

Article

# Model-based estimates of regional GVA: an overview

An overview of the econometric model used for producing experimental model-based quarterly estimates of regional Gross Value Added (GVA) output for the UK, at International Territorial Level 1 (ITL1).

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# 1 . Main points

- Improving the coverage and timeliness of regional data in the UK was a key theme in Professor Sir Charles Bean's [Independent Review of UK Economic Statistics](#).
- The Economic Statistics Centre of Excellence (ESCoE), an independent research centre sponsored by the Office for National Statistics (ONS), developed innovative econometric methods to improve both the timeliness and frequency of regional economic growth estimates in the UK to a similar timetable as the ONS' [GDP first quarterly estimate, UK](#).
- This article sets out to provide an overview of the model that has transitioned from ESCoE to the ONS, including the data inputs and performance of the model compared with the existing [GDP: UK regions and countries release](#).

## 2 . Overview of new model-based regional gross value added (GVA) estimates

From 8 October 2021, the Office for National Statistics (ONS) will publish experimental model-based quarterly estimates of regional gross value added (GVA) output for the UK, at International Territorial Level 1 (ITL1). This includes the nine English regions, Wales, Northern Ireland and Scotland. These estimates aim to provide an early indication of the ONS' [UK regions and countries publication](#), and will be published five months in advance of them.

The model that the ONS will publish has been adapted to include the official estimates already published in the ONS' [quarterly GDP, UK regions and countries](#).

The ONS has also chosen to present the estimates as quarter-on-quarter growth rates, which differs to the "growth in the year to" rolling four quarter, in-year estimates previously published in the [tables](#) and majority of [blogs](#) by Stuart McIntyre for the Economic Statistics Centre of Excellence (ESCoE). This will help with comparisons with the official quarterly UK GDP, regions and countries estimates.

This article:

- describes the model that has transitioned from ESCoE research to the ONS as an experimental publication
- compares the estimates with the subsequent official first release of the existing ONS' estimates of UK GDP, regions and countries
- provides an assessment of strengths and weaknesses of the model-based estimates

For the assessment in this article, we have produced model-based estimates as quarter-on-quarter growth rates and compared these with the ONS' publication of quarterly regional GDP, including the Scottish GDP and Northern Ireland's NICEI index that were included in the publication of GDP, UK regions and countries at that time.

## 3 . Methodological process for the model

The Office for National Statistics (ONS) has historically published [Regional economic activity by gross domestic product](#) for the UK regions at an annual frequency, with a lag of a year prior to publication, while UK gross domestic product (GDP), and other macroeconomic variables, are produced at a monthly or quarterly frequency. In September 2019, the ONS published the first estimates of quarterly [GDP, UK regions and countries](#), predominately based on value-added tax (VAT) data sources, with these data dating back to 2012 and which are released with a delay of five months relative to the first estimate of UK GDP. The new model uses these three data sources, along with other timely indicators, as shown in [section 4](#).

The model uses a mixed-frequency vector autoregressive (MF-VAR). This is described in technical detail in [UK Regional Nowcasting using a mixed frequency Vector Autoregressive Model \(Koop, McIntyre, Mitchell 2018\)](#).

A MF-VAR approach estimates the set of regressions (for example, one for each variable in the model) as a system. This allows us to take advantage of the interactions between variables to improve the fit of the model. In this case we expect there to be correlations between the GDP growth across regions, so a MF-VAR framework enables this information to be used rather than if we had a separate forecast model for each region. The explanatory variables in each regression are past values of all the other variables in the model. This approach allows the utilisation of data sources of different frequencies to arrive at the estimates of quarterly regional gross value added (GVA) to a similar timetable of the first estimate of UK GDP.

There are four main methodological processes in the model which are used to create the estimates:

- estimated historical relationships between regional growth and UK growth (this reflects how sensitive regional growth is to UK growth)
- estimated historical relationships between the growth of particular regions (this captures how growth in region x has translated into growth in region y)
- estimated historical relationships within the regions (this captures the persistence of regional growth from one quarter to the next)
- estimated historical relationships between other macroeconomic variables and regional growth (for example, how oil price changes can have a large impact on all the regions, particularly with regards to the additional UK quarterly macroeconomic variables, so in this example there can be substantial increases in the connectedness to measures for the oil price and the exchange rate)

For further information please visit the ESCoE [website](#).

## 4 . Data inputs

A key input to the model is the use of historical data. A historic regional time series was constructed back to 1966, based on data published by the [Office for National Statistics \(ONS\)](#), but with the Economic Statistics Centre of Excellence (ESCoE) researchers making some additional changes to address key issues such as changes to geographies at International Territorial Level 1 (ITL1). [Data appendix A.1](#) of the ESCoE paper describes how this data was constructed.

The ESCoE researchers also used these data to construct a "real-terms" series by deflating these nominal annual data with a UK deflator. These data inputs allow the model to estimate the pattern of regional growth based on estimated historical relationships between regional and national growth. The data inputs came from a number of publications.

The ONS' publications:

- [Regional GVA \(balanced\)](#), published annually, explores current price and chain volume measure, sourced from time series for total region £m
- [GVA at basic prices - nominal](#), published quarterly, explores (nominal) £m non-seasonally adjusted, sourced from series ID: ABML
- [GVA at basic prices - chained volume measures](#), published quarterly, explores chained volume measure £m seasonally adjusted, sourced from series ID: ABMM
- [GDP, UK Regions and Countries](#), published quarterly, explores chained volume measure, seasonally adjusted, sourced from 9 English regions and total industry Wales
- [Consumer Price Inflation](#), published monthly, explores CPI Index: All Items, 2015 = 100, sourced from series ID: D7BT

The Scottish government's publication:

- [Scotland quarterly GDP](#), published quarterly, explores chained volume measure, Index 2016 = 100

The Northern Ireland publication:

- [Northern Ireland composite Index](#), published quarterly, explores real GVA, seasonally adjusted, sourced from NICEI

The Bank of England publications:

- [Quarterly exchange rate](#), published quarterly, explores converting US \$ into £, sourced from quarterly spot exchange rate
- [Quarterly bank rate](#), published quarterly, sourced from the quarterly Bank of England base rate

The federal reserve publication:

- [Oil Prices](#), published quarterly, sourced from crude oil prices, Brent, Europe

## 5 . Constraining to total UK gross value added (GVA)

The model includes an inter-temporal restriction to ensure quarterly gross value added (GVA) sums to annual GVA as published by the Office for National Statistics (ONS) for the period where this is available. Similarly, the model includes a “cross-sectional” restriction, which ensures that the output of the UK regions in any quarter sum to UK quarterly GVA as published in the first estimate of gross domestic product (GDP). This ensures consistency for the different levels of aggregation.

The path of quarterly GVA is similar to the published quarterly GDP figures, meaning that GVA is a good proxy for GDP, and the terminology of GDP is used within the ONS statistical releases for ease of communication. When using the output approach to measuring gross domestic product (GDP) we are actually estimating the contribution of each industry or producer by using gross value added (GVA) at basic prices, or put simply the value of a unit’s outputs less the value of inputs used in the production process to produce the outputs. The link between GVA and GDP is: GVA at basic prices plus taxes on products less subsidies on products equals GDP at market prices (or headline GDP).

Table 1: Timeline of data sources available for the modelled period(examplefor Quarter 2 and Quarter 3 2021)

<b>Month published (or to be published)</b>	<b>Data source</b>	<b>Model-based estimates produced</b>	<b>Publications model based estimates constrain to</b>
<b>May 2021</b>	Annual Regional GVA 2019		
<b>Jul 2021</b>	Other 2021 Q2		
<b>Aug 2021</b>	Regional GDP 2020 Q4, UK GVA 2021 Q2		
<b>Sep 2021</b>	NICEI 2021 Q2, Scottish GDP 2021 Q2		
<b>Oct 2021</b>	Other 2021 Q3	Up to 2021 Q2	UK GVA 2021 Q2, Annual Regional GVA 2019, Regional GDP 2020 Q4, (Only uses Scottish GDP and NICEI up to 2020 Q4)
<b>Nov 2021</b>	Regional GDP 2021 Q1, UK GVA 2021 Q3	Up to 2021 Q3	UK GVA 2021 Q3, Annual Regional GVA 2019, Regional GDP 2021 Q1, (Only uses Scottish GDP and NICEI up to 2021 Q1)
<b>Dec 2021</b>	Scottish GDP 2021 Q3		
<b>Jan 2022</b>	NICEI 2021 Q3		
<b>Feb 2022</b>	Regional GDP 2021 Q2		

Source: Office for National Statistics

### Notes:

1. “Other” refers to the quarterly economic indicators (CPI, Bank Rate, Exchange Rate and Oil price).
2. NICEI - Northern Ireland Composite Economic Index.
3. Q1 refers to Quarter 1 (Jan to Mar), Q2 refers to Quarter 2 (Apr to June), Q3 refers to Quarter 3 (July to Sept), Q4 refers to Quarter 4 (Oct to Dec).



## 6 . Comparisons of model-based estimates with the Office for National Statistics' (ONS) experimental quarterly regional estimates

To evaluate the new model developed by the Economic Statistics Centre of Excellence (ESCoE), we produced quarter-on-previous-quarter modelled estimates from Quarter 2 (Apr to June) 2019, to compare with the first period available of quarter-on-quarter growths as published in our experimental value-added tax (VAT) based estimates for the UK Regions and Countries, along with the Scottish gross domestic product (GDP) and NISRA's NICEI index incorporated in this release.

This evaluation includes observations from the coronavirus (COVID-19) pandemic period. The pandemic represented an unprecedented economic shock, and most statistical models found it difficult to reconcile the economic data released during this period. For pre-pandemic evaluations of the performance of the model, including comparisons to the [GDP, UK regions and countries data](#), please see the published [academic paper](#).

In this publication we refer to the "model-based estimate" as the estimate of regional growth in a given quarter for which we have just received comparable UK data. For example, model-based estimates of Quarter 1 (Jan to Mar) 2021 can be produced just after the release of UK GDP data for Quarter 1 2021. However, the ONS' estimates of regional growth in Quarter 1 2021 will not be released until after we also have Quarter 2 (Apr to June) 2021 UK GDP data. This enables us to produce a second estimate of regional growth in Quarter 1 2021, incorporating the additional information contained in the UK data for Quarter 2021.

Table 2 shows how many periods the model-based estimates' direction of growth is in alignment with the ONS' quarterly regional GDP.

Table 2: Number of periods the model-based estimate was in alignment with quarterly Regional GDP

<b>Region</b>	<b>Number of quarters where the model estimated direction aligns with ONS' quarterly regional GDP (out of 7 quarters, Quarter 2 2019 to Quarter 4 2020)</b>
<b>East Midlands</b>	3
<b>East of England</b>	5
<b>London</b>	5
<b>North East</b>	6
<b>North West</b>	6
<b>Northern Ireland</b>	3
<b>Scotland</b>	6
<b>South East</b>	5
<b>South West</b>	7
<b>Wales</b>	6
<b>West Midlands</b>	6
<b>Yorkshire and The Humber</b>	5

Source: Office for National Statistics

The charts compare the model-based growth for each of the twelve regions and countries with the growth as first published in UK GDP regions and countries (labelled "VAT based"). The model is based on "real time" model performance, only including the latest information that was available at the time when it was generated. This was repeated for each successive quarter. The model includes the UK GDP, regions and countries (which includes the data for Scotland and Northern Ireland, that was included in the publication of GDP, UK regions and countries at that time) but this is two quarters behind the period for the model-based estimates.

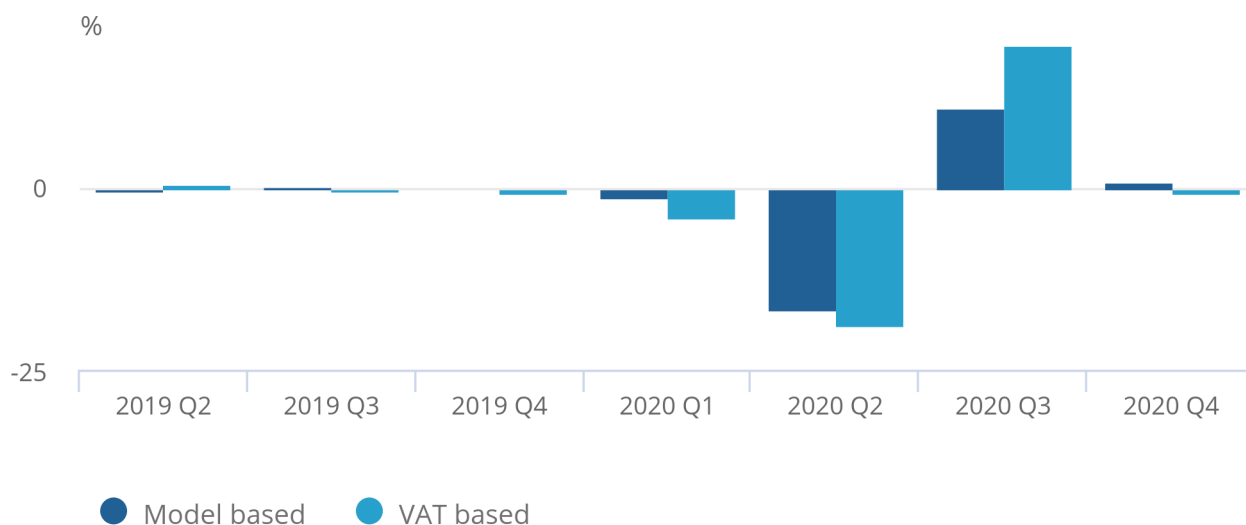
The charts show that when growth is closer to zero, the directions of the model-based estimate and the ONS' regional GDP can diverge. The magnitude of the model-based estimate can also be larger than quarterly regional GDP, especially over the pandemic period, for example, London in Quarter 2 (Apr to June) 2020.

**Figure 1: Model-based estimates' direction of growth aligns with regional GDP for East Midlands three out of seven quarters**

East Midlands, 2019 Quarter 2 to 2020 Quarter 4, percentage growth

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East Midlands, 2019 Quarter 2 to 2020 Quarter 4, percentage growth



Source: Office for National Statistics

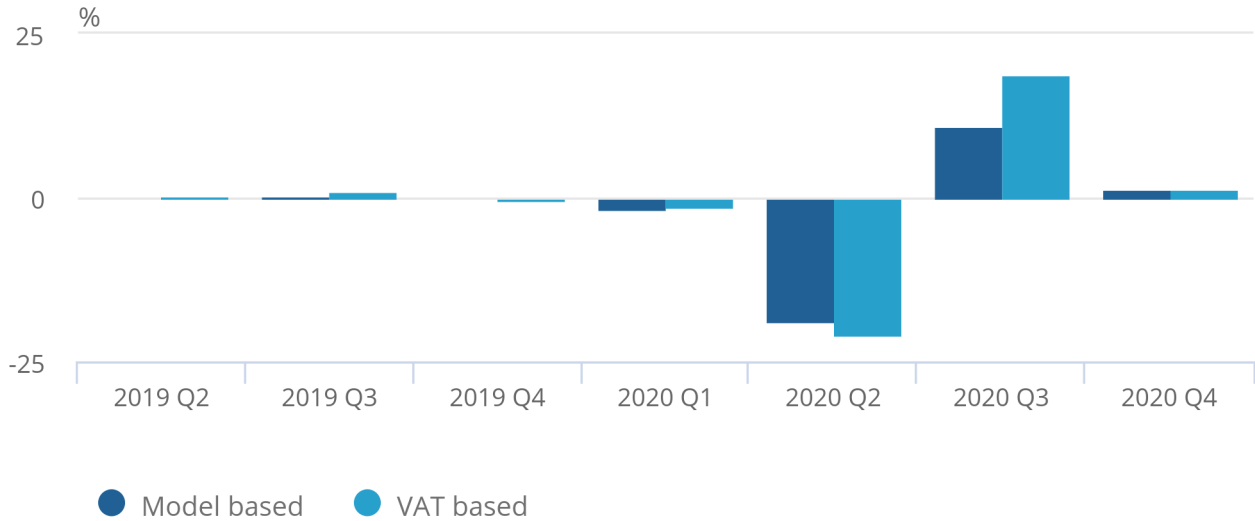


**Figure 2: Model-based estimates' direction of growth aligns with regional GDP for East of England five out of seven quarters**

East of England, 2019 Quarter 2 to 2020 Quarter 4, percentage growth

Figure 2: Model-based estimates' direction of growth aligns with regional GDP for East of England five out of seven quarters

East of England, 2019 Quarter 2 to 2020 Quarter 4, percentage growth



Source: Office for National Statistics

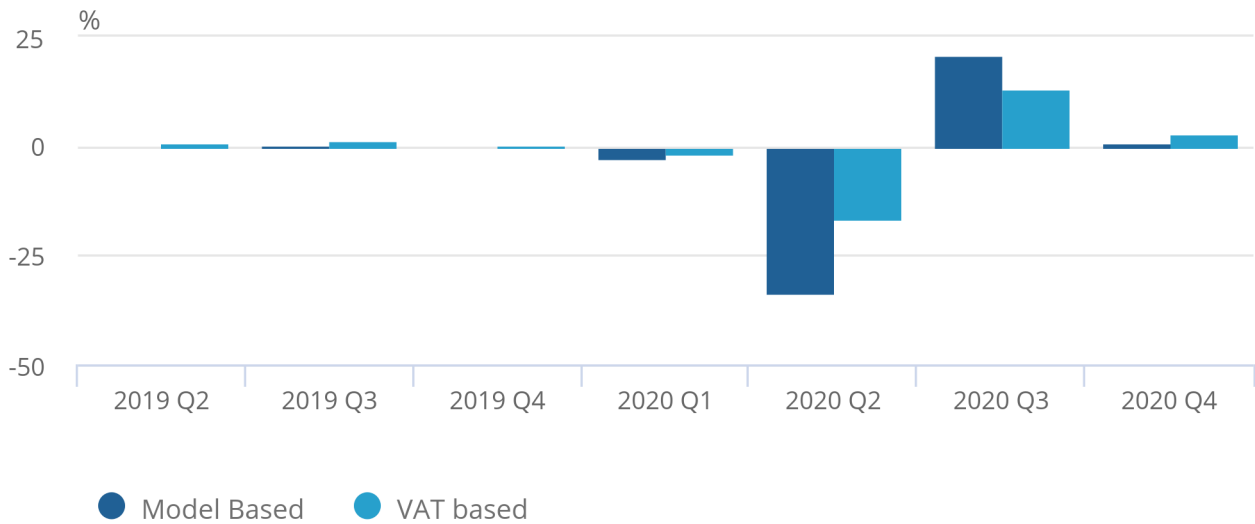
London's economy tends to exhibit greater cyclical volatility compared with the UK overall. Between 2012 and 2019, the UK economy's growth was consistently positive, but London's growth rate strongly surpassed this. London's GDP growth was also more volatile than for the UK as a whole. Therefore, the model is likely to view London as a more cyclical economy than the UK overall – so in the same way that London tends to outperform the economy in good times, it might be expected to do worse in bad times.

**Figure 3: Model-based estimates' direction of growth aligns with regional GDP for London five out of seven quarters.**

London, 2019 Quarter 2 to 2020 Quarter 4, percentage growth

Figure 3: Model-based estimates' direction of growth aligns with regional GDP for London five out of seven quarters.

London, 2019 Quarter 2 to 2020 Quarter 4, percentage growth



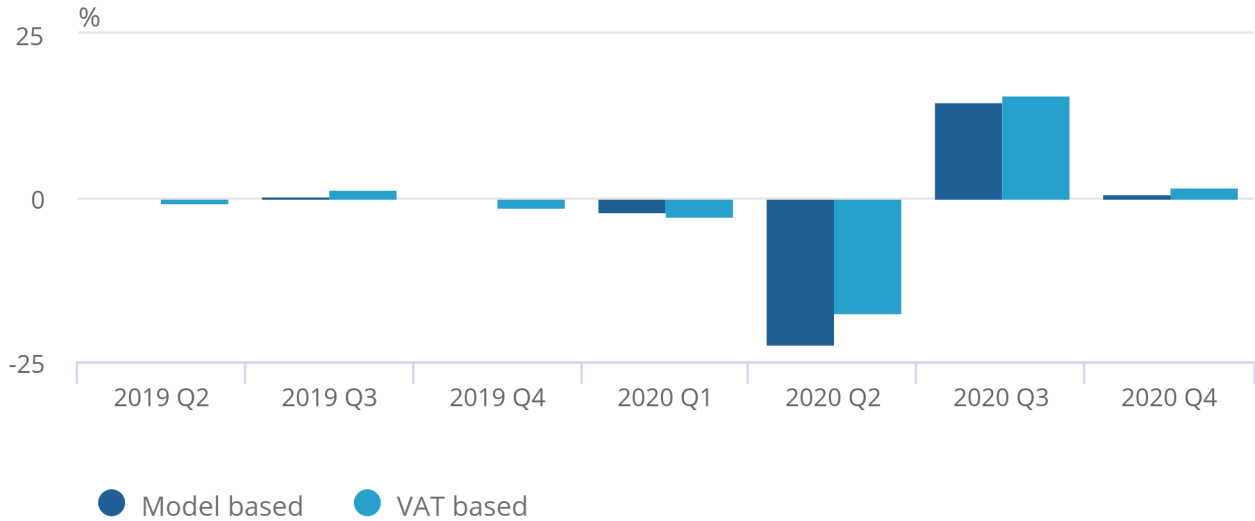
Source: Office for National Statistics

**Figure 4: Model-based estimates' direction of growth aligns with regional GDP for North East six out of seven quarters**

North East, 2019 Quarter 2 to 2020 Quarter 4, percentage growth

Figure 4: Model-based estimates' direction of growth aligns with regional GDP for North East six out of seven quarters

North East, 2019 Quarter 2 to 2020 Quarter 4, percentage growth



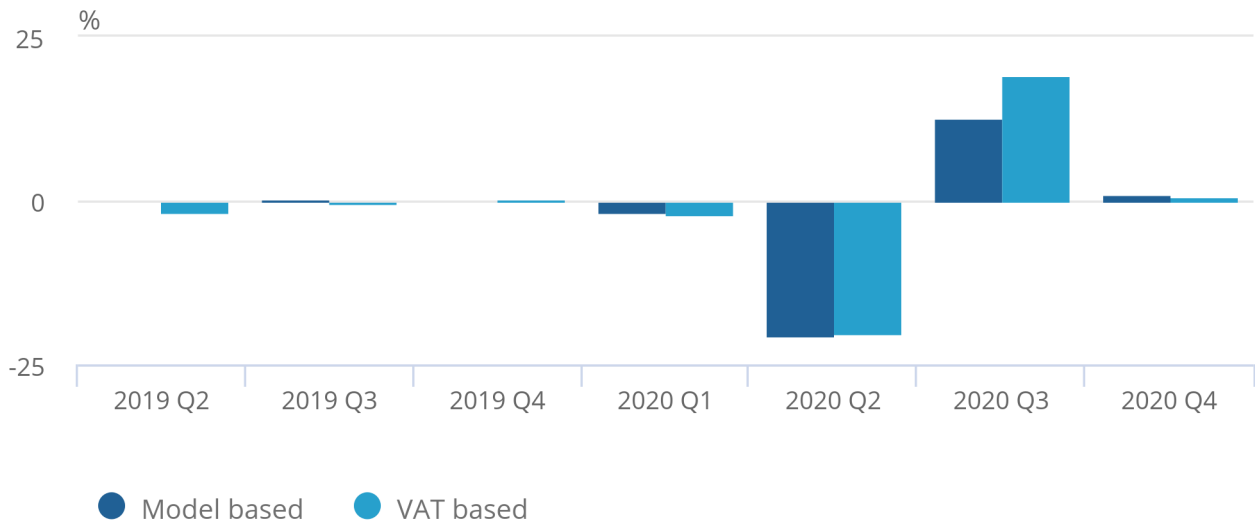
Source: Office for National Statistics

**Figure 5: Model-based estimates' direction of growth aligns with regional GDP for North West for six of the seven quarters**

North West, 2019 Quarter 2 to 2020 Quarter 4, percentage growth

Figure 5: Model-based estimates' direction of growth aligns with regional GDP for North West for six of the seven quarters

North West, 2019 Quarter 2 to 2020 Quarter 4, percentage growth



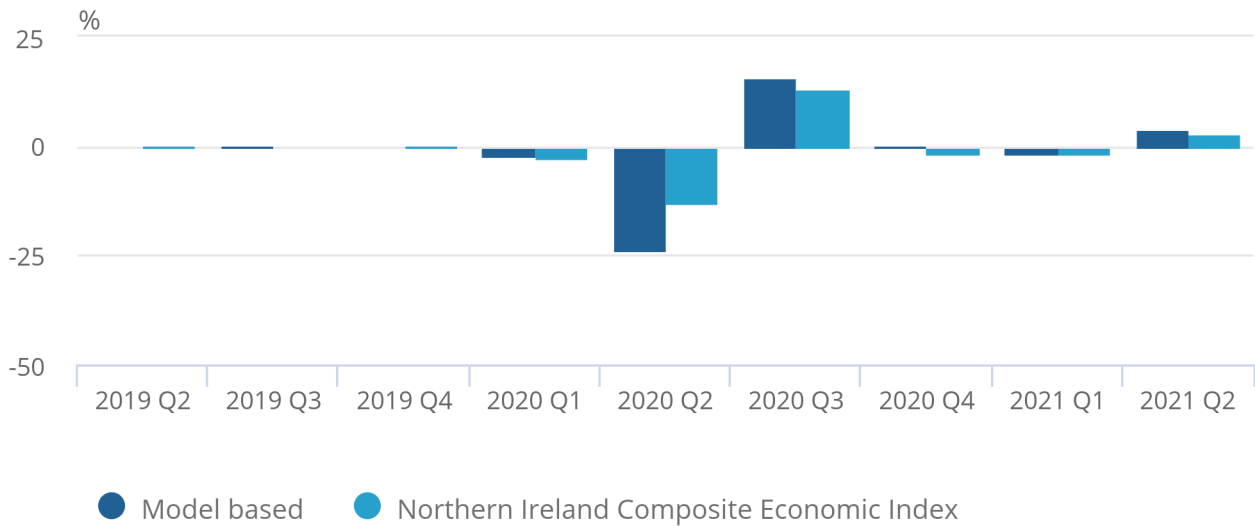
Source: Office for National Statistics

**Figure 6: Model-based estimates' direction of growth aligns with NISRA's NICEI index for Northern Ireland for five of the nine quarters**

Northern Ireland, 2019 Quarter 2 to 2021 Quarter 2, percentage growth

Figure 6: Model-based estimates' direction of growth aligns with NISRA's NICEI index for Northern Ireland for five of the nine quarters

Northern Ireland, 2019 Quarter 2 to 2021 Quarter 2, percentage growth



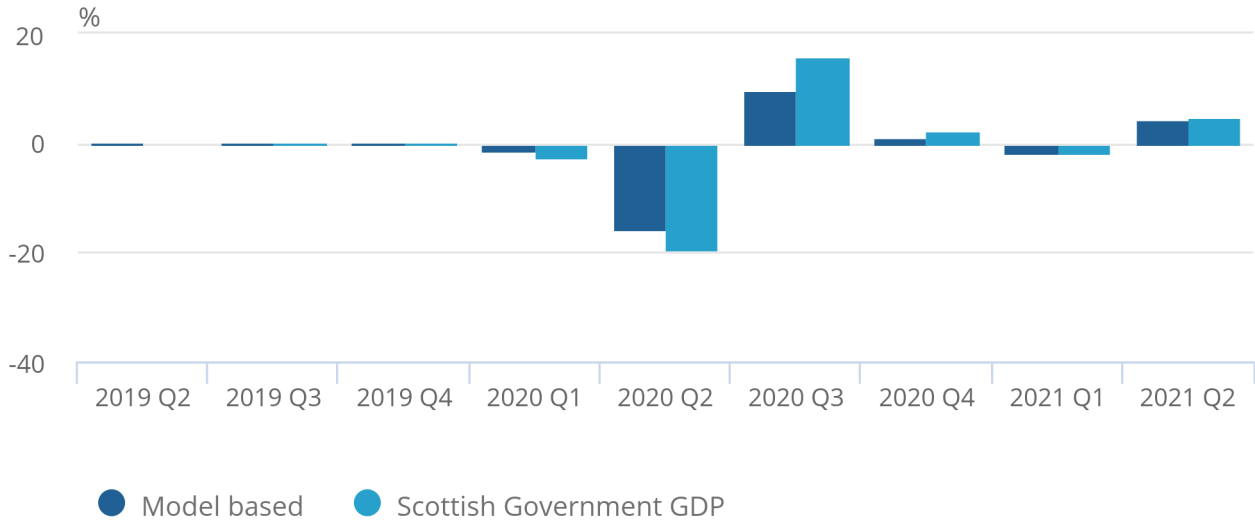
Source: Office for National Statistics

**Figure 7: Model-based estimates' direction of growth aligns with Scottish Government GDP for eight of nine quarters**

Scotland, 2019 Quarter 2 to 2021 Quarter 2, percentage growth

Figure 7: Model-based estimates' direction of growth aligns with Scottish Government GDP for eight of nine quarters

Scotland, 2019 Quarter 2 to 2021 Quarter 2, percentage growth



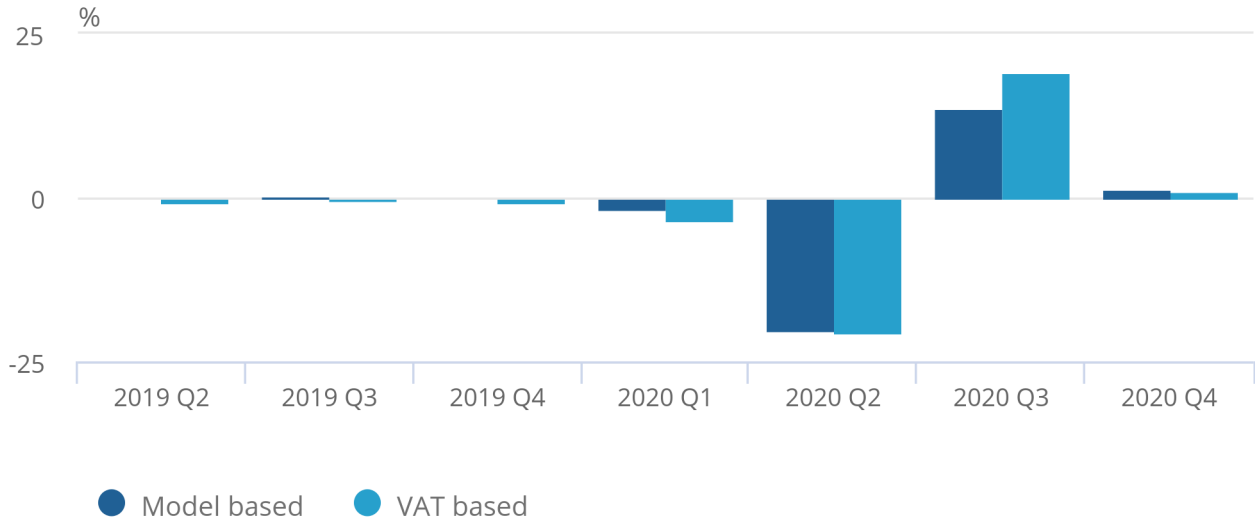
Source: Office for National Statistics

**Figure 8: Model-based estimates' direction of growth aligns with ONS' Regional GDP for the South East for five of seven quarters**

South East, 2019 Quarter 2 to 2020 Quarter 4, percentage growth

Figure 8: Model-based estimates' direction of growth aligns with ONS' Regional GDP for the South East for five of seven quarters

South East, 2019 Quarter 2 to 2020 Quarter 4, percentage growth



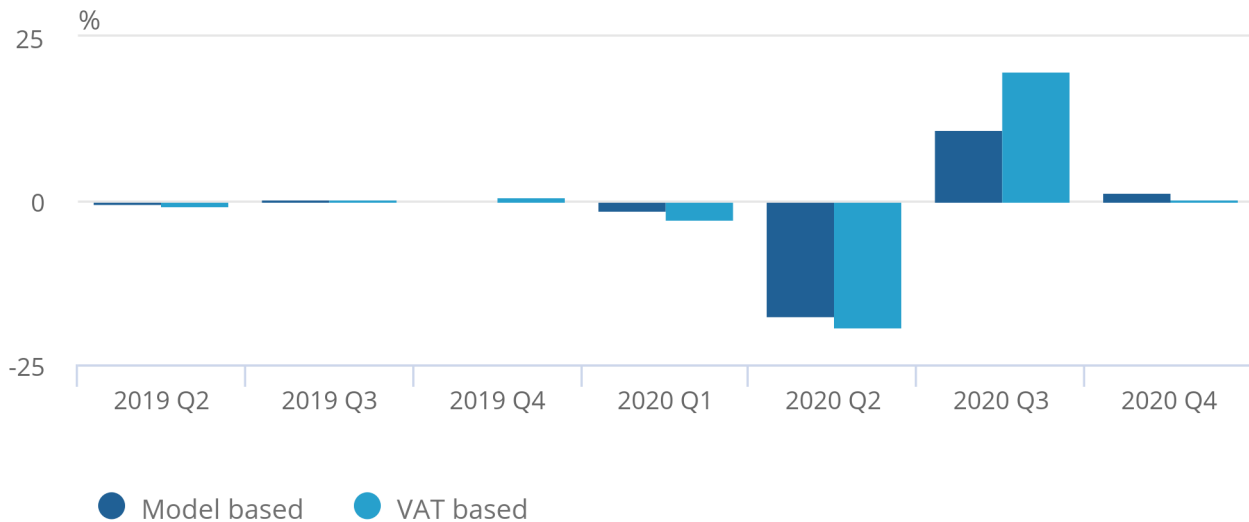
Source: Office for National Statistics

**Figure 9: Model-based estimates' direction of growth aligns with ONS' Regional GDP for the South West for six out of seven quarters**

South West, 2019 Quarter 2 to 2020 Quarter 4, percentage growth

Figure 9: Model-based estimates' direction of growth aligns with ONS' Regional GDP for the South West for six out of seven quarters

South West, 2019 Quarter 2 to 2020 Quarter 4, percentage growth



Source: Office for National Statistics

The modelled Welsh GVA were also excessively negative compared with the ONS' VAT based estimates. One of the factors driving the model estimates is the performance of each regional economy in recent past quarters. It can be seen that, prior to the pandemic, Wales had also recorded a steep decline in GDP during 2019 and especially in the last quarter of that year. The model-based estimates may therefore be reflecting this recent trend in Wales' GDP. The Welsh Government publish [short-term output indicators](#), the next release up to Quarter 2 (Apr to Jun) 2021 is scheduled for publication on 28 October 2021. These data are not included in the ONS' GDP, UK regions and countries release nor the model-based estimates of regional GVA.

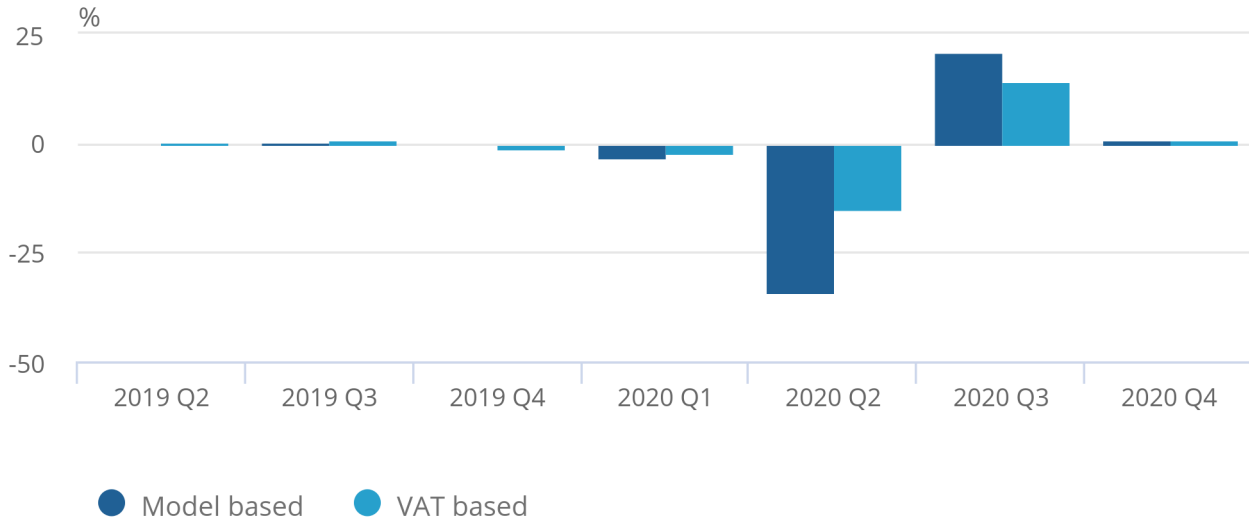


**Figure 10: Model-based estimates' direction of growth aligns with ONS' Regional GDP for Wales for six out of seven quarters**

Wales, 2019 Quarter 2 to 2020 Quarter 4, percentage growth

Figure 10: Model-based estimates' direction of growth aligns with ONS' Regional GDP for Wales for six out of seven quarters

Wales, 2019 Quarter 2 to 2020 Quarter 4, percentage growth



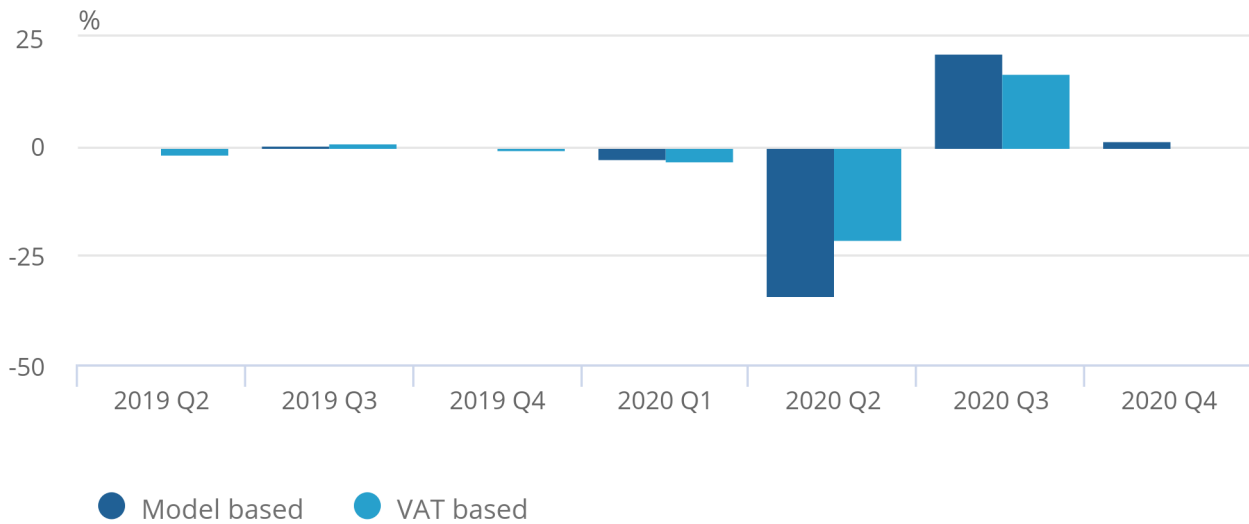
Source: Office for National Statistics

**Figure 11: Model-based estimates' direction of growth aligns with ONS' Regional GDP for West Midlands for six out of seven quarters**

West Midlands, 2019 Quarter 2 to 2020 Quarter 4, percentage growth

Figure 11: Model-based estimates' direction of growth aligns with ONS' Regional GDP for West Midlands for six out of seven quarters

West Midlands, 2019 Quarter 2 to 2020 Quarter 4, percentage growth



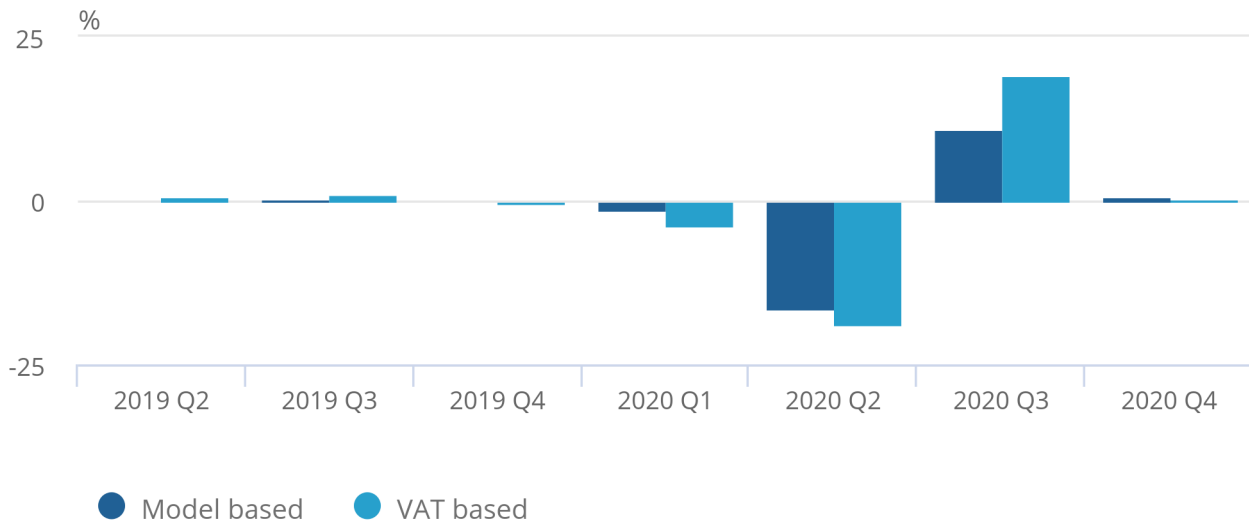
Source: Office for National Statistics

**Figure 12: Model-based estimates' direction of growth aligns with ONS' Regional GDP for Yorkshire and the Humber for five out of seven quarters**

Yorkshire and The Humber, 2019 Quarter 2 to 2020 Quarter 4, percentage growth

Figure 12: Model-based estimates' direction of growth aligns with ONS' Regional GDP for Yorkshire and the Humber for five out of seven quarters

Yorkshire and The Humber, 2019 Quarter 2 to 2020 Quarter 4, percentage growth



Source: Office for National Statistics

Table 3 shows the root mean square error (RMSE) to evaluate the differences between the prediction (the first model-based estimate) and the observed as published in GDP, UK regions and countries. The RMSEs are the square root of the mean square error (MSE), which is the sum of the variance and the square of the bias. MSE is a measure of overall accuracy, in this context, the accuracy of the modelling.

The RMSE and confidence intervals have been provided both including Quarter 2 (Apr to Jun) and Quarter 3 (Jul to Sep) 2020, as well as excluding those two periods.

Unsurprisingly, the periods of the pandemic generated larger RMSE for Wales, London and Northern Ireland mainly. For this reason, users will need to be cautious in interpreting the movements at times of shock within the economy and the ONS will continue to review these time periods as part of our publishing approach from October 2021.

Table 3: Root Mean Square Error (RMSE) valuating differences between model based and observed estimates

Region	RMSE (Q2 2019 to Q4 2020)	
	2020	excluding Q2 and Q3 2020
East Midlands	3.5%	1.5%
East of England	3.1%	0.4%
London	7.1%	1.3%
North East	2.0%	1.0%
North West	2.6%	0.8%
Northern Ireland	4.1%	0.9%
Scotland	2.6%	0.5%
South East	2.2%	0.9%
South West	3.6%	0.9%
Wales	7.7%	0.7%
West Midlands	5.3%	1.0%
Yorkshire and The Humber	3.4%	1.1%

Source: Office for National Statistics

Table 4: Confidence Interval Root Mean Square Error (RMSE), relative to the published estimate

Region	Q2 2019 to Q4 2020	
	2020	excluding Q2 and Q3 2020
East Midlands	estimate +/- 6.9%	estimate +/- 3.0%
East of England	estimate +/- 6.1%	estimate +/- 0.8%
London	estimate +/- 13.9%	estimate +/- 2.6%
North East	estimate +/- 3.9%	estimate +/- 1.9%
North West	estimate +/- 5.1%	estimate +/- 1.5%
Northern Ireland	estimate +/- 8.1%	estimate +/- 1.7%
Scotland	estimate +/- 5.2%	estimate +/- 1.0%
South East	estimate +/- 4.3%	estimate +/- 1.7%
South West	estimate +/- 7.0%	estimate +/- 1.7%
Wales	estimate +/- 15.1%	estimate +/- 1.3%
West Midlands	estimate +/- 10.3%	estimate +/- 2.0%
Yorkshire and The Humber	estimate +/- 6.6%	estimate +/- 2.2%

Source: Office for National Statistics

Note that Scottish Government and Northern Ireland data are produced separately with different methodology to the ONS' GDP, UK regions and countries covering the nine English regions and Wales. An ESCoE paper describes this in more detail [Regional Output Growth in the United Kingdom: More Timely and Higher Frequency Estimates](#).

## 7 . Strengths and limitations of the model-based estimates

### Strengths

#### Timeliness

The model-based estimates of quarterly regional gross domestic product GDP are available to approximately the same timetable as the release of the UK first estimate of GDP from published data sources of mixed frequencies. The [Regional Economic Activity, by Gross Domestic Product](#) is published annually and more recently, since September 2019, the [GDP, UK regions and countries](#) is published quarterly. However, there still remains a delay on publication of sub-national estimates because of the data sources being less timely compared with UK estimates of gross value added (GVA).

#### Peer reviewed

The model has been peer reviewed as part of the Economic Statistics Centre of Excellence (ESCoE) process and methodologists at the Office for National Statistics (ONS) were involved at various stages of the project and publications.

#### Performance

The model will continue to be evaluated against our existing predominately value-added tax (VAT) based GDP, UK regions and countries estimates.

### Limitations

The main limitation that applies to modelling in general, and not exclusively to this model, is mainly seen during times of economic uncertainty and extreme values. This applies to the periods of the coronavirus (COVID-19) pandemic. The pandemic observations led to parameter instability in the model (which includes the GDP, UK regions and countries publication). The model required updated parameters using data estimated from 2019, for Quarter 2 (Apr to June) 2020 and Quarter 3 (Jul to Sep) 2020 only.

It should be noted that the quarterly movements in GDP during 2020 for the UK and the regions were exceptional, and most modelling approaches would be vulnerable to large errors. Modelling in times of economic uncertainty using the mixed-frequency vector autoregressive (MF-VAR) has been discussed in a recent National Institute Economic Review paper.

Because of the model construction, the Scottish Government's GDP and NISRA's NICEI index can only be, at present, entered into the model ending on the same quarter as the ONS' VAT-based regional estimates for the nine English regions and Wales. In this case, we would recommend users view the official estimates for Scotland and Northern Ireland, where they are available.

For the model, a historic regional time series was constructed by the researchers back to 1966. Deflating the nominal data by the total UK GDP deflator in ESCoE's view is a strong assumption, as there is no reliable regional price data currently available.

## 8 . Future developments

The Office for National Statistics (ONS) will publish the experimental model-based estimates at ITL1 to provide public access for consideration as a timely indicator of quarterly gross value added (GVA) in UK countries and regions.

We will keep these estimates under review, regularly monitoring them against the observed values of our existing, predominately value-added tax (VAT) based estimates of quarterly gross domestic product (GDP), UK regions and countries to help understand quality and gathering feedback from users about relevance and usability to inform longer term plans.

We welcome user feedback at [regionalgdp@ons.gov.uk](mailto:regionalgdp@ons.gov.uk).

## 9 . Related links

### [Regional nowcasting in the UK, ESCoE](#)

Article | 17 February 2021

Newly developed nowcasting model produces estimates of quarterly economic growth for all UK regions to approximately the same timetable as the release of UK GVA data. Note that these are published as rolling in year quarters, therefore not comparable with the ONS quarter-on-quarter estimates.

### [Reconciled Estimates and Nowcasts of Regional Output in the UK, National Institute Economic Review](#)

Article | 28 July 2020

Discusses more timely estimates of regional GVA in the UK.

### [Regional output growth in the United Kingdom: More timely and higher frequency estimates from 1970](#)

Article | 17 November 2020

Discusses the development of a mixed-frequency multivariate model to produce consistent estimates of quarterly regional output growth dating back to 1970.

### [UK Regional Nowcasting using a Mixed Frequency Vector Autoregressive Model with Entropic Tilting](#)

Article | 16 July 2019

Discusses entropic tilting and methods within the mixed frequency vector autoregressive model.