ASSESSING LONG-RUN GROWTH PROSPECTS FOR THE UK'S REGIONS

George Verikios,* Ian Hurst** and Garry Young**

The UK faces a number of economic challenges in the short to medium term. Prior to COVID-19, renegotiation of trading arrangements with the European Union was the most prominent of these. We build on existing macroeconomic analysis by assessing prospects for the UK's regions generated by combining a global macroeconometric model and a regional computable general equilibrium of the UK. A central macroeconomic scenario shows a national average annual GDP growth rate of 1.7 per cent to 2044. When the macroeconomic scenario is applied across regions, growth rates range from 1.6 per cent for Cambridge to 2.2 per cent for Pembrokeshire; the standard deviation is low at 0.07 per cent and the coefficient of variation is 0.04 per cent. In contrast, much wider variation is observed in the standard deviation for exports (0.36 per cent), investment (0.11 per cent) and consumption (0.14 per cent). The country results favour Scotland, which grows at an annual rate of 1.8 per cent, whereas Wales is the slowest growing of the countries at 1.7 per cent. Consistent with the macroeconomic analysis, international trade is the most important contributor to the regional variation in growth rates. We also analyse the effects of higher government consumption relative to the forecasts and find most regions are predicted to experience lower economic activity except the handful in which government consumption is a much higher share of GDP than average.

Keywords: computable general equilibrium, government consumption shock, economic growth, macroeconometric model, trade shocks, regional analysis.

JEL codes: E27; E37; O11; R11.

1. Introduction

The United Kingdom (UK) faces a number of economic challenges in the short to medium term. Prior to COVID-19, the most prominent of these, given the vote to leave the EU in the referendum of 2016, was the state of future trading arrangements with the European Union (EU) and with other countries. The UK left the EU in January 2020, but the ultimate trading relationship is still to be determined. The future economic and legal relationship with the EU will affect UK trade with the EU and has significant potential for economic disruption as roughly half of all UK trade occurs with EU members. A second major medium-term challenge is the slowdown in productivity growth in the UK over the past two decades and the associated low overall labour productivity growth relative to other high-income countries. A third major challenge is the persistent and significant government budget deficit and corresponding accumulation of government debt that now stands at over 100 per cent of GDP and has the potential to rise further.

These challenges have been analysed by the UK government and others as regards their aggregate effects on the UK economy (e.g., Behrens and Mion, 2017; Douch *et al.*, 2018; Hantzsche *et al.*, 2019) but there has been little research focussing on how these challenges will affect different regions of the UK. This work focusses on this issue by projecting growth outcomes for UK regions out to 2044. The projections are generated by combining two sophisticated analytical frameworks: a global macroeconometric model and a regional computable general equilibrium (CGE) of the UK.

At the macro level we apply NiGEM (National Institute's Global Econometric model). NiGEM is a large model of the world economy that is used for forecasting and scenario analysis. It encompasses discrete models for most OECD economies and regional blocks for the remaining countries in Asia, America, Africa, the Middle East and Europe. The regional sub-models that make

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up NiGEM depend on both theory and data. There is a common (estimated and calibrated) underlying structure across all economies. The model's long-run equilibrium properties are neoclassical. That is, output is tied down in the long run by factor inputs and technical progress interacting through production functions. In contrast, the short-term dynamic properties and underlying estimated properties are consistent with data. The model can treat agents as forward looking, as holding rational expectations or applying adaptive learning. The model is flexible in the treatment of different policy environments.

NiGEM is applied to generate a macroeconomic scenario for the UK economy out to 2044. The scenario is based on NIESR's November 2018 forecast and at that time encompassed all known future changes in economic variables for the UK and other major economies. The forecast also encompassed judgements on the future effects of Brexit and other economic challenges. These quarterly outcomes are converted to annual changes and subsequently applied to a regional model of the UK.

The UK regional model (UK-SCGE) is a dynamic spatial CGE model with long-run properties similar to NiGEM. The short-run behaviour is mainly characterised by the movement from an initial steady-state that is consistent with the latest input-output data, and national and regional accounts. Over time the model slowly moves from the initial steady-state along a balanced growth path to a new steady-state. The model represents 29 industries, 109 regions, 44 investment inputs for each industry, and a central and local government sector with detailed government expenditure and revenue accounts. Exports and imports are specified by EU and non-EU destinations and sources. It also includes a detailed representation of the current and capital accounts, accumulation of foreign assets, foreign liabilities and government debt.

NiGEM and UK-SCGE belong to different classes of model. NiGEM is a multi-country macroeconometric macro model whereas UK-SCGE is a multi-region, multi-sector CGE model of a single country. Both models are dynamic but their periodicity varies; NiGEM is a quarterly model whereas UK-SCGE is, like most dynamic CGE models, an annual model. The nature of the dynamics also varies. The dynamics of NiGEM are driven by lagged error correction around trend growth rates determined by econometric estimation. The dynamics of UK-SCGE are purely deterministic and are mostly driven by the behaviour of stock-flow relationships. Of these, the capital stock is the most important and those for financial assets less so. Applying a forecast from NiGEM to UK-SCGE thus poses challenges in reconciling divergent approaches to representing economic behaviour through time.

The NiGEM results are applied as annual inputs to the regional model. The inputs include the expenditure- and income-side components of GDP, labour productivity, price deflators (import, exports and consumer goods) and the exchange rate. This ensures that at the macro level the two models are consistent in their representation of the path of the aggregate economy. Using the macro inputs from NiGEM, the regional model generates a rich pattern of effects for 109 regions. The effects provide an internally consistent story of changes in regional output. These changes are decomposed to explain how regions are affected differentially by the various long-run trends in the UK economy that are projected by the macro model. Further, the regional results also provide a ranking of growth prospects across the UK regions. This ranking can provide policy makers with a view on where economic policy changes might be focussed to reduce the largest disparities in regional outcomes.

2. The NiGEM model

The NiGEM[1] model represents the world economy. It contains 46 countries and 7 regional groupings. Most OECD countries are modelled individually. There is a common underlying structure across all economies; this structure is estimated and calibrated. The model's long-run is neoclassical. Expectations can be characterised as forward looking, rational or adaptive learning. The country models have a comprehensive representation of the demand and supply side, and asset structures. Most behavioural equations are estimated in error-correction form.

Expenditure-side GDP is defined as the familiar national accounts identity $GDP = C + I + G + X - M$. In the short to medium run the model is Keynesian and GDP is demand driven. In the long run GDP is supply-side driven and related to potential output (Y^P)

$$Y_t^P = \gamma \left\{ [\beta K_t^{-\rho} + (1-\beta) L_t^{-\rho}]^{-1/\rho} \right\}^{(1-\alpha)} M_t^{\alpha}. \quad (1)$$

Thus, production is represented by CES technology applying capital (K) and effective labour (L) where $\sigma = 1/(1+\rho)$ is the elasticity of substitution between labour and capital. The capital-labour composite is combined with oil (M) by a Cobb-Douglas production function with α as the share parameter for oil: thus, the elasticity of substitution between the labour-capital composite and oil is one. Effective labour equals actual labour (N) adjusted for labour productivity (LP) and the speed of

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adjustment per period towards the long-run (λ): $L = Ne^{\lambda LP}$.

The first-order condition for labour defines labour demand as

$$\ln(L_t / Q_t) = \vartheta - \sigma \ln(W_t / P_t) - (1-\sigma)\lambda LP, \quad (2)$$

where Q_t is total primary factor usage, and P_t is the primary factor price index, being a CES aggregate of the rental price of capital R_t and the effective wage rate W_t/P_t.

The first-order condition for capital defines the equilibrium capital-output ratio (K_t/Q_t) as a function of the effective user cost of capital $U_t = (R_t/P_t)$:

$$\ln(K_t / Q_t) = \eta - \sigma \ln U_t. \quad (3)$$

The user cost of capital includes corporate taxes, depreciation and risk premia. It is a weighted average of the cost of equity finance and the long real interest rate. The supply of capital evolves as

$$K_t = (1-\delta)K_{t-1} + I_t, \quad (4)$$

where δ is geometric rate of depreciation. As full capacity utilisation is not assumed, business investment is determined by the relationship between actual and equilibrium capital stocks, which is of error correction form.

Unit total cost is a function of the prices of labour, capital and oil. The wage rate is a function of unit total cost and the unemployment rate, which acts as a proxy for bargaining power for workers. Short-term wage dynamics depend on a weighted average of expected and current inflation.

Capacity utilisation (Y/Y^P) drives producer prices so that full capacity utilisation is achieved over time. Consumer prices are a mark-up on unit total costs and import prices, adjusted for the indirect tax rate.

Consumption follows a dynamic adjustment path around real household disposable income ($RHDI$) and the sum of real housing wealth (RHW) and real financial wealth (RFW):

$$\ln C = \phi + \beta \ln RHDI + (1-\beta)\ln(RFW + RHW). \quad (5)$$

Each country has a stock of foreign assets and liabilities. These are linked to the stock of domestic financial assets and the stock of domestic private sector and public sector liabilities. A proportion of government debt is owned abroad, as are proportions of the national stock of equities and the stock of banking assets. Some national financial wealth is held in foreign equities and bonds as well as banks. Income flows from asset stocks are allocated in relation to ownership, and hence net property income from abroad depends on income receipts and payments on bonds, equity holdings and banks. Once model and judgement-based forecasts for asset prices, exchange rates and interest rates have been made, the forecast for wealth follows automatically. The wealth and accumulation system allows for flows of saving into wealth and for revaluations of existing stocks of assets in line with their prices determined as above. When foreign equity and bond prices change, domestically held assets change in value.

The government sector is represented as raising direct and indirect taxes, undertaking consumption spending and making interest payments. A tax rule is imposed that ensures long-run solvency. Government consumption and investment have an exogenous component and an endogenous component. The endogenous component is linked to Y^P. The exogenous component dominates.

Exports are a function of external market size (S) and relative export prices (PX/APX)

$$X = \mu + S + \kappa(PX / APX). \quad (6)$$

where PX represents export prices and APX is the weighted average of competitor export prices. Imports are a function of total final expenditure (TFE) and relative import prices (CP/APM)

$$M = \psi + \upsilon TFE + \omega(CP / APM), \quad (7)$$

where CP represents consumer prices and APM is the weighted average of export prices in import source countries.

Long-term interest rates (i_t^L) are related to expected future short-term interest rates (i_t)

$$1 + i_t^L = \prod\nolimits_{t=1}^{T}(1 + i_{t+j}). \quad (8)$$

Equity prices (EQP) reflect the present discounted value of expected profits (PR), including an equity risk premium (RP)

$$EQP_t = \frac{EQP_{t+1}}{1+i_t} + PR_t(1 + RP_t). \quad (9)$$

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Exchange rates (ER) are forward-looking and reflect an uncovered interest parity condition:

$$ER_t = ER_{t+1} + \left(\frac{1+i_t^*}{1+i_t}\right)(1+RP_t), \tag{10}$$

where i_t^* is the short-term interest rate abroad.

Short-term interest rates are determined by monetary policy rules. The standard treatment is to target a combination of inflation and a nominal aggregate:

$$i_t = \upsilon(\inf_t - \inf t_t) + (1-\upsilon)(GDPN_t - GDPNT_t), \tag{11}$$

where inf_t and $inft_t$ are the actual and target inflation rate, and $GDPN_t$ and $GDPNT_t$ are actual and target nominal GDP.

3. The regional model

UK-SCGE is a spatial computable general equilibrium model of the United Kingdom that we apply to determine how the NiGEM forecast is distributed across the UK. The model represents 109 regions of the UK – 86 in England, 9 in Scotland, 13 in Wales, and Northern Ireland – as separate economies linked by inter-regional trade flows.[2] Figure 1 shows a geographic breakdown of the regions. The regions represent Housing Market Areas that reflect "…the optimal areas within which planning for housing should be carried out" (Jones *et al.*, 2010).[3]

UK-SCGE is a dynamic model. The baseline simulation is designed to move the economy from an initial steady-state along a balanced growth path to a new steady-state. The policy simulation quantifies deviations of variables from their baseline values caused by the simulated policy change. The differences in the values of variables in the baseline and policy simulations quantify the effects of moving the variables of interest away from their baseline values.

UK-SCGE distinguishes 105 sectors and commodities based on the 2013 input-output (IO) tables published by ONS (2016). Primary factors are distinguished by 105 types of capital (one type per industry), 9 occupations and 2 types of land. The national IO table is disaggregated into regional IO tables using a combination of industry shares in employment or labour hours and commodity-specific consumption shares to split industries, investment, and government and private consumption across regions. This approach to deriving regional IO data is characterised as a hybrid method by Miller and Blair (2009). It most closely resembles the GRIT (Generation of Regional Input–Output Tables) technique; see, for example, West (1990).

A representative firm in each sector produces a single commodity. Some commodities produced for use in the domestic market are divided into a margin and non-margin component. The margin component of a commodity is used to facilitate the movement and sale of both imported and domestic commodities within the UK, and of the exported commodities to the point of exportation; EU and non-EU export destinations are distinguished. Margin commodities include such activities as the various modes of transportation, and

Figure 1. The 109 regions in UK-SCGE

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wholesale and retail trade. The non-margin component is used as a direct input into industry activity, investment and government or private consumption across all regions.

Production technology is represented by nested CES and CRESH functions (Hanoch, 1971) allowing a high degree of flexibility in the parameterisation of substitution and technology parameters. The supply of labour within each region is determined by a labour-leisure trade-off that allows workers in each occupation to respond to changes in after-tax wage rates thus determining the hours of work they offer to the labour market. The overall supply of labour is normalised on working-age population, which typically moves with population.

Household consumption decisions are determined by a Stone-Geary utility function (Stone, 1954) that distinguishes between subsistence (necessity) and discretionary (luxury) consumption.

UK-SCGE has detailed central and local government fiscal accounts, including the accumulation of public assets and liabilities. Government revenue is represented by direct and indirect taxes, and income from government enterprises. Government expenditure is represented by government consumption, investment and payments of various types of transfers (such as pensions and unemployment benefits).

Investment behaviour is industry specific and is positively related to the rate of return on capital. This rate incorporates into council taxes on housing and business rates on non-dwellings.

Foreign asset and liability accumulation is represented at the national level, as are the cross-border income flows they generate and that contribute to the evolution of the current account. Other foreign income flows, such as labour payments and unrequited transfers, are also represented giving a complete representation of primary and secondary income flows in the current account.

The following sections provide a formal presentation of those parts of the model important for understanding the analysis in the latter sections.

3.1 Production technology

Within each region, a representative firm in each sector produces a single commodity.[4] Two broad categories of inputs are recognised: intermediate inputs and primary factors. Representative firms choose inputs of primary factors and intermediate inputs to minimise costs subject to a given production technology and given factor and commodity prices. Primary factors include two types of land, nine types of labour (occupations)[5] and physical capital. Intermediate inputs potentially consist of 105 domestically-produced goods and services, each with a foreign substitute.[6] Demands for primary factors and intermediate inputs are modelled using nested production functions. The nested production functions have three tiers.

At the top level, industry i's activity Q_i^{ACT} is determined as a Leontief combination of the intermediate input composite Q_{*i}^{INT} and the primary factor composite Q_{*i}^{FAC} :

$$Q_i^{ACT} = \min\left[\frac{Q_{\bullet i}^{INT}}{A_{\bullet i}^{INT}}, \frac{Q_{\bullet i}^{FAC}}{A_{\bullet i}^{FAC}}\right] \qquad (12)$$

where the A variables represent unit input requirements.

At the second level of the production nest firms choose the optimal mix of the c individual intermediate inputs Q_{ci}^{INT} using CRESH (constant ratios of elasticities of substitution, homothetic):

$$\sum_c \left[\frac{Q_{ci}^{INT}}{Q_i^{ACT}\ A_{ci}^{INT}}\right]^{h_c} \frac{X_c}{h_c} = \alpha, \qquad (13)$$
$$0 < h_c < 1, X_c > 0, \sum_c X_c = 1, \alpha > 0,$$

where X_c, h_c and α are parameters and the A variables represent unit input requirements. The CRESH formulation is due to Hanoch (1971) and it relaxes the assumption implied by CES functions that the elasticity of substitution between all pairs of inputs must be the same. Thus, the elasticity of substitution between inputs i and j is

$$\sigma_i / \sigma_j / \sum_{k=1}^{105} S_k \sigma_k$$

where $\sigma_i = 1/1{-}h_i$ is the CRESH parameter associated with input i and S_k is the k^{th} input's cost share. In the special case when all σ_i have the same value, the CRESH system is equivalent to CES and all substitution elasticities are equal.

At the second level of the production nest firms also choose the optimal mix of the f individual primary factors Q_{fi}^{FAC} using CES production technology:

$$Q_{\bullet i}^{FAC}\left[\sum_f \chi_f \left(\frac{Q_{fi}^{FAC}}{A_{fi}^{FAC}}\right)^{-\rho}\right]^{-1/\rho}, \qquad (14)$$
$$0 < \chi_f < 1, \sum_f \chi_f = 1, \rho \geq 1, \rho \neq 0.$$

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where χ_f and ρ are parameters and the A variables represent unit input requirements. The CES elasticity of substitution is $\sigma = 1/(1+\rho)$.

At the third level of the production nest, the composition of each commodity, land and labour are determined, by firms minimising costs subject to the constraints that:

(i) each commodity is a CES composite of a domestic and imported variety;

(ii) land is a CES composite of primary-production land and non-primary production land; and

(iii)labour is a CES composite of nine skill types (that is, broad occupational categories).

3.2 Zero-pure profits and market-clearing conditions

Within each region, all firms are assumed to operate in competitive markets and thus take their output prices as given. Consistent with this, we impose a zero-pure-profits condition that equates revenues with costs and determines each industry's activity level or output:

$$P_{ir}Q_{ir}^{ACT} = \sum_c P_{cir}^{INT}Q_{cir}^{INT} + \sum_f P_{fir}^{FAC}Q_{fir}^{FAC}. \quad (15)$$

In (15) the left-hand side is revenue for industry i in region r; the right-hand side is the sum of intermediate input and primary factor costs for industry i in region r.

Output prices of domestically-produced commodities are determined by a market-clearing condition that equates the quantity of each commodity supplied to a region with the total quantity of the commodity demanded by all users within the region. The same type of market-clearing condition applies to the imported varieties of each commodity by region of use. Note that imports are distinguished between those from EU and non-EU sources. The market-clearing condition is expressed as:

$$Q_{csd}^{USE} = \sum_u Q_{csud}^{USE}, \quad s = domestic, imported, \quad (16)$$

where Q_{csud}^{USE} is the quantity of commodity c from source s used by user u in region d and Q_{csd}^{USE} is the quantity of commodity c from source s supplied to region d. Q_{csd}^{USE} is a CES composite, across all r supplying regions, of Q_{csrd}^{DEL}, the delivered supply of commodity c from source s produced or landed in region r and delivered to region d.

There is also a market-clearing condition for margins that requires

$$\sum_p Q_{mrdp}^{SUPMAR} = \sum_{cs} Q_{csmrd}^{MAR}, \quad s = domestic, imported, \quad (17)$$

where Q_{mrdp}^{SUPMAR} is the supply of margin m produced in region p and used to facilitate the trade in goods and services from region r to region d, and Q_{csmrd}^{MAR} is the quantity of margin m used to facilitate the trade in commodity c from source s to destination d.

The treatment of interregional trade embodied in equations and builds on the innovative approach developed by Horridge (2011). The two matrices that calibrate these equations are constructed by disaggregating national IO data across regions using production shares and consumption shares at the most detailed regional level available and then grossed up to the 109 regions applied in the model database.[7] Once the initial regional disaggregation is completed, a modified gravity formula is applied to determine trade across regions in a way that is consistent with each region's implied excess demand by commodity. The trade totals and the gravity-formula-derived trade matrices are then reconciled using a matrix balancing algorithm (the RAS procedure).

3.3 Primary factor supplies

Two types of land are distinguished within each region: primary production and non-primary production land. Primary production land is used only by the agricultural and mining industries. Non-primary production land consists of commercial land and residential land. Non-primary production land used by the dwellings sector represents residential land; non-primary production land used by all other sectors represents commercial land. In a baseline simulation (see section 5.2) land supply grows at the 30-year average GDP growth rate; in a policy simulation (see section 6) the supply of each type of land is fixed. For a given supply of the land type l, movements across the i industries are governed by a CRETH (constant ratio of elasticities of transformation, homothetic) function due to Vincent *et al.* (1980):

$$\sum_i \left[\frac{Q_{li}^{LND}}{Q_l^{LND}\ A_{li}^{LND}} \right]^{h_i} \frac{V_i}{h_i} = \beta, \quad (18)$$
$$h_i > 1, V_i > 0, \sum_i V_i = 1, \beta > 0,$$

where V_i, h_i and β are parameters, and Q_l^{LND} is the supply of land type l and A represents unit input requirements. The CRETH functional form is identical to the CRESH form except for the restrictions on m_i; the CRESH form requires $0 < h_c < 1$ whereas the CRETH form requires $h_i > 1$.

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Nine labour types are distinguished in each region, the supplies of which Q_n^{LAB} (n = 1,...,9) are determined by an infinitely-lived representative household based on a labour-leisure trade-off that allows workers in each occupation to respond to changes in real post-income-tax wage rates RW_n. This gives upward-sloping labour supply curves for industries and occupations:

$$\frac{Q_n^{LAB}}{POP} = (RW_n)^{\sigma}\Gamma_b, \tag{19}$$

where σ is the uncompensated labour supply elasticity. There is a similarly defined labour supply function at the national level. At the national level the elasticity of labour supply is set at 0.15 reflecting econometric evidence for the UK (Bargain *et al.*, 2011). At the regional level the labour supply elasticity is set at 0.5 to reflect limited interregional mobility of labour types. The divergent assumptions on regional and national labour supply responsiveness are reconciled by movements in Γ_n.

Each industry uses capital specific to its own production process. Thus, the supply of an industry's capital stock available for use in year t is of similar form to NiGEM but is specified by industry. This representation of capital accumulation assumes that there is a one year gestation lag between investment by firms and an increment to the capital available for use by firms.

5. Regional growth prospects

Here we describe the central macroeconomic scenario over the medium term. We then describe the regional outcomes conditional on this macroeconomic scenario.

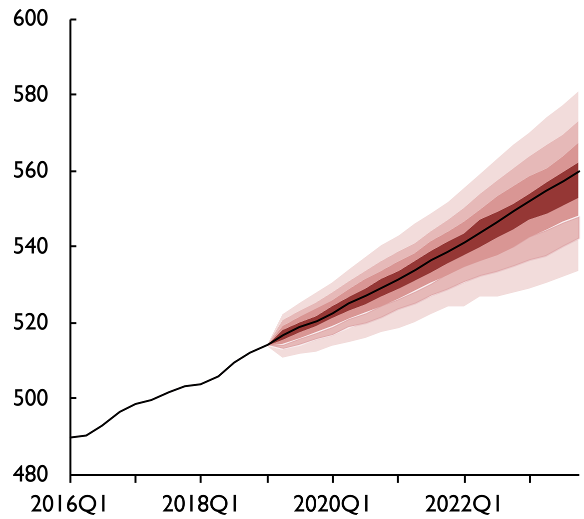
5.1 The macroeconomic scenario

The macro scenario used for this analysis is the NIESR November 2018 central forecast discussed in Hantzsche *et al.* (2018). It is conditional on a 'soft' Brexit, broadly an assumption that the UK would trade on similar terms with the EU after Brexit as it had when it was an EU member. At the time this was a possible outcome and a useful assumption for forecasting purposes and scenario analysis. NIESR analysed other possible scenarios against the soft-Brexit benchmark in, for example, Hantzsche *et al.* (2019).

There is much uncertainty around this central scenario due partly to the unresolved nature of the future relationship between the UK and the EU. The short-term uncertainty is illustrated in figure 2 by a fan chart for UK GDP showing 'standard' macroeconomic risks. The fan is constructed so that there is an 80 per cent chance that future outcomes for GDP lie within the fan. Unusual risks, such as COVID-19, are ever-present and reflected in the 20 per cent chance that GDP lies outside of the fan.

Under this central scenario the UK government is able to comply with the fiscal mandate but it is not able to

Figure 2. GDP per quarter (£bn, 2016 prices)



Note: The fan-chart is intended to represent the uncertainty around the central forecast. There is a 10 per cent chance that GDP in any particular quarter will lie within any given shaded band in the chart. There is a 20 per cent chance that GDP will lie outside the shaded area of the fan.

Table 1. Macro forecasts (average annual growth rates)

	2021–30	2031–40	2040–44
Household consumption	1.66	2.02	2.08
Investment	1.79	1.23	1.68
Government consumption	2.22	1.89	1.90
Exports	1.83	1.12	1.89
Imports	1.58	2.31	2.19
GDP	1.86	1.51	1.89
Capital	2.07	1.68	1.58
Labour hours	0.39	0.36	0.43
Labour productivity	1.47	1.08	1.43
Employment	0.39	0.37	0.44
Labour supply	0.48	0.45	0.44
Population	0.46	0.33	0.29
Real wage	1.68	1.81	1.47
GDP deflator	2.03	2.35	2.09
CPI	1.97	1.82	1.97
Export price index	2.16	2.08	2.07
Import price index	2.35	0.64	1.64
PSBR (% of GDP)	–0.026	–0.020	–0.017
Current account (% of GDP)	–0.019	–0.025	–0.019

Note: All figures are percentage changes unless otherwise stated. PSBR = Public Sector Borrowing Requirement.

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Figure 3. GDP expenditure components

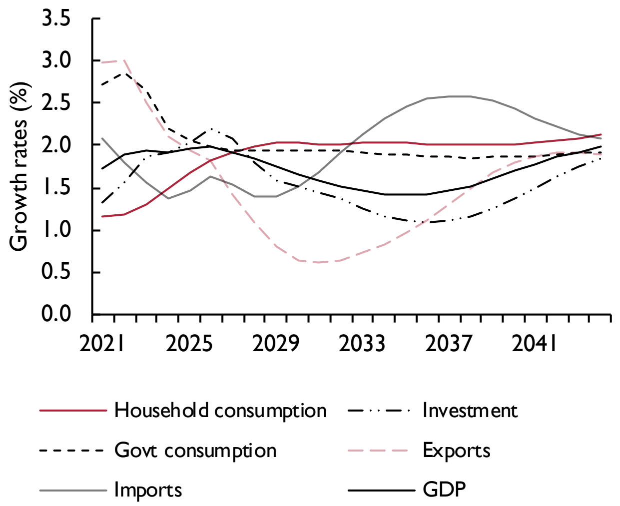
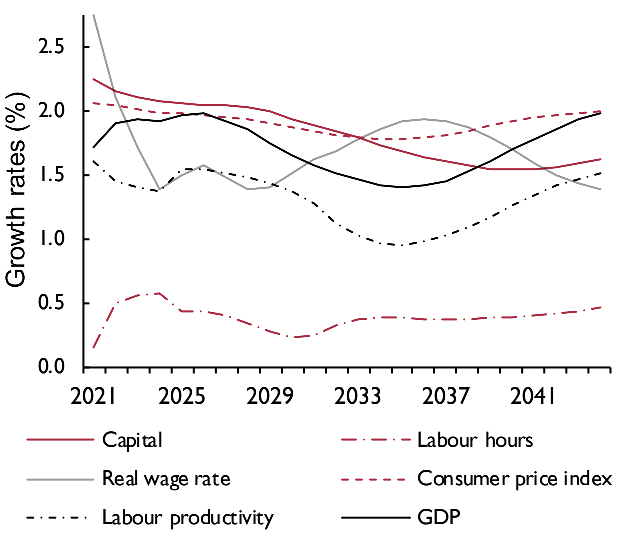


Figure 4. GDP income components



achieve its medium-term objective to balance the budget unless it chooses to tax more. The details of the forecast appear in table 1. Figures 3 and 4 present the time path of the forecast variables in the central scenario.

The fiscal central scenario faces a number of other risks. If population ageing was faster than is currently expected, spending requirements would be higher. External shocks due to global trade tensions would affect spending requirements and the revenue base, and might increase borrowing costs if risk premia rose. Higher than forecast productivity growth would improve the long-term fiscal outlook.

The assumptions on the path of economywide productivity growth are independent of Brexit. The central scenario reflects ten years of low productivity performance and hourly productivity growth is assumed to be just under 1.5 per cent per annum. Labour productivity continues to recover very gradually some of the losses made since the financial crisis but given the lack of clarity about future trading relationships with the EU, the outlook remains uncertain in the short and medium term. The annual growth rate of output per hour is forecast to stabilise at around 1.5 per cent in the medium term.

The central scenario assumes that the UK population grows according to principal projections provided by the Office for National Statistics. These imply a fall in net migration to around 200,000 people per year in the medium term.

The central scenario assumes that the household saving rate will begin to rise over the medium term towards its long-run average and that the corporate saving to GDP ratio remains around 9 per cent in the medium term. Corporate investment remains at about 10 per cent of GDP in the medium term.

5.2 The regional picture

Applying the macro forecast to UK-SCGE allows us to generate long-run results for the 109 regions as presented in table 2, column 5.[8] Aggregating these results to the four countries indicates the degree of divergence across broad parts of the UK. Figure 4 shows that country output growth diverges little across the forecast horizon. The only noticeable feature is that Scotland grows noticeably faster over the periods 2020–24 and 2033–41. In terms of average annual growth, Scotland leads with 1.78 per cent, followed by England and Northern Ireland at 1.71 per cent and 1.72, and then Wales at 1.70 per cent. These growth rates translate into cumulative changes of 55.7 per cent (England), 55.2 per cent (Wales), 58.4 per cent (Scotland) and 56.10 per cent (Northern Ireland) over the forecast period.

There are four major drivers of GDP growth in the NiGEM forecast: labour productivity, housing investment, business investment and export prices. Figure 5 presents the GDP outcomes when we apply each of these drivers individually. This gives an indication of the importance of each driver to the overall GDP

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Figure 5. Country GDP

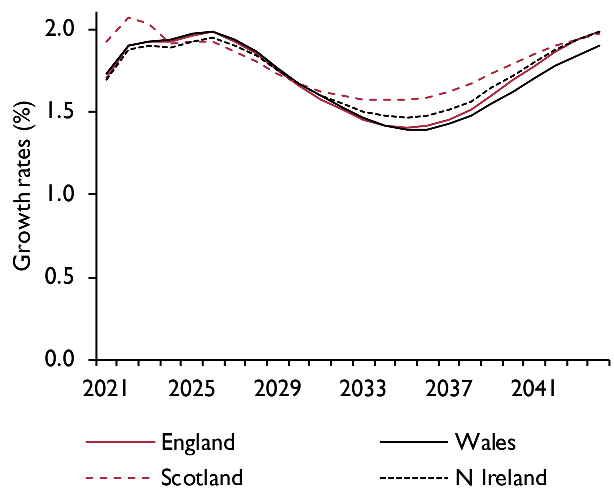
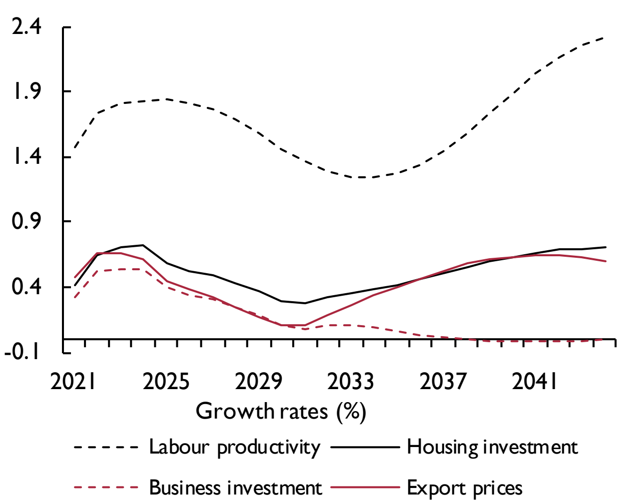


Figure 6. Decomposition of GDP



outcome. Labour productivity is the most important driver of GDP growth over the forecast horizon. The other drivers are much less important; of these, housing investment and export prices are the most important. Business investment makes the smallest contribution of the four drivers, and in the second half of the horizon makes almost no contribution to GDP.

The weak contribution of business investment to GDP growth reflects the slow growth in business investment relative to GDP growth over the forecast horizon: see figure 3. Business investment averages 1.43 per cent growth compared with 1.71 per cent for GDP. By contrast, housing investment is the second most important contributor to GDP growth: it averages 2.52 per cent. Growth in total investment (business, private and government) averages 1.62 per cent over the forecast horizon. The weak contribution of business investment to GDP growth reflects the longer-run effects of Brexit where risk premia are expected to be higher than otherwise.

Relative export prices make a strong positive contribution over the first and last third of the forecast horizon. These movements reflect movements in the exchange rate and import prices in export destinations. Initially, higher export prices reflect the expected depreciation of the exchange rate due to the uncertainties related to Brexit. The depreciation dissipates by 2025, after which the movements in export prices mainly reflect price movements in export destinations.

5.3 The fastest and slowest growing regions

In a model with 109 regions there is a major challenge to understand what determines the differences in growth rates across regions. Inspection of table 2 reveals that the fastest growing region is Pembrokeshire (south-west Wales) with average growth of 2.17 per cent and the slowest growing region is Cambridge (east England) with average growth of 1.64 per cent. We can present a decomposition of the four major drivers of GDP growth (similar to figure 6) for all regions. This is done in figure 7. Due to the clustering of growth rates it is difficult to discern strong patterns in figure 7. One discernible pattern is that labour productivity is the largest contributor to GDP growth for all regions; other patterns are less clear.

To aid in revealing more patterns requires that the results are filtered to some extent. In figure 8 we present the results for the five fastest and five slowest growing regions. The five fastest growing regions are Pembrokeshire (south-west Wales) 2.17 per cent, North Lincolnshire (east England) 2.11 per cent, Allerdale (north-west England) 1.91 per cent, Cheshire West (north-west England) 1.90 per cent, North East Lincolnshire (east England) 1.86 per cent. The five fastest slowing regions are Boston (east England) 1.67 per cent, East Dunbartonshire (west central Scotland) 1.66 per cent, Guildford (south England) 1.66 per cent, Barrow-in-Furness (north-west England) 1.66 per cent, and Cambridge (east England) 1.64 per cent.

Figure 8 confirms that although the average growth rate between the five fastest and five slowest growing

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Table 2. Regional GDP outcomes: decomposition (average annual growth rates)

	(1)	(2)	(3)	(4)	(5)
National	*1.66*	*0.53*	*0.20*	*0.47*	*1.72*
1. Dudley	1.59	0.57	0.31	0.52	1.76
2. Birmingham	1.64	0.51	0.18	0.44	1.73
3. Cannock Chase	1.63	0.61	0.30	0.55	1.77
4. Babergh	1.69	0.32	0.20	0.42	1.75
5. Aberdeen	2.12	1.05	0.68	1.12	1.80
6. Scottish Borders	1.61	0.51	0.18	0.41	1.68
7. Dumfries Galloway	1.62	0.44	0.25	0.43	1.69
8. Angus	1.62	0.48	0.17	0.43	1.68
9. Fife	1.66	0.46	0.20	0.45	1.68
10. Eilean Siar	1.70	0.60	0.21	0.52	1.68
11. Perth & Kinross	1.63	0.53	0.15	0.43	1.68
12. Clackmannanshire	1.84	0.67	0.30	0.63	1.73
13. East Lothian	1.76	0.50	0.14	0.48	1.69
14. East Dunbartonshire	1.64	0.50	0.10	0.41	1.66
15. East Ayrshire	1.60	0.49	0.25	0.43	1.68
16. London	1.68	0.50	0.08	0.34	1.69
17. Southend-on-Sea	1.60	0.50	0.12	0.38	1.72
18. Medway	1.65	0.60	0.19	0.47	1.74
19. Mole Valley	1.80	0.53	0.12	0.46	1.69
20. Guildford	1.67	0.35	-0.04	0.30	1.66
21. Dacorum	1.66	0.47	0.02	0.35	1.70
22. East Hertfordshire	1.65	0.52	0.13	0.43	1.72
23. Stoke-on-Trent	1.58	0.59	0.30	0.55	1.78
24. Charnwood	1.67	0.45	0.19	0.45	1.70
25. East Staffordshire	1.56	0.65	0.28	0.48	1.75
26. Cheshire East	1.74	0.40	0.10	0.42	1.71
27. Derby	1.64	0.49	0.22	0.47	1.74
28. Leicester	1.62	0.52	0.21	0.44	1.71
29. Carlisle	1.59	0.66	0.30	0.51	1.75
30. Manchester	1.65	0.53	0.21	0.47	1.71
31. Halton	1.64	0.53	0.24	0.50	1.75
32. Cheshire West and Chester	1.64	0.48	0.28	0.68	1.90
33. Barnsley	1.62	0.51	0.20	0.44	1.70
34. Doncaster	1.59	0.54	0.26	0.49	1.71
35. Coventry	1.64	0.47	0.17	0.46	1.74
36. Bradford	1.66	0.55	0.29	0.50	1.74
37. Hartlepool	1.68	0.69	0.37	0.67	1.82
38. Blackburn with Darwen	1.65	0.49	0.29	0.50	1.73
39. Blackpool	1.63	0.59	0.29	0.55	1.75
40. East Riding of Yorshire	1.63	0.60	0.32	0.55	1.76
41. York	1.61	0.54	0.21	0.46	1.68
42. North East Lincolnshire	1.71	0.38	0.31	0.57	1.89
43. North Lincolnshire	1.59	0.40	0.26	0.89	2.11
44. Rutland	1.64	0.49	0.21	0.44	1.68
45. Nottingham	1.58	0.50	0.21	0.44	1.70
46. Herefordshire	1.60	0.61	0.27	0.50	1.75
47. Cheltenham	1.67	0.48	0.17	0.45	1.72
48. Telford and Wrekin	1.68	0.56	0.26	0.53	1.75
49. Bath and North East Somerset	1.63	0.54	0.17	0.45	1.73
50. Bristol	1.69	0.52	0.14	0.44	1.70
51. Plymouth	1.55	0.51	0.26	0.45	1.69
52. Torbay	1.54	0.62	0.28	0.50	1.71
53. Bournemouth	1.63	0.55	0.21	0.44	1.72
54. Swindon	1.73	0.52	0.17	0.48	1.72
55. Bedford	1.66	0.43	0.11	0.40	1.70
56. Brighton and Hove	1.71	0.54	0.17	0.47	1.73
57. Portsmouth	1.63	0.49	0.17	0.42	1.72
58. Southampton	1.68	0.39	0.09	0.41	1.73
59. Isle of Wight	1.56	0.47	0.21	0.40	1.73
60. Isle of Anglesey	1.77	0.38	0.41	0.56	1.80
61. Gwynedd	1.65	0.99	0.77	0.93	1.75
62. Ceredigion	1.66	0.90	0.69	0.86	1.74
63. Conwy	1.63	1.01	0.79	0.95	1.76
64. Shropshire	1.58	0.70	0.29	0.56	1.78
65. Carmarthenshire	1.69	0.86	0.67	0.85	1.77
66. Powys	1.67	0.87	0.68	0.84	1.75
67. Blaenau Gwent	1.73	0.80	0.60	0.79	1.76
68. Pembrokeshire	1.66	0.51	0.44	0.99	2.17
69. Bridgend	1.76	0.80	0.60	0.80	1.75
70. Cambridgeshire	1.62	0.35	0.03	0.31	1.64
71. Cherwell	1.66	0.43	0.01	0.36	1.68
72. King's Lynn and West Norfolk	1.55	0.65	0.30	0.48	1.75
73. Cornwall	1.53	0.63	0.32	0.51	1.71
74. Isles of Scilly	1.62	0.64	0.23	0.50	1.86
75. Allerdale	1.65	0.53	0.30	0.72	1.91
76. Eden	1.63	0.56	0.34	0.53	1.69
77. Barrow-in-Furness	1.62	0.30	0.23	0.36	1.66
78. South Lakeland	1.65	0.57	0.29	0.51	1.71
79. Lancaster	1.70	0.68	0.41	0.68	1.73
80. East Devon	1.57	0.65	0.22	0.48	1.73
81. Sedgemoor	1.57	0.54	0.26	0.46	1.68
82. North Devon	1.64	0.58	0.26	0.50	1.72
83. South Somerset	1.63	0.49	0.23	0.46	1.73
84. West Dorset	1.56	0.57	0.25	0.46	1.70
85. Eastbourne	1.56	0.53	0.18	0.40	1.72
86. Braintree	1.62	0.59	0.21	0.47	1.75
87. Malvern Hills	1.61	0.63	0.22	0.49	1.77
88. Ashford	1.57	0.48	0.18	0.40	1.69
89. Canterbury	1.63	0.32	0.20	0.42	1.76
90. Lincoln	1.61	0.55	0.28	0.50	1.71
91. Boston	1.59	0.46	0.30	0.45	1.67
92. East Lindsey	1.52	0.53	0.36	0.51	1.69
93. Breckland	1.66	0.51	0.23	0.46	1.69
94. Forest Heath	1.65	0.50	0.17	0.45	1.70
95. Great Yarmouth	1.63	0.47	0.26	0.46	1.68
96. Corby	1.61	0.50	0.20	0.44	1.72
97. Hambleton	1.65	0.60	0.30	0.54	1.71
98. Ryedale	1.69	0.51	0.18	0.48	1.72
99. Scarborough	1.58	0.63	0.39	0.58	1.72
100. Argyll & Bute	1.68	0.58	0.20	0.50	1.71
101. County Durham	1.61	0.65	0.38	0.59	1.77
102. Gateshead	1.62	0.54	0.24	0.49	1.73
103. Inverclyde	1.63	0.53	0.21	0.46	1.73
104. Hillingdon	1.67	0.40	0.07	0.38	1.70
105. Stratford-on-Avon	1.73	0.59	0.22	0.60	1.85
106. Sunderland	1.69	0.61	0.34	0.61	1.81
107. Bracknell Forest	1.71	0.40	0.02	0.39	1.69
108. Northumberland	1.59	0.69	0.41	0.60	1.75
109. Northern Ireland	1.65	0.54	0.27	0.52	1.73

Note: Key to columns – (1) = Labour productivity; (2) = Housing investment; (3) = Business investment; (4) = Export price; (5) = Total.

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Figure 7. Decomposition of GDP: all regions

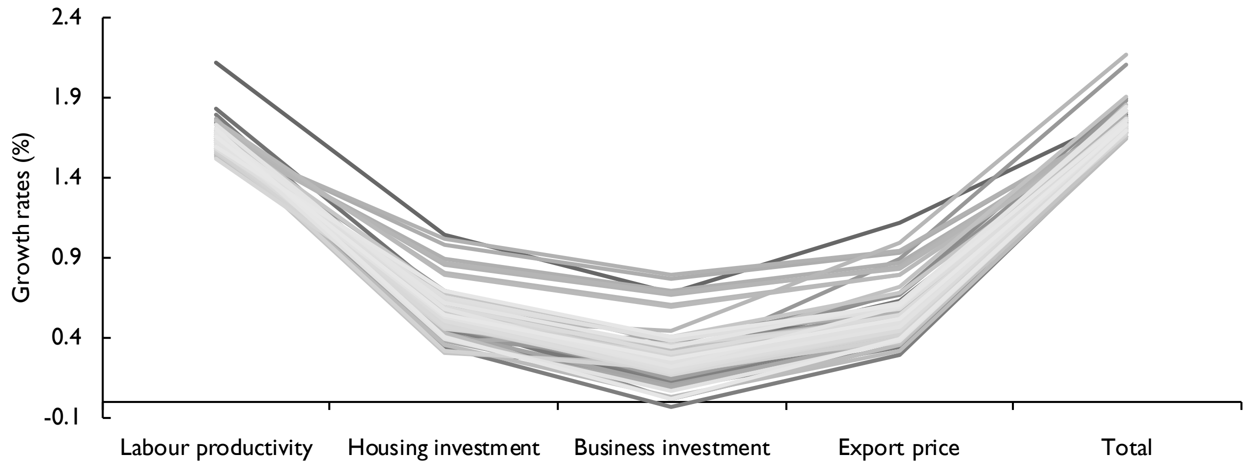
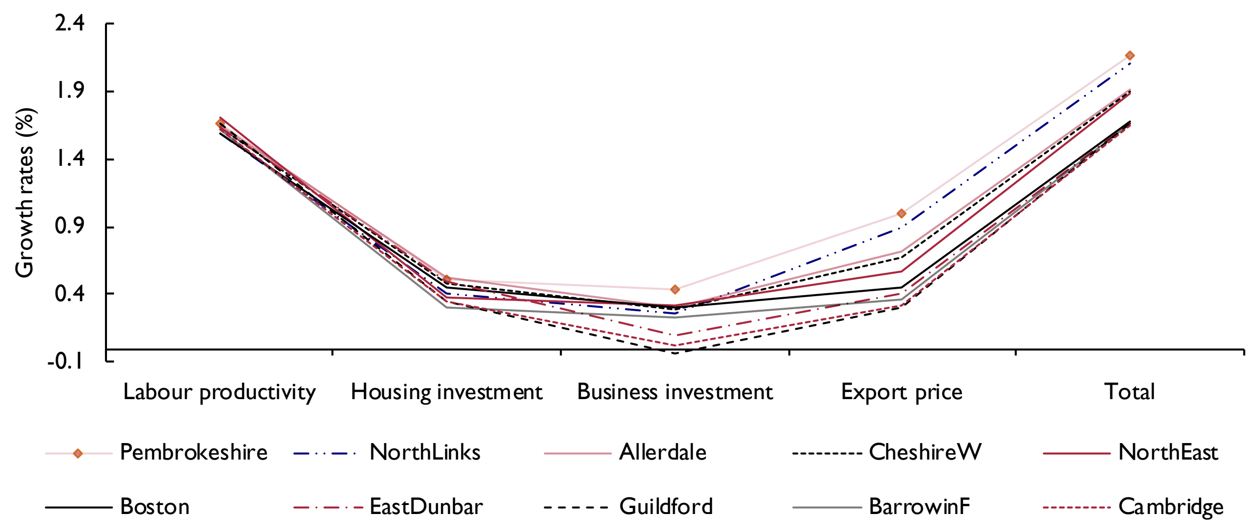


Figure 8. Decomposition of GDP: 5 fastest and 5 slowest growing regions



regions varies from 2.17 per cent to 1.64 per cent, labour productivity makes an almost identical contribution to GDP growth for each of these regions. While housing investment is a much less important contributor than labour productivity, nevertheless its contribution is also very even across these ten regions. The largest variation in GDP contributions is seen for business investment and export prices.

The contribution of export prices reflects the importance of international trade in each regional economy. Pembrokeshire, North East Lincolnshire and North Lincolnshire have very high trade shares in GDP (ranging from 70 per cent to 370 per cent). Exports and output in these regions are dominated by manufactures: some of the most important manufactures are oil refining in Pembrokeshire and North Lincolnshire, and basic chemicals, fertilisers and plastics in North East Lincolnshire. The importance of these industries in each of these regions means there are large output multipliers from international exports of these products. In contrast, Guildford, Barrow-in-Furness and Cambridge have

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much lower trade shares (ranging from 7 per cent to 30 per cent). Thus, Pembrokeshire, North East Lincolnshire and North Lincolnshire benefit strongly from higher export prices whereas Guildford, Barrow-in-Furness and Cambridge do not.

Housing investment makes a similar contribution to GDP for the five fastest and five slowest growing regions. By contrast, the contribution of business investment varies significantly between these two groups of regions. Nationally, housing and business investment comprise 3 per cent and 17 per cent of GDP. All other things being equal, a given growth rate in housing investment will be much less important in determining output growth for a region than a given growth rate in business investment. Thus, we observe that variations in the importance of business investment in a region reflect differences in growth rates across these two groups of regions. That is, the fastest growing regions have business investment shares less than average and the slowest growing regions have business investment shares above average.

6. A government expenditure shock

Having generated long-run results for the 109 regions we now impose a deviation around this baseline to demonstrate the policy behaviour of the regional model. We impose a permanent 10 per cent increase in central and local government consumption expenditure in all regions over 2019–20. The increased government consumption is initially financed by government borrowing, thus allowing the government budget to deteriorate. From 2021 onwards the income tax rate slowly rises to restore the government budget as a share of GDP to baseline levels. Note that the current account as a share of GDP is held at baseline levels via an endogenous household saving rate.

6.1 National effects

During the expansion in government consumption the budget balance deteriorates by 2.5 percentage points of GDP (figure 9). From 2021 the income tax rate rises at a decreasing rate until the baseline budget-to-GDP ratio is approximately restored in 2034. The macroeconomic effects of these changes are shown in figures 10 and 11. In imposing the increase in government consumption over 2019–20 we apply a modified version of the NIGEM wage equation for the UK:

$$\ln W_t = \ln W_{t-1} + \upsilon labhrs_t + \ln(CPI_t / CPI_{t-1}) - \psi UNR_{t-1}, \quad (20)$$

where *W* is the wage rate, *labhrs* is labour hours, *CPI* is the consumer price index and *UNR* the unemployment rate. υ and ψ are NIGEM parameters multiplied by four to approximate annual dynamics.

In the standard model treatment occupational wage rates are determined by market clearing by assuming fixed occupational unemployment rates. In contrast, equation (20) allows the aggregate wage rate to rise more slowly in response to the increase in government consumption compared to standard model treatment. We expect the aggregate wage rate to rise as government consumption is dominated by three labour-intensive services: health,

Figure 9. Budget balance and income tax rate

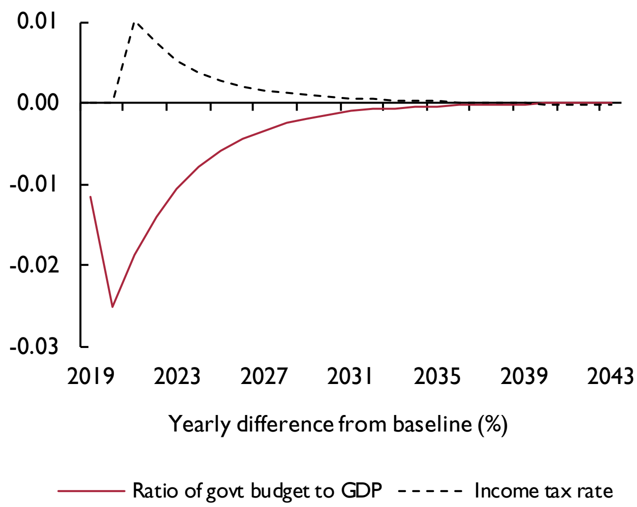

Figure 10. GDP income components

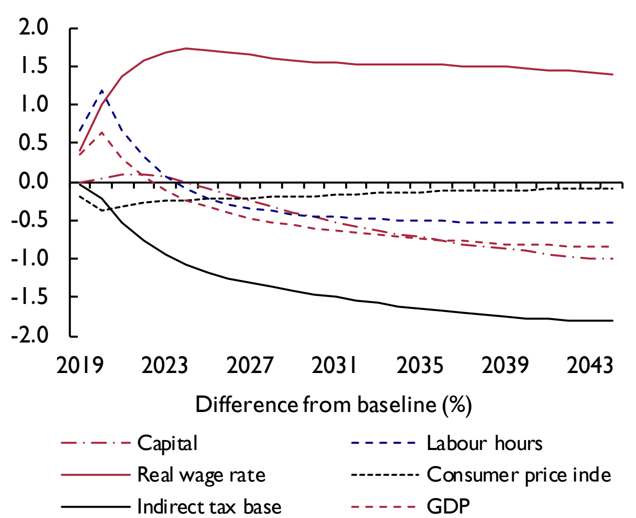

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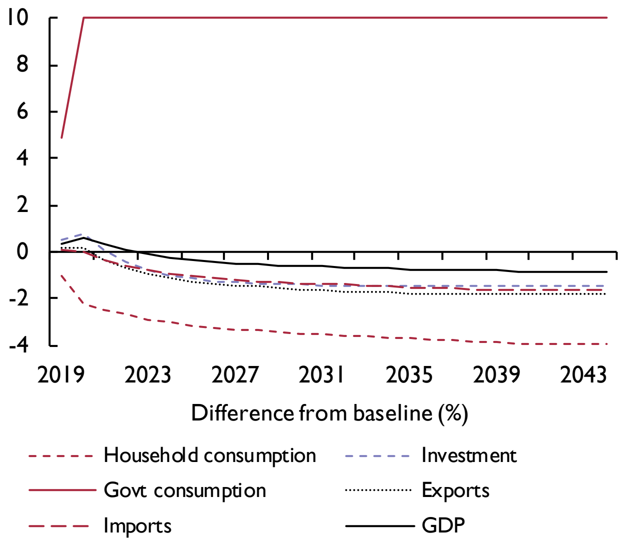
Figure 11. GDP expenditure components



education and public administration. A 10 per cent increase in demand for these services in the presence of inelastic labour supply (see equation (19)) will drive up wage rates for all sectors. Figure 10 shows that while the aggregate real wage rate rises over 2019–20 it does so slowly enough that labour hours also rise. This translates into a fall in the unemployment rate of 1.5 percentage points by 2020.

From 2021 onwards wage rates adjust so that the unemployment rate slowly returns to baseline levels by around 2026. Thus, labour hours eventually move 0.5 per cent below baseline (figure 10). Employment settles at 0.24 per cent above baseline, reflecting a higher real wage and therefore labour supply. The capital stock is 1 per cent lower by 2044, reflecting a fall in the capital-labour ratio. This is consistent with the expansion in government-provided services that are labour intensive and a contraction in other industries. Thus GDP is 0.84 per cent lower by 2044 compared to baseline.

A smaller capital stock and reduced labour hours make a negative contribution to GDP but they do not fall enough to explain the fall in GDP. A further negative effect arises from the significant reduction in allocative efficiency, i.e., the indirect tax base (figure 10). The indirect tax base reflects the quantity base upon which indirect taxes are applied.[9] As taxes (subsidies) reduce (increase) output and sales below (above) their optimal (undistorted) level, a decrease in the overall indirect tax base reflects a movement away from the optimal level of output. This occurs because the expanding industries (health, education and public administration) are lightly-taxed relative to industries as a whole. This means that an expansion in government-dominated industries relative to other industries reduces the indirect tax base and thus allocative efficiency. By 2044 the indirect tax base is 1.8 per cent below baseline.

6.2 Regional effects

Figure 12 presents the regional GDP effects from lowest to highest. These range from –1.54 per cent in London to 2.67 per cent in Conwy. What explains this range of results? The nature of the shock we are assessing

Figure 12. Regional GDP effects versus fitted regression (%)

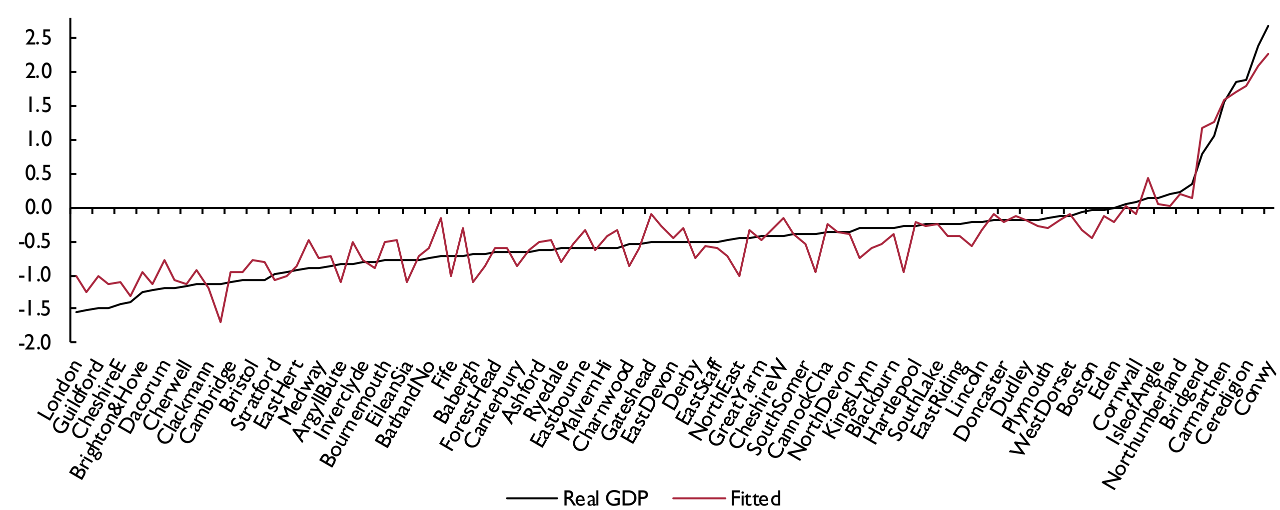


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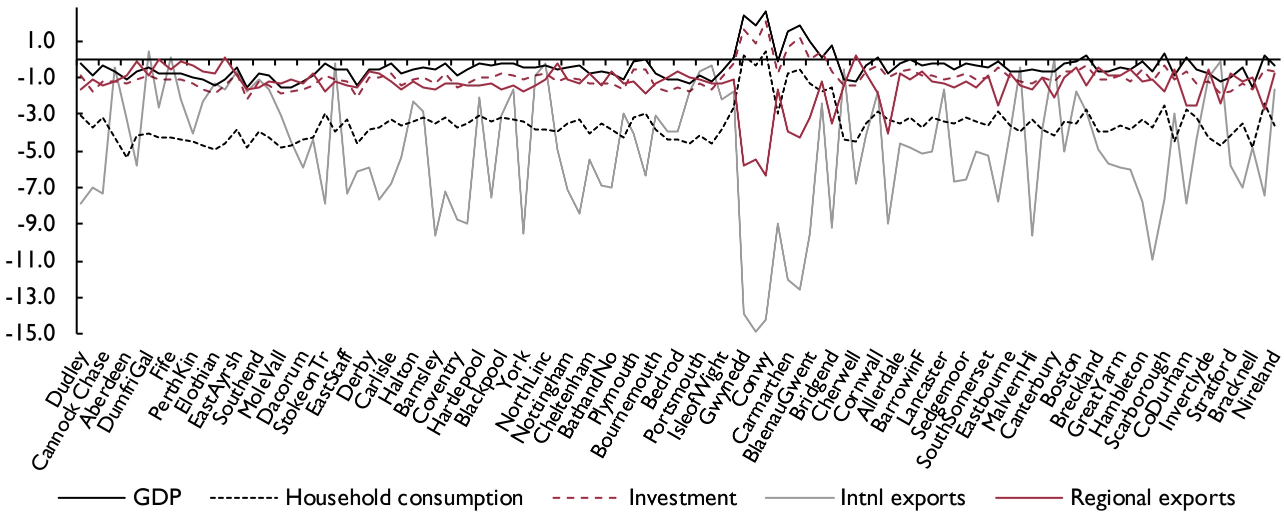
Figure 13. Regional GDP effects and expenditure components (%)



is generic across regions: a 10 per cent increase in government consumption. What is not region-generic is the importance of government consumption in regional economic activity. Thus, it is probable that the main driver of regional GDP is the share of government consumption in regional GDP. To test this idea we regress the percentage change in regional GDP ($\%\Delta GDP_r$) on the share of government consumption in regional GDP (G_r/GDP_r). This gives us the equation $\%\Delta GDP_r = -2.2495+9.0715(G_r/GDP_r)$ with an R^2 of 0.88. Thus the importance of government consumption in regional economic activity explains most of the GDP response by region. The regional GDP results and the fitted line are presented in figure 12. The regression under- and over-predicts regional GDP with no discernible pattern. It seemed likely that adding variables reflecting the importance of international and domestic exports to the regression might further raise the explanatory power of the regression; these variables did so only marginally.

Figure 13 presents the effects on regional GDP and the expenditure components. The results show the crowding out effects of the increase in government consumption. Household consumption as a share of GDP noticeably contracts in all regions. This is to be expected as the increase in government consumption is eventually financed by a higher income tax, which reduces household disposable income and thus consumption. Investment is also crowded out but much less so as the company tax rate is unchanged. Nevertheless, as labour can migrate across regions it is drawn into the expanding regions. This partly ameliorates the crowding out effect on household consumption in the expanding regions.

International exports are strongly negatively affected in most regions. This reflects the increase in domestic prices relative to international prices, which makes international exports less competitive. Domestic prices are driven upwards by the higher real wage costs that are a result of the expansion in labour-intensive government-dominated industries. Domestic or regional exports are also negatively affected in most regions but much less so than international exports; this is because wage costs rise in all regions and so the relative price effects across regions are much smaller than the increase in domestic prices relative to international prices.

The crowding out effects on domestic and regional exports are most notable in those regions that experience the largest increases in GDP (Isle of Anglesey, Gwynedd, Ceredigion, Conwy, Carmarthenshire, Powys, Blaenau Gwent, Pembrokeshire and Bridgend). These are also the regions with the highest shares of government consumption in GDP.

6. Conclusion

Prior to COVID-19 the UK faced a number of economic challenges in the short to medium term. Renegotiation of trading arrangements with the European Union was the most prominent of these. A second important medium-term challenge was the slowdown in productivity growth in the UK over the past two decades and the associated low overall labour productivity growth relative to other

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high-income countries. A third important challenge was the persistent and significant government budget deficit and corresponding accumulation of government debt.

These challenges have been analysed using the NiGEM model: a macroeconomic framework that is internally consistent, robust and built on micro-theoretic foundations (Hantzsche *et al.*, 2018). NiGEM is a multi-country macroeconometic model of the global economy that is data driven in the short to medium term and neoclassical in the long term. We build on existing macroeconomic analysis of these challenges by projecting the effects on the UK's regions. The forecast scenario is generated by combining NiGEM with UK-SCGE, a regional computable general equilibrium of the UK.

The UK regional model is a dynamic CGE model with long-run properties similar to NiGEM. Short-run behaviour is mainly characterised by the movement from an initial steady-state that is consistent with the latest input-output data, and national and regional accounts. Over time the model slowly moves from the initial steady-state along a balanced growth path to a new steady-state. The version of the model applied here represents 29 industries and 109 regions. Like NiGEM, UK-SCGE includes a government sector with expenditure and revenue accounts, a representation of the current and capital accounts, accumulation of foreign assets, foreign liabilities, and government debt.

The NiGEM results are applied as annual inputs to the regional model. The inputs include expenditure-side components of GDP, labour supply, employment, labour hours, labour productivity, and consumer prices. This ensures that at the macro level the two models are consistent in their representation of the path of the aggregate economy. Using the macro inputs from NiGEM, the regional model generates a rich pattern of effects for 109 regions. These changes are decomposed to explain how regions are affected differentially by the various long-run trends in the UK economy that are projected by the macro model. Further, the regional results also provide a ranking of growth prospects across the UK regions. This ranking can provide policy makers with a view on where economic policy changes might be focussed to reduce the largest disparities in regional outcomes.

The central macroeconomic scenario shows a national average annual GDP growth rate of 1.7 per cent over the period 2019–44. When the macroeconomic forecasts are applied across regions, growth rates range from 1.6 per cent for Cambridge to 2.2 per cent for Pembrokeshire. Despite wide variation at the extremes the standard deviation is low at 0.07 per cent and the coefficient of variation is 0.04 per cent. The country results favour Scotland, which grows at annual rate of 1.8 per cent, whereas Wales is the slowest growing of the countries at 1.70 per cent.

Decomposing the forecasts we find that labour productivity is the most important contributor to the overall growth rate. Housing investment and export prices are the next most important contributors to the overall growth rate. Business investment makes the smallest contribution to the overall growth rate. While labour productivity is the most important contributor to the overall growth rate, it has a rather even effect on regional growth rates reflecting the even importance of labour shares in GDP across regions. There is much greater variation in the importance of exports in GDP. Thus, we find that movements in export prices cause the largest variations in regional growth rates.

Combining macro inputs from NiGEM with UK-SCGE generates a rich pattern of effects for 109 regions. The effects provide an internally consistent story of changes in regional output. The regional results also provide a ranking of growth prospects across the UK regions. This ranking can provide policy makers with a view on where economic policy changes might be focussed to reduce the largest disparities in regional outcomes. Our results suggest that policies focussed on improving productivity in regions with low growth prospects would reduce some of the unevenness in expected growth outcomes.

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NOTES

1 National Institute's Global Econometric model. 2044 is the last forecast period available on the NiGEM base used in the exercise.
2 The regions are listed in appendix 1 (available on-line).
3 In terms of the Nomenclature of Territorial Units for Statistics applied in all European Union countries, the regions contain slightly less detail than the 139 regions in the NUTS Level 3 classification (ONS, 2019).
4 All the variables in this subsection have a region subscript but it has been dropped to reduce notational clutter, that is, the equations in this subsection are replicated in all regions of UK-SCGE.
5 The occupational classification corresponds to 1-digit occupations in ONS (2010).
6 The actual number of intermediate inputs for each commodity will depend on the input data as represented in the IO tables.
7 The method applies gross value added data from the Regional Accounts, industry employment data from the Business Register and Employment Survey, and population data by Local Authority Districts. All of these data are sourced from the Office for National Statistics website.
8 See appendix 2 (on-line) for a description of how the NiGEM forecasts are applied to UK-SCGE.
9 In simplified form the indirect tax base is tX where t is the tax rate and X is the quantity demanded. tX is related to the excess burden of a tax. For linear supply and demand curves the excess burden $\approx -1/2tX$ (see Auerbach, 1982).

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