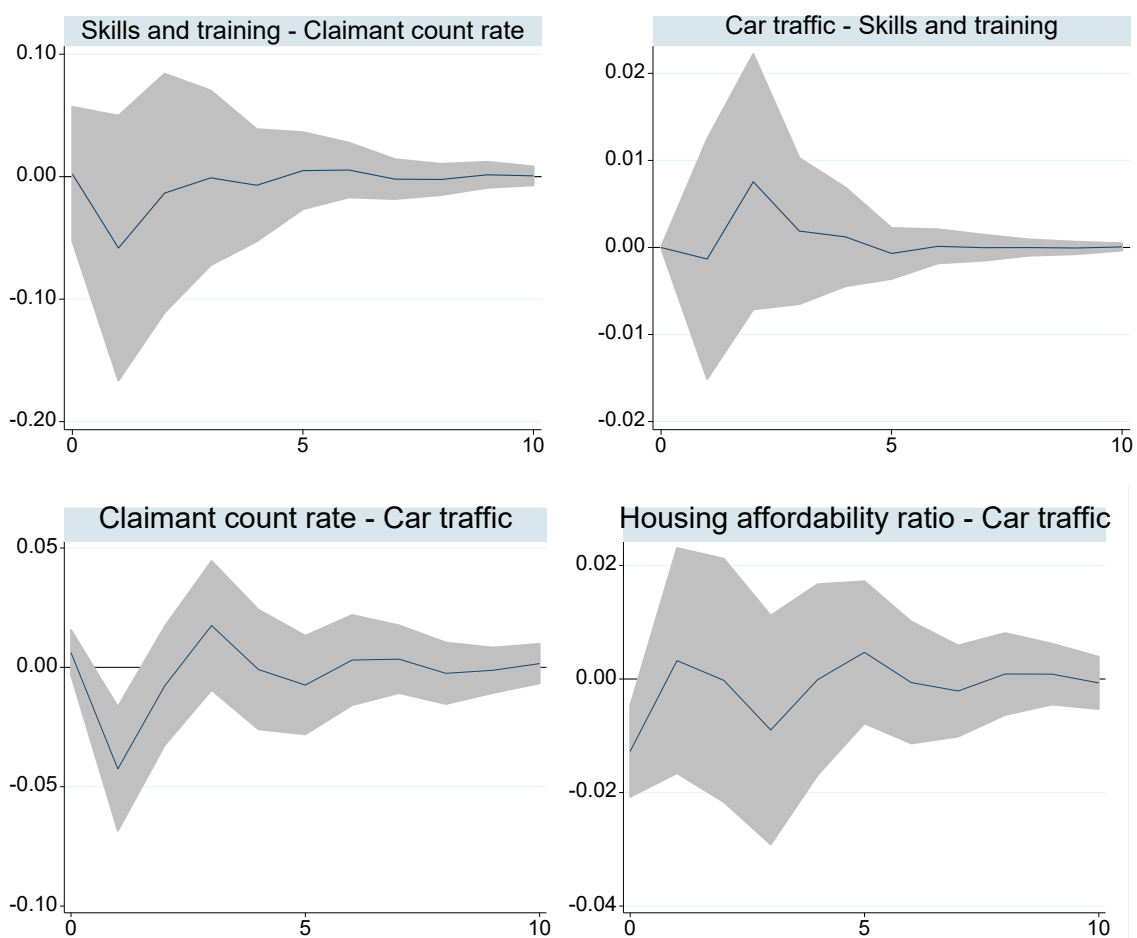
positively affecting regional economic performance. However, achieving equal transport access for all and pursuing a sustainable pathway for transportation require continued efforts of local government in many policies.

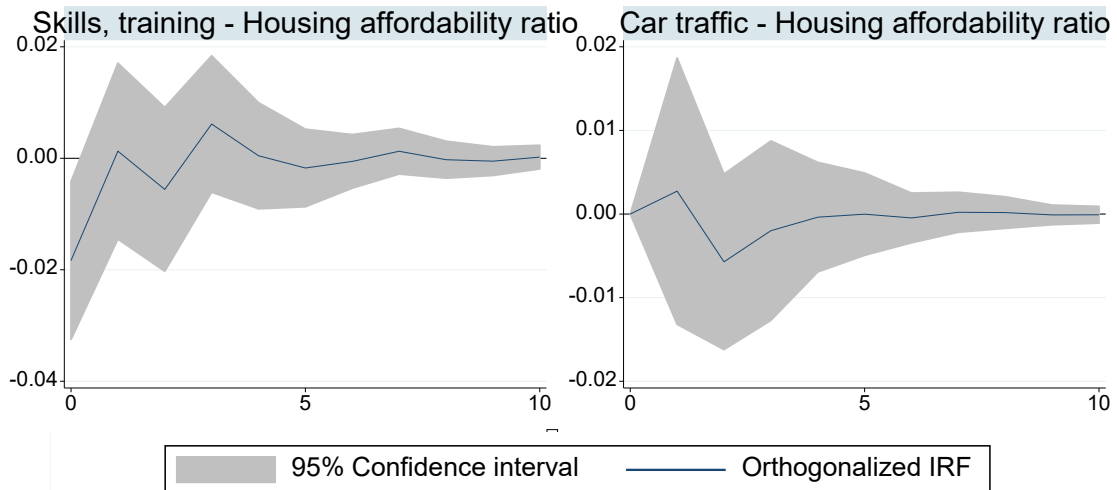
Measuring the movement of components

In the second set of impulse-response functions, we measure dynamic impacts within the proposed dynamic systems-based model. Figure 12 shows varying sensitivity of all socioeconomic variables to shocks of other variables during the first 5 periods followed by rather little sensitivity in remaining ones.

The left figure of the 1st row shows that an impulse on skills and training of local workforce reduces the claimant count rate, which represents the unemployment level, by 0.05 percentage point over the 1st period with decreasing negative impacts over following periods. The right figure of the 1th row indicates the sensitivity of skills and training to a contemporaneous shock of traffic connectivity. Positive impacts start from the 2nd period and persist at reducing rates until the 5th period. This finding further confirms that better transport connectivity for cars and other vehicles helps link travel journeys from and to educational providers for better skills of local workforce.

FIGURE 12: THE MOVEMENT OF SOCIOECONOMIC COMPONENTS





Source: Authors' estimation

The 2nd row of Figure 12 shows effects of contemporaneous shocks of unemployment (measured by claimant count rate) and housing affordability on transport connectivity issues. Higher unemployment levels are linked to less dependence on cars, which may suggest an otherwise increase in demand for public transport in certain areas of the region. A shock to housing prices, however, shows rather mixed impacts throughout entire response periods with strong negative and positive impacts in first-half periods.

The last row of Figure 12 shows sensitivity of housing affordability. Housing affordability ratios increase, which means homes become less affordable, as the result of an innovation shock of skills of local, so is a shock of car traffic. Only until the 2nd period do homes become more affordable (i.e., housing affordability ratio reduces). These finding suggests that a strategic action regarding education and transport connectivity in the present helps shape future social plan of making homes more affordable to attract resources, talents, and businesses. A policy concern at the regional level is that increased housing prices due to rising demand likely correlated with increasing demand for local labour may attract workers from commutable, neighbouring areas if transportation infrastructure allows (Haynes, 1997, Fingleton et al., 2018). The issues between housing affordability, labour supply and transport connectivity at the regional level are closely related, with shared socio-spatial patterns.

CONCLUSION

The ultimate goal of a sustainable, fair and inclusive economy poses a challenge to measurement of regional economic growth. Using a single metric of economic and financial values somehow fails to gauge effecting changes in the way local people work and live and local businesses develop and thrive. As local people and businesses are key contributors of regional economic output, the growth measurement should add multiple metrics of economic, social and environmental values emerging from a dynamic systems-based model and presenting a shift from short-term to long-term value creation. The focus on longer-term future is essential for 'levelling up' and 'build back better' plans across UK regions for a national recovery resilience in response to the Covid-19 pandemic and long-standing regional imbalances (Local Government Association, 2021).

The focus of this briefing note is on West Yorkshire's economy as a direct response to a request by West Yorkshire Combined Authority. There are three main areas of focus emerging to build a sustainable, fair and inclusive economy of the region: adding combined metrics of social and environmental values in measuring economic growth; investigating the shifts in local, smaller geographic areas within the region for better inclusivity approaches; recommending the harnessing of new and innovative local data sources.

Combined shifts to economic, social and environmental values

The two aspects of social and environment values are crucial for overall economic impact, especially in post-pandemic recovery interventions. Our dynamic systems-based model proposed shows various interventions needed to have collective impacts on the economic performance of West Yorkshire region. Undoubtedly, the policy interventions in the present will affect the future regional performance for years to come as well as place West Yorkshire higher in the future 'race to the top' across UK regions. These interventions inevitably require control and devolution at the local level over many social and environmental aspects including skills and training for local workforce, housing affordability, business support, digital and transport connectivity, climate emergency, future green jobs. We have two recommendations related to policy interventions.

First, collate every subsection of each policy intervention as an interlinked system and use real-time community data and insight.

The systems-based model is a set of interlinked subsections that altogether contribute to the region's economic performance. Within a broad systems-based model, one can easily identify a combined shift to social and environmental economies on a large scale for the future's better outcomes in many ways. Improved digital and transport connectivity helps stimulate employment and training activities in disconnected and various parts of the region, thereby improving livelihood of local workforce as well as creating business opportunities for further

collaboration and exchange ideas. Upskilling local workforce with relevant skills in demand for future work is a must to satisfy employment demands from local businesses, and to match green jobs opportunities which are in higher demand in coming years. Ensuring housing affordability to improve liveability of local residents and also attract talents to the region. Supporting businesses, especially newly established and small businesses to level up and ensure connections between education providers and employers to match skillsets of labour workforce. Also, societies increasingly cast environmental values as a norm in businesses' operating context and people's lives from transportation to housing. To make West Yorkshire a great place to work and live, local leaders should put equal weights on social and environmental performance in many aspects that become increasingly tied to businesses' prospects and people's lives, other than traditional dichotomisation of financial performance.

Second, forecast social and environmental performance with further considerations of imminent disruptive changes along with national and regional goals.

The forecasts of social and environmental performance should be put in place with relevant the globe or the nation's radical changes as well as the region's targets. Radical changes can be listed as emergence of disruptive technology that utterly reshape businesses and people's lives, digital skills in ever-increasingly higher demand at businesses and education providers, raising environmental concerns in businesses and transport models—to name a few. Additionally, macroeconomics and political events such as Brexit, inflation expectations, or constrained potential for monetary policy, sector-specific wage growth and pay rises can affect labour shifts in sector and geography. Citing the region's goals, the West Yorkshire has introduced the climate and environment plan to transit the region to a net-zero carbon, climate-resilient economy by 2038, going faster than the national target by 2050. Also, the region has established itself as home to medical technology innovation centre through collaboration with universities, businesses, NHS healthcare providers. Thus, adding these regional targets with disruptive changes help to adjust forecasts of social and environmental aspects accordingly.

The ultimate goal of a fair, just and inclusive regional economy

Challenges of deriving fairness and inclusiveness in each subsection of the proposed systems-based model remain an obstacle to reach an ultimate goal that the society acts in a fair, just, inclusive and sustainable fashion. There exist unevenly distributed levels of transport and broadband connectivity, housing affordability, and welfare throughout West Yorkshire. Identifying disconnected parts and underrepresented social communities within the economy is crucial to finding ways to facilitate wider access to sustainable socioeconomic opportunities, and to understanding the related areas on which they impact within the interlinked system. In order to transform West Yorkshire to be a promising region of a more inclusive economy, we offer two recommendations as follows.

First, properly measure inclusiveness of each subsection in the systems-based model at local, smaller geographic areas and across different social groups to gauge further insights of spatial differentials.

In the dynamic systems-based model proposed, there are several subsections that we struggle to provide analyses on place-based availability of resources such as business support and climate impacts. As for other subsections such as digital and transport connectivity, despite availability of community data, there are inconsistency or at different geographic levels across data sources. It is therefore become harder to understand the inclusiveness and vulnerability of sustainable socioeconomic performance at a certain level of local areas. Similarly, there is lack of data for different social groups at more granular local levels in skills and education or housing affordability. Thus, having a single unit of local geographical areas is conducive for further spatial analyses, as is for the second recommendation.

Second, construct an inclusiveness index for economic, social and environmental performance to fully understand the combined impact.

As the dynamic system-based model demonstrates long-term connectivity between interlinked policy areas and interventions, there necessitates a composite index constructed for all these areas to study joint effects. We draw inspiration from a composite car dependence and housing affordability index for local areas in London by Cao and Hickman (2018) who use the index to find relation with social deprivation of vulnerable people in the areas. Thus, we can further understand social and environmental problems spatially and find how to connect more vulnerable parts of the region with the remaining for a more inclusive society.

Incorporation of local data

In addition to the dynamic systems-based model approaches, insight data is highlighted as an important contributor to the fair, inclusive economy. Recommending the harnessing of new and innovative local data sources is cited throughout this briefing note to provide key insight and policy direction to the aim of creating a fair, just and long-lasting recovery. We specifically note the need for timely data to inform policy. The wider institutional and governance frameworks contain a wealth of data that could be harnessed to provide insight, not only into the momentum of recovery (simple GVA) but of its drivers, components, and characteristics in order to support inclusive growth. This could help develop a unique and robust data from which to support an equal recovery and a re-imagined resilient economy working for all, especially disconnected parts and underrepresented social communities of the economy. We have two recommendations of getting insight data relevant for policy makers.

First, incorporate 'on the ground' data garnered from community sources, business networks, anchor institutions and local governance.

The harnessing of multiple data sources and the incorporation of qualitative insights could indeed be time consuming and require investment in a system of capture, process, and input. Naturally, the potential for data overload, inconsistency, instability, and unreliability is considerable, leading to difficulty in data cleaning, merging and analysing processes. Having noted, we need timely data, and in some cases, high-frequency data (e.g., quarterly data) rather than low-frequency (e.g., yearly data).

Second, develop foundational measures which provide accurate insight for key areas.

There are several considerations in harnessing the abundance of multi-levelled local data. We offer two for further thought: (i) The inclusion of a machine learning approach to suggest key reliable indicators from the abundance of data (see Guido de Blasio and Alessio (2021)); (ii) The inclusion of qualitative data and community insight.

We would suggest that the nowcasting techniques discussed in the previous section could aid here, but more pertinently that a mantra of ease and availability over perfection is utilised. We should not seek to create new data but incorporate what is available using Artificial Intelligence to refine and prioritise available data into a stream of near real time indicators which are then used by policy professionals to aid design.

The ambition of a fair and just recovery for all requires data generated from numerous interactions and collections within disadvantaged communities. Vulnerability has many faces (Brown et al., 2017), accessing this community is exceptionally difficult (Emmel et al., 2007) requiring a detailed understanding of the interconnected networks, institutions and support (Emmel and Clark, 2009). Predominantly these data are qualitative and their development to speedy policy intelligence is required. Simple but robust proxies may be developed which give a direction of change due to ERP policy rather than magnitude.

It remains vital that those 'on-the ground' sense check this data and input into recovery policy planning. Poverty, precarity, instability and exclusion are difficult to accurately assess. A multi-disciplinary approach to data collection is key for successful policy design.

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APPENDIX

A1 Vector Autoregression (VAR) model and data definition

Following Koop et al. (2020), we use mixed-frequency Vector Autoregression (VAR) model to nowcast Yorkshire and The Humber's GVA estimates for the last two quarters of 2021.²⁴ Prior to the nowcast model, we recursively run VAR models every 4 quarters based on quarterly real GVA indices from 2012 Q1 to 2021 Q2 to produce historical estimates dated back to late 1980s. In this way, our sample size will increase over historical estimates with a total of over 120 observations available (approx. 31 years) for the nowcast model. To find a number of quarters for recursive historical VAR models for each region, we trace the annual growth rate. The quarterly historical real GVA are estimated/produced using the formula: $GVA_{A_YRS_t} = GVA_{Q_YRS_t} + GVA_{Q_YRS_{t-1}} + GVA_{Q_YRS_{t-2}} + GVA_{Q_YRS_{t-3}}$ with $GVA_{A_YRS_t}$ denotes annual GVA and only observed in quarter 4 of each year.

For the nowcast model, we apply $p = 7$ lags in our VAR model which involves the inter-temporal restriction in the form:

$$\begin{aligned} \Delta \ln GVA_{QA_YRS_t} &= \frac{1}{4} \Delta \ln GVA_{Q_YRS_t} + \frac{1}{2} \Delta \ln GVA_{Q_YRS_{t-1}} + \frac{3}{4} \Delta \ln GVA_{Q_YRS_{t-2}} \\ &+ \Delta \ln GVA_{Q_YRS_{t-3}} + \frac{3}{4} \Delta \ln GVA_{Q_YRS_{t-4}} + \frac{1}{2} \Delta \ln GVA_{Q_YRS_{t-5}} \\ &+ \frac{1}{4} \Delta \ln GVA_{Q_YRS_{t-6}} \end{aligned}$$

Where $\Delta \ln GVA_{QA_YRS_t}$ is Yorkshire and The Humber's annualised GVA growth rate based on quarterly GVA growth rate at time t $\Delta \ln GVA_{Q_YRS_t}$ and its lags.

Also, our Yorkshire and The Humber's quarterly GVA growth rates are obtained by running a VAR model endogenously on quarterly macroeconomic indicators: oil prices, bank rates, consumer prices, exchange rates, and exogenously on regional economic condition — claimant count rate.²⁵

²⁴ As our focus is on Yorkshire and The Humber region, we do not consider the cross-sectional restriction where in our VAR models as in Koop et al (2020)'s VAR models. We keep inter-temporal restrictions.

²⁵ As socioeconomic data is not available quarterly to produce a dynamic systems-based model as described, we add unemployment factor to capture regional economic condition, assuming the core of the dynamic model short-term to be job creation.

$$\begin{aligned}
\Delta \ln \text{GVAQ_YRS}_t &= \alpha_t + \sum_{p=1}^7 \theta_{GVA,p} \Delta \ln \text{GVAQ_YRS}_{t-p} + \sum_{p=1}^7 \theta_{oil,p} \Delta \ln \text{oil}_{t-p} \\
&+ \sum_{p=1}^7 \theta_{bank,p} \Delta \ln \text{bank_rate}_{t-p} + \sum_{p=1}^7 \theta_{exchange,p} \Delta \ln \text{exchange_rate}_{t-p} \\
&+ \sum_{p=1}^7 \theta_{CPI,p} \Delta \ln \text{CPI}_{t-p} + \gamma \Delta \ln \text{claimantcount}_t + \varepsilon_t
\end{aligned}$$

Where α_t denotes a constant and ε_t denotes error term at quarter t .

TABLE 2: DEFINITION AND DATA SOURCES OF VARIABLES USED IN THE MODEL

Variable	Definition	Source	Time period used
Regional variables			
- GVAQ_YRS	Yorkshire and the Humber's quarterly GDP indices (2016=100) based on GVA chained volume indices	ONS ²⁶	2012Q1-2021Q2
- GVAA_YRS	1987-1998: Yorkshire and the Humber's annual GDP measured at factor costs in basic prices and deflated by UK-wide deflator, £million 1998-2019: Yorkshire and the Humber's annual GVA in balanced approach using chained volume measures in 2018 constant prices, £million	ONS ^{27,28}	1987-2019

²⁶ <https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/quarterlycountryandregionalgdp>

²⁷

<https://www.ons.gov.uk/economy/grossvalueaddedgva/datasets/nominalandrealregionalgrossvalueaddedbalancedbyindustry>

²⁸

<https://www.ons.gov.uk/economy/regionalaccounts/grossdisposablehouseholdincome/adhocs/006226historiceconomicdataforregionsoftheuk1966to1996>

- claimantcount_YRS	Claimant count rate – a measurement of unemployment	nomisweb.co.uk ²⁹	1987Q2-2021Q4
Macroeconomics variables			
- oil	Oil price (brent crude \$/barrel)	fred.stlouisfed.org ³⁰	1987Q2-2021Q4
- bank_rate	Bank of England base interest rate	BOE ³¹	1987Q2-2021Q4
- exchange_rate	Exchange rate between US \$ and UK £	BOE ³²	1987Q2-2021Q4
- CPI	Consumer price inflation indices (2015=100)	ONS ³³	1987Q2-2021Q4

Definition and data sources of variables used in the model are detailed in Table 2. Note that all quarterly variables (except for CPI) entering VAR models are transformed in log form and taken first difference relative to the previous quarter to obtain the quarter-on-quarter rates of change. For CPI, we take log difference relative to same quarter in the previous year.

²⁹ <https://www.nomisweb.co.uk/sources/cc>

³⁰ <https://fred.stlouisfed.org/series/DCOILBRENTU>

³¹ <https://www.bankofengland.co.uk/boeapps/database/Bank-Rate.asp>

³² <https://www.bankofengland.co.uk/boeapps/database/>

³³ <https://www.ons.gov.uk/economy/inflationandpriceindices/datasets/consumerpriceindices/current>

A2 Gigabit availability and digital inclusion at spatial small-area level

FIGURE 13: GIGABIT AVAILABILITY BY MSOA AREAS, WEST YORKSHIRE, 2020

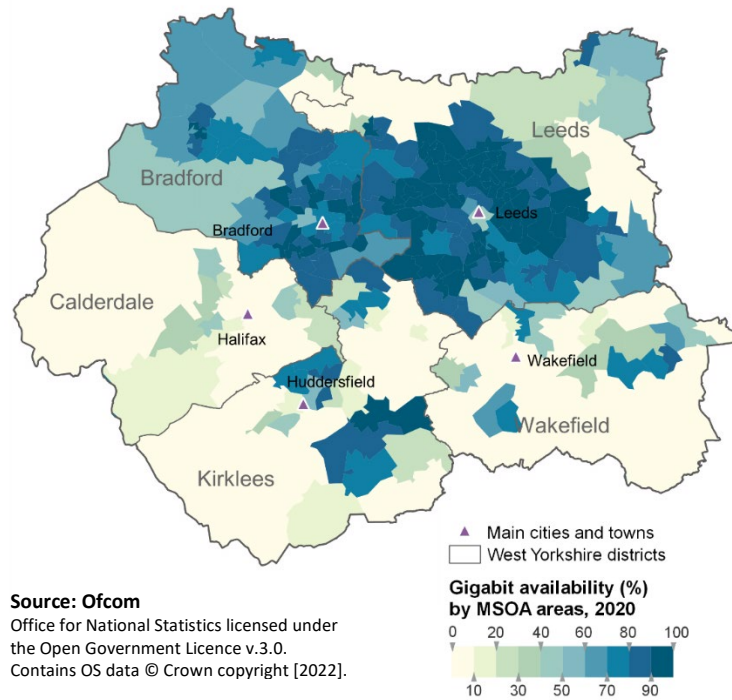
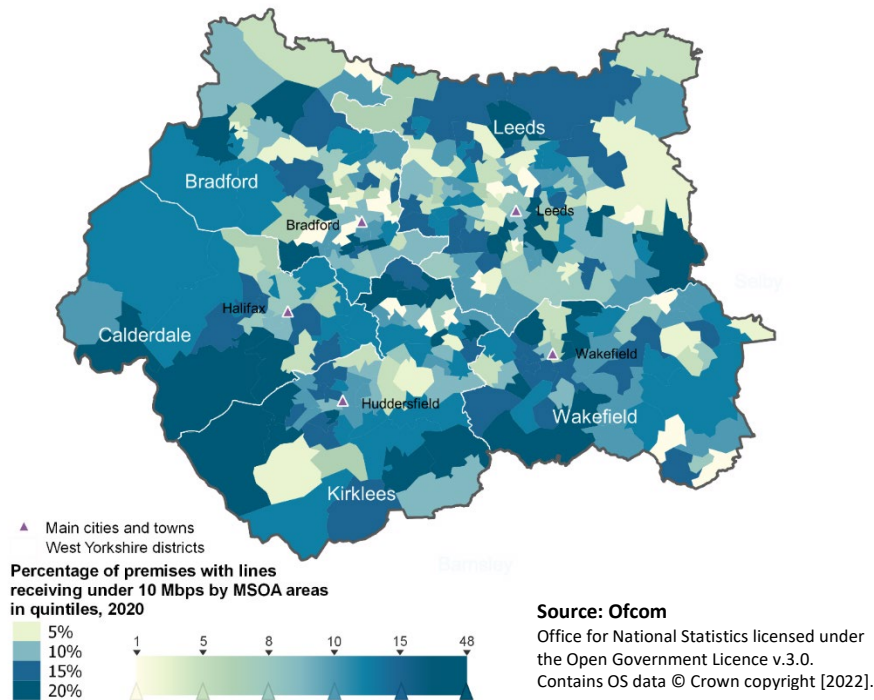


FIGURE 14: PERCENTAGE OF PREMISES WITH LINES RECEIVING UNDER 10 MBPS BY MSOA AREAS, WEST YORKSHIRE, 2020



Place-based Economic Recovery Network

Place-based Economic Recovery Network (PERN), is an academic-led, multi-university network of experts from West Yorkshire Combined Authority (WYCA), Leeds City region Enterprise Partnership (LCR LEP), and academics from universities within and outside Yorkshire to build a place-based economic recovery, regeneration and resilience of the region. The key general strengths and features of academic research are built upon and regionally showcased or channelled by PERN, via the PERN academic steering group. The PERN academic steering group aims to facilitate building closer, longer-term relations of academic research in West Yorkshire (and beyond) with regional and local bodies around economic recovery, whilst maintaining academic research independence and integrity.

Leeds University Business School

Leeds University Business School at the University of Leeds is a leading, triple accredited business school. The Business School has a mission of making an exceptional impact on business and society through leadership in research and teaching. We produce and disseminate research of world-class quality, within the School and through international partnerships. We enable students to develop their academic potential, employability, global and cultural insight to enhance their potential to benefit business and society. The Business School shares the University of Leeds' values of professionalism, inclusiveness, integrity and community.