Annex D: Multisectoral analysis of economic change

This technical annex provides additional detail on the MDM-E3 model, the scenarios and results for the Fast Track Analysis (FTA).

The remainder of the annex covers the following:

- An overview of the MDM-E3 model
- A description of the new model developments for the FTA
- The specification of the FTA scenarios
- The results of the projections from the model

The annex ends with some concluding remarks about the analysis, looking ahead to Work Stream 1 of the research programme.

D.1 OVERVIEW OF MDM-E3

MDM-E3[1] is maintained and developed by Cambridge Econometrics (CE) as a framework for generating forecasts and alternative scenarios for the economy of the UK and its regions, analysing changes in economic structure and assessing energy-environment-economy (E3) issues and other policies. MDM-E3 provides a one-model approach in which the detailed industry and regional results are consistent with the macroeconomic whole: the model projects key indicators separately for each industry sector and region, building up the macroeconomic picture by aggregating this detail. MDM-E3 is one of a family of models which share the same framework, general design, methodology and supporting software. The scope of the E3ME[2] model is European, that of E3MG[3] global.

This section describes the key features of the model, its exogenous input assumptions and key outputs. It then goes on to discuss the uncertainties inherent in long term economic projections and the limits of an econometric model like MDM-E3.

1 Multisectoral Dynamic Model, Energy-Environment-Economy: http://www.mdm-e3.com/

2 Energy-Environment-Economy Model of Europe: http://www.e3me.com/

3 Energy-Environment-Economy Model at the Global level: http://www.e3mgmodel.com/

D.2 KEY FEATURES OF THE MODEL

The key characteristics of MDM-E3 and its sister models are:

- A high level of disaggregation in terms of industrial sectors and categories of final expenditure; regional disaggregation of key economic variables.
- A national accounts-consistent input–output framework that explicitly identifies the interdependencies between sectors in terms of their purchases of inputs for production, i.e. a supply chain that transmits direct impacts on sectors as indirect impacts on others.
- Two-way linkages between the economy and energy system such that changes in one (e.g. from policy) affect, and are reflected consistently, in the other.
- Dynamic econometrically-estimated behavioural equations, capturing short-term impacts followed by medium-term adjustment to a long-run steady state.

The first characteristic, sectorally- and regionally-disaggregated projections, is a requirement of the ITRC programme, in order to provide inputs to the Capacity/ Demand Assessment Models (CDAMs) for each of the infrastructure sectors. Moreover, disaggregation is necessary to answer certain questions of economic interest; those that are intrinsically structural, where a more aggregate representation of heterogeneous agents may lead to bias.

Spatially, MDM-E3 separately identifies the 12 NUTS 1 regions of the UK: the nine Government Office Regions of England, and the devolved administrations: Wales, Scotland and Northern Ireland. For the purposes of ITRC, this is a relatively restrictive level of spatial resolution but is the most detail that can be supported by the available data for an econometric model such as MDM-E3.[4]

The following two characteristics, accounting; and inter-industry and energy-economy feedback, are important features of any model that is to be used for long term projection, to ensure coherence and internal consistency across all elements of the economy. The input–output structure of the economy changes over time, accounting for technological change, relative price movements (in terms of the prices of input factors) as well as changes in the composition of each industry's output.

While MDM-E3 retains an essentially Keynesian logic to determining final expenditure, output and employment, it is differentiated from other, purely macroeconomic, models in its level of disaggregation and its complete specification of the accounting relationships, mirroring the organising framework of official national statistics that maps the flows between economic agents and industry sectors.

The final characteristic, empirically-validated dynamics, is an important distinguishing feature of the models, emphasising the time path and non-equilibrium transition states of an economy. The behavioural relationships are estimated using historical time series data rather than being imposed by theory, although ranges to limit the values of some variables, informed by theory, are sometimes necessary to prevent implausible relationships between variables. The historical data that make up the MDM-E3 databases are sourced principally from official UK statistics, as published by the UK Office for National Statistics.

4 CE's approaches to producing output and employment projections at higher spatial resolutions are typically less model-based and more mechanistic, generally relying on the assumption of a continuation of trends in past relative performance of the sectors in a particular locality.

The purpose of MDM-E3 is to simulate the dynamics of the UK economy (as observed in past data). We expect this property of the model to be more important in the Work Stream 1 analysis that follows the FTA, when we will use the model for scenario/policy analysis, in which the process of economic adjustment and the presence of short-term constraints becomes more important to the path of the economy. In contrast, in the FTA, the scenarios are specified as target trend growth rates for UK GDP; there are no shocks to respond to and essentially no deviations from the steady state. We discuss this in more detail in the results section, in which we present price and wage results that highlight a particular property of the model: economies of scale.

The MDM-E3 framework allows for the integration of more detailed sub-models to feed back into the main E3 system.

Notably, MDM-E3 includes a bottom-up, engineering-based treatment of the power sector. The Energy Technology Sub-model (ETM) allows nascent low-carbon technologies, which are not currently financially viable, to displace conventional fossil fuel-based generation in response to, inter alia, learning curve effects and rising carbon prices. The investment decision follows a least-cost optimisation approach derived from the technical characteristics of an array of alternative technologies.

Electricity generation for a given level of capacity in a single year is determined by an Electricity Supply Industry (ESI) model that employs a cost-minimisation approach to determining the fuel mix.

D.3 INPUTS

The key exogenous inputs to MDM-E3 are:

- UK population projections by UK region:
  - Children
  - Working-age
  - Pensioners
- Current and capital expenditure by the UK Government
- UK tax rates and allowances
- Economic conditions in the rest of the world:
  - Economic activity (i.e. GDP growth) in other world regions
  - Prices in other world regions (including exchange rate effects)
  - Interest rates in other world regions
- Global fossil fuel prices:
  - Coal
  - Oil
  - Gas
- Global commodity prices:
  - Food
  - Agricultural raw materials
  - Metals and minerals
- Availability of UK natural resources for extraction (a constraint on domestic production; the remaining demand is implicitly met by imports):

- Coal
- Oil
- Gas

UK population is a key driver of household expenditure. Household expenditure in MDM-E3 is projected from expenditure per capita. Other things being equal, a larger population leads to higher levels of household expenditure. Moreover, the demographic structure of the population affects consumption through changes in child and OAP dependency ratios, potentially leading to changes in consumption patterns. Demography also affects travel demand in MDM-E3, which is driven by income per household. Demand for road transport fuel is affected as a consequence.

MDM-E3 endogenously determines government revenues from taxes on income and production (which are themselves endogenous in the model), although the rates are set by assumption. MDM-E3 includes a number of tax rates, all of which can be modified by the model operator. These include VAT, fuel duty, but also energy and carbon taxes.

Tax revenues are not automatically recycled back into the economy: it is up to the model operator to decide the allocation of government spending, i.e. government expenditure is exogenous. Government revenues not spent are implicitly used to reduce the Public Sector Net Cash Requirement (PSNCR). Because tax rates and government expenditure are exogenous, there are no behavioural effects linked to the PSNCR. There is no mechanism in the model that leads to contemporaneous government expenditure affecting household expenditure as a result of expectations regarding future higher or lower taxation.

Although MDM-E3 is a UK-centric model, the UK economy is characterised by a relatively high level of trade; it is an 'open' economy. As such, the model requires a view on economic conditions in the rest of the world, which affects UK competitiveness overseas as well as foreign demand for UK production. As an open economy, the UK also imports a large quantity of goods and services. Higher GDP in other world regions (MDM-E3 distinguishes 19 world regions) signals higher wealth in the rest of the world and, depending on the importance of a particular world region as a UK trade partner, leads to a higher demand for UK production.

Inflation in the rest of the world and exchange rates affect the relative prices of UK and rest-of-world production, i.e. competitiveness. These are not altered in the FTA scenarios.

Global commodity prices are another set of exogenous inputs to MDM-E3. The most important are the prices of fossil fuels, which feed into energy (and thus production) costs, affecting the prices of UK-produced goods and services for both domestic and overseas consumption; these are competitiveness effects.

Assumptions about UK natural resources place a constraint on indigenous extraction activity. This has economic effects when (the assumptions on) fossil fuel prices are taken into account; higher prices increase the value of UK output. However, these assumptions do not place constraints on UK access to natural resources; excess demand over the maximum level of UK production is assumed to be met by imports.

The model also requires input parameters, principally for the behavioural equations. Projected changes in the input–output coefficients (the nature of the supply chain over time) also fall under this category, although the version of the model used for the FTA does not incorporate these effects; only purchases of energy inputs per unit of output change in the projections.

The FTA defines a relatively narrow set of dimensions for scenario analysis and the majority of the above inputs do not differ across scenarios. The input assumptions that do differ across the FTA scenarios are:

- UK population projections by UK region
- Current and capital expenditure by the UK Government
- Economic conditions in the rest of the world, specifically GDP
- Global fossil fuel prices

The section on scenario specification provides more detail on how these assumptions vary across the scenarios.

D.4 SUMMARY OF OUTPUTS

MDM-E3 generates annual comprehensive forecasts for the following key variables:

- UK output, prices, exports, imports and employment at the 41-industry level (yielding the macroeconomic outcome)
  - » The input–output structure in MDM-E3 allows for the identification of industry expenditure on electricity, gas and water services
- Household expenditure by 51 categories including expenditure on electricity, gas and water services
- Investment by 27 investing sectors
- Nine Government Office Regions, Wales, Scotland and Northern Ireland for key variables:
  - » Output and employment for 30 sectors
  - » Household expenditure
  - » Investment
- UK-level energy demand and emissions, for 25 fuel users (2 primary energy users and 22 final users) and 8 main fuel types (the model distinguishes 11 fuels in total)

All of the above are of interest and thus reported for the FTA.

D.5 UNCERTAINTIES IN LONG-RUN ECONOMIC PROJECTIONS

As mentioned previously, the purpose of MDM-E3 is to simulate the year-by-year dynamics of the UK, as observed in historical data. A key assumption of this approach (and of econometrics in general) is that the past is a useful guide to the nature of future relationships. We require constancy/stability of the behavioural relationships over time such that agents respond in a similar way to future developments and policies as they have in the past. The possibility that this might not hold is the essence of the 'Lucas Critique' in economics[5]: behavioural parameters estimated on past data do not necessarily ensure the validity of a model applied for future forecasting and policy analysis if there is the possibility that agents' behaviour might change in the future. In some sense this is perhaps an unsurprising assertion and certainly of great theoretical importance. It is an issue that must be accepted by modellers, and those that make use of the model results.

5 Lucas, R. E. (1976) Econometric policy evaluation: A critique, Carnegie-Rochester Conference Series on Public Policy. *Elsevier*, Vol. 1(1), pp 19–46.

However, whether explicit or implicit, some notion of a model or system is necessary to conduct forward-looking analysis, with its assumptions and premises subject to scrutiny. At some point the model's parameterisation and premises must, however, loosely be based on observation. With respect to parameter estimation and validation in an econometric model such as MDM-E3, the past is the only information we have to go on. Moreover, the practical significance of the Lucas Critique has proved difficult to determine, empirically.

As an econometric model, MDM-E3 belongs to a class of models that is far from immune to this criticism and it is important to highlight the limitations and uncertainties regarding long term projections of the kind presented here.

The principal uncertainty in projecting into the future is the nature of structural and technological change. Over short time horizons, changes in the structure of the economy are likely to be relatively small. However, as the forecast horizon moves away, the differences are likely to grow wider, as old UK industries decline and new ones are born. Indeed this can be seen in the changes over time to the UK Standard Industrial Classification (SIC), the official list of categories of economic activity used to classify different types of business. The latest revision (SIC 2007) contains a more detailed breakdown of services than the previous one, recognising the increasing range of services-oriented economic activities in the UK.

Successfully predicting such changes in future economic structure becomes more difficult as the time period increases and implicitly requires some view on the nature of future goods and services, including how (the nature of the inputs and production process) and where (the, possibly increasingly global, geography of the supply chain) they are produced. Such trends (based on history) are captured to some degree in the MDM-E3 framework, tracking the general pattern of structural change over time but more sudden upheaval in economic structure is not something the model is able to replicate endogenously. Examples of this include the rise of rail transport and, more recently, the ICT revolution, sudden innovations that transformed the UK and global economy.

While there are no hard-and-fast rules regarding the time horizon (there is always some element of judgement and trade-off involved), for ITRC, the forecast horizon of the model is 2010–2050, i.e. around 40 years of projection. The behavioural relationships are estimated over a similar timespan, using data over the period 1970-2010. For projection purposes, this seems a reasonable and convenient limit on the time horizon of the economic scenarios; we are not projecting forward for more years than we have data.

D.6 MODEL DEVELOPMENTS FOR THE FTA

The development work for MDM-E3 can be divided into three main tasks:

- Extending the forecast horizon out to 2050 (from the previous end point of 2030)
- Extending the exogenous inputs to 2050
- Constructing an initial baseline projection

The sub-sections that follow present the model developments implemented for the FTA.

D.6.1 Extending the forecast horizon

Prior to the FTA, MDM-E3 projected annually to 2030. For the FTA, it was necessary to extend this forecast horizon out to 2050. The act of extending the model was relatively straightforward, because it already solves year-by-year; at a high level, the development involved extending an existing iterative process and relatively few changes were made to the source code, written in Fortran, that embeds the economic logic of the model.

In general, changes were restricted to lines of code that explicitly referenced the year 2030 as the final year of solution, for example, where solution diagnostics and summary results are printed at the end of the run. These values were either replaced with 2050 or, where possible, generalised to avoid a hard-coded value, so as not to present any problem in future extensions of the forecast horizon.

More substantive changes were required to the underlying solution system, IDIOM,[6] to accommodate a larger internal storage space (to contain the extra 20 years of solution).

All remaining changes to the model code were for maintenance purposes such as restructuring code for clarity and to aid debugging.

D.6.2 Extending the exogenous inputs

As mentioned in the previous sub-section, the extension of the forecast horizon was, for the most part, a mechanical process to expand and extend existing features of the model. MDM-E3 requires a number of exogenous inputs and it was necessary to extend these series to 2050. A Business as Usual (BaU) approach was applied to extend these series:

- Inputs in levels were extrapolated using trend growth rates
- Rates (e.g. tax rates) were held constant

D.6.3 Constructing the baseline

Various off-model calculations, such as the implications for future GDP, consumption and income per capita, suggest that a Principal scenario GDP growth rate of 2.3% pa is plausible, given the input assumptions. The initial baseline projection was constructed using the 'raw' model results out to 2050 using the extended input assumptions. For some variables, the series either fell to zero rapidly, or exhibited exponential growth when allowed to solve over a 40-year time horizon (arguably stretching the forecasting ability of an econometric equation given that it is a similar time period to the historical data over which the parameters themselves are estimated). The former destabilises the model solution while the latter leads to an implausible projection. In both cases, a simpler extrapolation of the series was carried out and the model calibrated to reproduce this outcome. The Principal scenario was then produced by a small amount of fine-tuning through the world activity assumptions.

6 IDIOM, the International Dynamic Input-Output Modelling language, is a set of Fortran routines common to all of CE's E3 models. IDIOM is intended to provide a general system for organising input data and parameters for a large-scale economic model and to allow a high level of control of the model solution without requiring modifications to the compiled model source code. http://www.camecon.com/ModellingTraining/suite_economic_models/IDIOM.aspx

D.7 SCENARIO SPECIFICATION

In this section we outline the scenarios for the FTA and their implementation in MDM-E3.

D.7.1 The three FTA scenarios

The FTA identifies three key drivers:

- Population growth
- Economic growth
- Energy costs

From the above scenario dimensions, the specification of the three FTA scenarios is as follows:

- Medium growth (BaU) scenario:
  - » Population growth in line with the principal ONS projection (a total UK population of 76.4m by 2050)
  - » Economic (GDP) growth of 2.3% pa
  - » Energy costs in line with the DECC Central assumptions of future fossil fuel prices
- High growth scenario:
  - » Population growth in line with the high ONS projection (UK population of 86.4m)
  - » GDP growth of 3.0% pa
  - » Energy costs in line with the DECC Low assumptions of future fossil fuel prices
- Low growth scenario
  - » Population growth in line with the low ONS projection (UK population of 66.8m)
  - » GDP growth of 1.6% pa
  - » Energy costs in line with the DECC High assumptions of future fossil fuel prices

Of the key drivers, two are inputs to MDM-E3 (population growth and energy costs) while the other (economic growth) is an output of the model. It is not necessarily the case that the input assumptions on population growth and energy costs will yield the desired GDP outcome. In fact, the ranges of these two driver dimensions are insufficient to achieve the desired GDP growth profiles.

Relative to the medium growth scenario, the differences in the annual rate of population growth in the high and low growth scenarios are around +/- 0.4 pp. Assuming, momentarily, that all other factors remain unchanged, while an increase in population would lead to a one-for-one increase in household expenditure, this does not translate to a one-for-one increase in GDP because household expenditure accounts for only part (currently 60–70%) of final demand. This initial, first-round, impact is curbed by other compensating feedbacks, such as an increase in the size of the workforce (from a higher UK population), which has implications for labour supply and income growth, potentially negating some of the population effect.

The transmission channel for fossil fuel prices to the economy as a whole is relatively long; the effect of changes in fossil fuel prices is thus substantially diluted as far as the UK macroeconomy is concerned. The global wholesale price is but one element of the energy price faced by fuel users; the remainder comes from other taxes and margins meaning that retail energy prices increase by less than one-for-one with wholesale prices. Energy is in turn but one input to production reducing further the effect on production costs of a, say, 1% increase in fossil fuel prices.

There is one more step before the change in the fossil fuel price is transmitted to the price of goods and services: cost pass-through. The theoretical framework of MDM-E3 does not impose the assumption of perfect competition in markets. Consequently, a 1% increase in production costs does not necessarily lead to a corresponding 1% increase in price; firms may only pass on a portion of the cost increase in order to remain competitive, choosing to absorb some of the cost increase as lower profits.

D.7.2 Scenario inputs to MDM-E3

The population-growth assumptions in the MDM-E3 scenarios are taken from the demography projections produced for the FTA (which were constrained to the ONS projections – see Annex C).

Similarly, the input fossil fuel price assumptions are consistent, matching the DECC assumptions to 2030. Over 2030–2050, the assumed prices are held constant in real terms (in line with the other modelling analysis for the FTA).

Relative to the medium growth scenario, government expenditure is higher in the high scenario and lower in the low scenario, roughly in line with the differences in population growth. Government expenditure is an exogenous input in MDM-E3 and would have remained identical across the three runs without any intervention.

The remainder of the +/- 0.7 pp growth differential (and fine-tuning of growth in the medium growth scenario) is achieved by adjustments to the assumptions on world economic growth over 2015–2050 (post-recession and recovery). Changes in these assumptions alter the pattern of trade through the demand for UK exports by the rest of the world. Exporting sectors are affected directly (through changes in export demand) while other sectors are affected indirectly through the supply chain and changes in income.

All other assumptions (including exchange, interest and tax rates, as well as inflation in the rest of the world) are unchanged across the scenarios; all the differences in the model outcomes arise from the changes in the inputs described above.

D.8 RESULTS

This section presents the results of the scenarios. The first sub-section provides an overview of the UK macroeconomic results, focusing on the contributions of the various components of final demand to the GDP trajectories; and employment. It follows with further discussion at the level of UK industry sectors and regions.

We then present the results for demand for infrastructure services by households and industry and the energy and emissions projections.

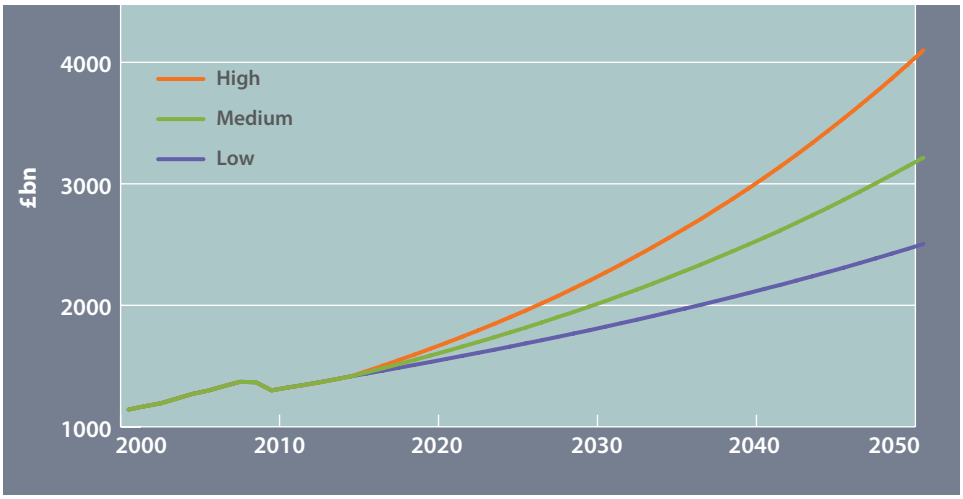
The section ends with an explanation of the price and wage effects seen in the long term results.

D.8.1 Macroeconomic Results

D.8.1.1 GDP

The 0.7 pp growth differential over 2015–2050 leads to an appreciable widening of the GDP trajectories in the scenarios. In 2050, GDP in the high growth scenario is 27.5% higher than in the medium growth scenario. In the low growth scenario, GDP is around 22% (Figure 1).

Figure 1: UK GDP.



Differences in export growth (owing to different assumptions about world economic activity and demand for UK production) drive the differences in GDP. Exports in 2050 are 47.9% higher in the high growth scenario than in the medium growth scenario, and almost 40.7% lower in the low growth scenario. Higher income is an eventual consequence of higher export demand. The higher export demand increases the requirements for UK production and thus a greater overall labour input, leading to more wage income in the aggregate.

In 2050, import demand in the high growth scenario is 18.5% higher than in the medium growth scenario owing to higher income (leading to greater demand for goods and services produced overseas), as well as greater requirements for imported inputs to production (to support higher UK output). This serves to reduce GDP, but its effect is more than outweighed by increases in all other components of final demand. Conversely, lower income and lower output requirements in the low growth scenario lead to lower import demand relative to the medium growth scenario, by 13.8%.

The volume of UK imports exceeded the volume of exports in 2008 and this remains the case in 2050 (Figure 2, Table 1), in the medium and low growth scenarios. Export demand growth is stronger in the high growth scenario (by design) and exports exceed imports in this scenario in 2050.

Figure 2: UK GDP by component of final demand.

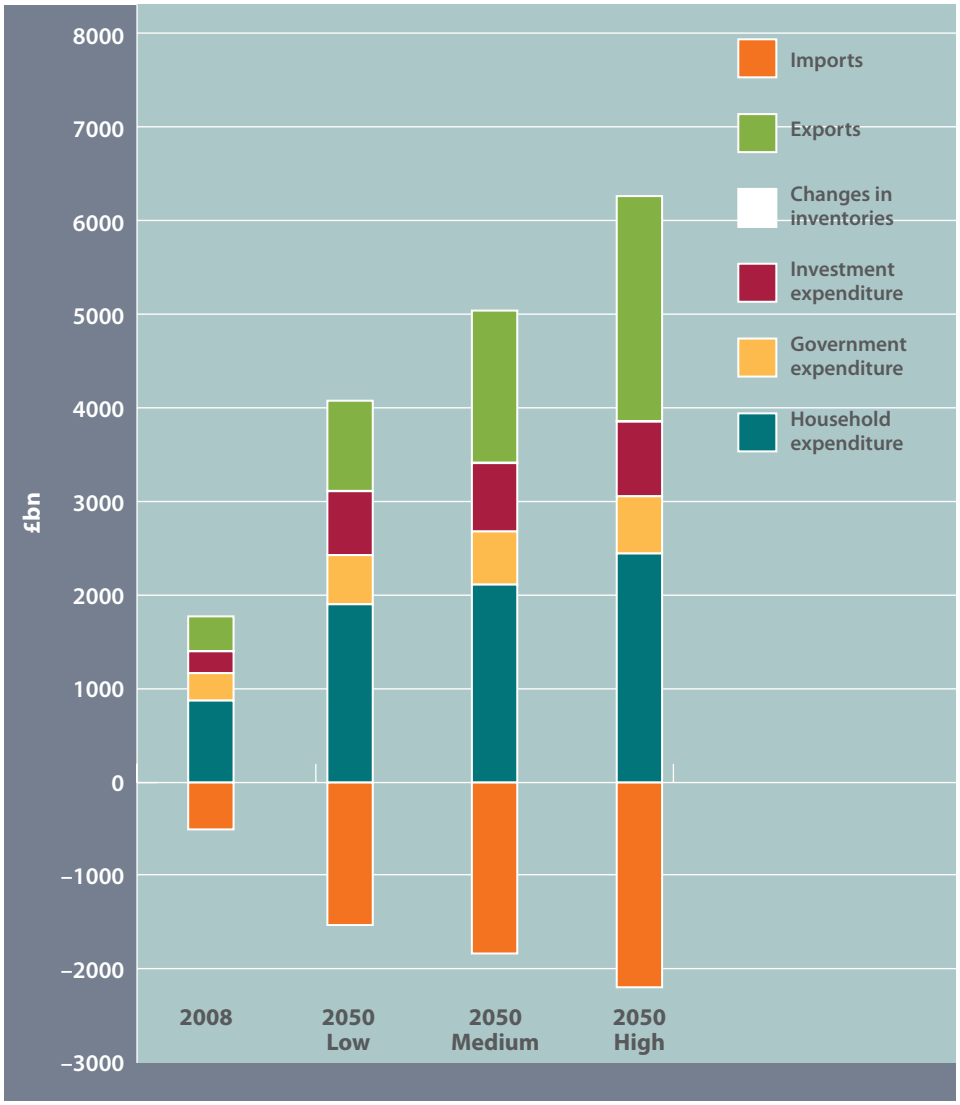


Table 1: UK GDP by component of final demand

	2008 (£2006bn)	2050 (£2006bn)			Difference from medium growth in 2050 (%)	
		Low	Medium	High	Low	High
GDP	1367	2505	3215	4099	–22.1	27.5
Household expenditure	875	1903	2113	2445	–9.9	15.7
Government expenditure	293	525	567	611	–7.2	7.8
Investment expenditure	233	682	730	796	–6.6	9.0
Changes in inventories	1	3	4	6	–20.9	29.8
Exports	372	963	1624	2402	–40.7	47.9
Imports	–407	–1573	–1824	–2160	–13.8	18.5

The differences in income across scenarios (highest in the high growth scenario and lowest in the low growth scenario) also drive the differences in household expenditure relative to BaU: +15.7% in the high growth scenario in 2050 and –9.9% in the low growth scenario.

In MDM-E3, higher industry output leads to higher investment expenditure, implicitly to augment the capital stock in order to sustain higher production. The scenarios reflect this in higher investment expenditure in the high growth scenario (+9% relative to the BaU) and lower expenditure in the low growth scenario (–6.6%).

Changes in government expenditure are exogenous inputs to the scenarios and higher in the high growth scenario and lower in the low growth scenario by design. In 2050, government expenditure is 7.8% higher in the high growth scenario and 7.2% lower in the low growth scenario.

D.8.1.2 Employment

Total UK employment follows the GDP results: employment is higher in the high growth scenario relative to the medium growth scenario and relatively lower in the low growth scenario (Figure 3). In the medium growth scenario, there are more than 37m jobs in 2050. In the high growth scenario there are 3.2m more jobs and in the low growth scenario there are 3.3m fewer jobs; the employment effects, like the GDP impacts, are largely symmetrical. These increases in employment compare to differences in population of roughly 10m higher in the high growth scenario and 10m lower in the low growth scenario (although only a fraction of this population is of working age and thus the available workforce grows or contracts by less than 10m).

The size of the differences in total employment (+8.6% and –8.8% in the high and low growth scenarios, respectively) is less than the differences in GDP (+27.5% and –22%). In these scenarios, a 1% change in GDP implies a change in total employment of 0.3–0.4%.

A possibly unusual result across the three scenarios is that price and wage inflation is lowest in the high growth scenario and highest in the low growth scenario. This result is discussed in more detail in the sub-section on prices and wages.

D.8.2 UK-level results by sector

D.8.2.1 GVA

Post-recession and recovery, total GVA across all UK sectors increases in the scenarios. In 2050 total GVA is higher in all three scenarios compared to 2008 (Figure 4, Table 2).

In the scenarios, GVA increases between 2008 and 2050 in all broad sectors with the exception of Mining & quarrying, a small industry in terms of GVA, accounting for some 2.5% of the UK total in 2008. This reflects the terminal decline of the UK Continental Shelf and the concomitant decline in the UK fossil fuel extraction industries. GVA in other UK mining activities is largely flat over the projection period of the medium growth scenario; the decline in the broad Mining & quarrying sector (by 50% over 2008–2050) is due to the decline of indigenous extraction of fossil fuels. The modest differences either side of the medium growth scenario in the high and low growth scenarios are driven by higher and lower demand, respectively, for mining exports owing to the changes in the assumptions on economic activity in the rest of the world.

Figure 3: UK Employment

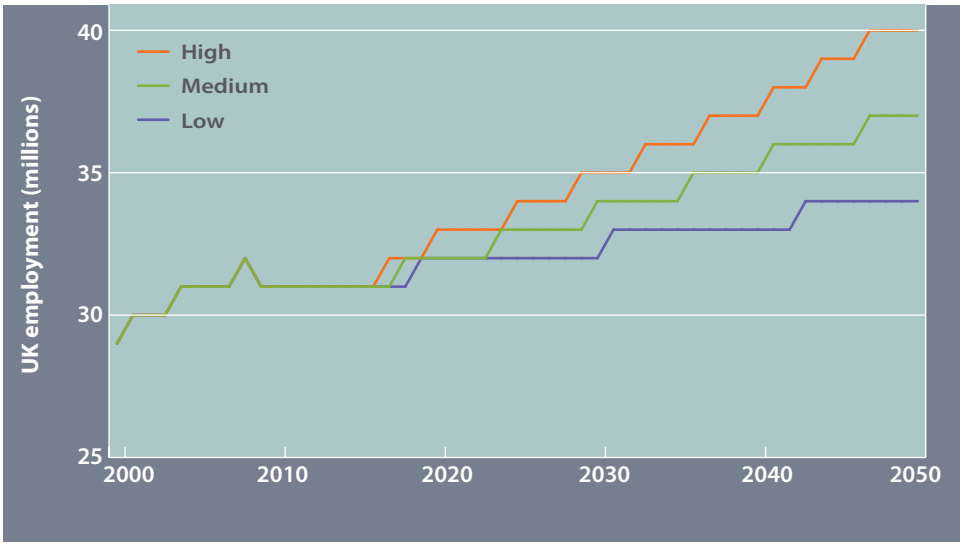
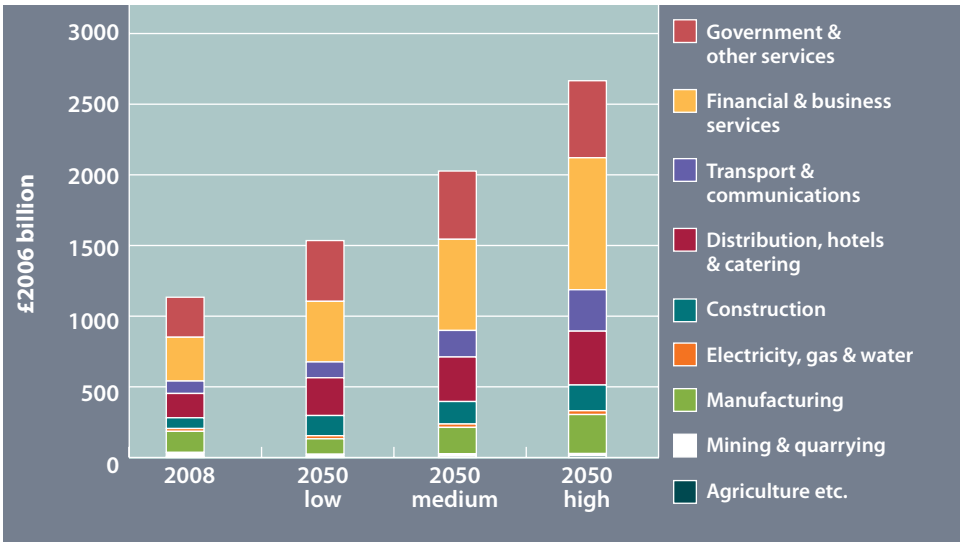


Figure 4: UK GVA by sector.



Over the projection period, the medium growth scenario shows a pronounced shift in emphasis towards a more services-oriented economy, reflecting the pre-recession recent history of changes in the structure of the UK economy.

In 2008, UK services accounted for around three quarters of UK GVA, concentrated particularly in Financial & business services and Government & other services (i.e. public services); these two broad sectors accounted for over half of UK GVA in this year. Distribution, hotels & catering (essentially, wholesale and retail activities and the hospitality industries) accounted for 15% and Transport & communications another 8%. Construction accounted for around 7% of UK GVA in 2008 and Manufacturing just over 13%. The remaining broad sectors (Agriculture etc., Mining & quarrying and Electricity, gas & water) are small in GVA terms, between them accounting for around 5% of the UK total in 2008.

Table 2: UK GVA by sector						
	2008 (£2006bn)	2050 (£2006bn)			Difference from medium growth in 2050 (%)	
		Low	Medium	High	Low	High
Agriculture etc.	7	8	10	12	–19.3	22.2
Mining & quarrying	29	15	16	16	–2.3	3.6
Manufacturing	149	109	187	276	–41.8	47.4
Electricity, gas & water	20	22	24	27	–9.0	11.7
Construction	76	143	159	182	–10.5	14.2
Distribution, hotels & catering	172	267	315	381	–15.4	20.7
Transport & communications	88	112	188	293	–40.6	56.1
Financial & business services	310	429	645	934	–33.6	44.7
Government & other services	283	430	483	545	–10.9	13.0
Total	1134	1534	2028	2666	–24.4	31.5

In the medium growth scenario, the emphasis on UK services increases, driving the growth in the UK economy. As in recent history, Financial & business services and Government & other services are the main sources of this growth. The share of Financial & business services in the UK total grows appreciably, to almost one third of UK GVA in 2050, compared to 27% in 2008, while the share of Government & other services is relatively stable over the projection period to meet increasing demand for such services from an increasing (and aging) population. GVA growth is steady in the other service sectors.

As mentioned previously, UK Mining & quarrying declines in the medium growth scenario, while growth in Agriculture etc. and Electricity, gas & water over the projection period is modest, leading to falling shares in total UK GVA.

Manufacturing GVA continues to grow in the medium growth scenario to 2050, although at a substantially lower rate than services. Consequently this broad sector's share of UK GVA declines, from 13% in 2008 to just over 9%.

Relative to the medium growth scenario, the key driver of the GVA results in the high and low growth scenarios is world activity. Thus, those sectors most affected in the high and low growth scenarios are those with high export ratios; other sectors are relatively less affected because the impacts are indirect; they are transmitted through the supply chain and by changes in the levels of household and investment expenditure. Growth in household expenditure comes from higher income owing to higher UK production, while higher investment expenditure follows higher UK output, to support the higher levels of production required in the high growth scenario.

In percentage terms, changes in world activity in the high and low growth scenarios affect Manufacturing and Financial & business services most strongly, particularly Printing & publishing, Chemicals, and Banking & finance. In these sectors, GVA is more than 40% higher in the high growth scenario in 2050 relative to the medium growth scenario, owing to their high export ratios. Growth in other sectors is a consequence of higher UK exports and depends on these sectors' importance in the supply chain (as represented by the input–output table at the core of MDM-E3). Construction, Distribution, hotels & catering (the wholesale and retail trade element) and Transport & communications (mainly the warehousing, haulage and communications sectors) all see strong increases in GVA growth.

The differing sectoral impacts lead to a slight shift in the composition of UK GVA in 2050 when the high and medium growth scenarios are compared. Manufacturing's share is slightly higher, as is Transport & communications'. However, despite the increase in Manufacturing output, the overall trend of a shift towards a more services-oriented economy remains in the high scenario, owing to the growth in Financial & business services, which accounts for 35% of UK GVA in 2050 in the high growth scenario, compared to 32% in the medium growth scenario.

The effects of lower world activity in the low growth scenario are generally of similar magnitude but opposite direction to the high growth scenario, reflecting the symmetry of the scenario specification. In the low growth scenario, the lower export activity leads to Manufacturing GVA in 2050 that is lower than in 2008.

D.8.2.2 Employment

As mentioned previously, the direction of the employment effects is in line with the direction of the output (GDP) effects: higher GDP growth in the high growth scenario leads to higher employment growth compared to the medium growth scenario; the effect is in the other direction in the low growth scenario (Figure 5, Table 3). In the aggregate, a 1% change in GDP in the scenarios is associated with a change in employment of 0.3–0.4% across scenarios (indicating growing labour productivity over time).

Higher GVA by broad sector is associated with higher employment: compared to the medium growth scenario, employment is higher in the high growth scenario and lower in the low growth scenario.

Across scenarios, the results illustrate the relative differences in labour productivity across sectors. The extraction industries have very high levels of value-added per worker (but are small in GVA terms, contributing a negligible amount to the overall employment effect). Insurance and utilities have similarly high levels of labour productivity, leading to relatively smaller employment effects for a given increase in output. At the other end of the spectrum, Agriculture etc. and public services are relatively more labour intensive, leading to employment impacts more in line with the size of the GVA effects.

The employment effects from increasing output are reduced further by higher productivity in the high growth scenario and lower productivity in the low growth scenario, relative to the medium growth scenario. This reflects the economies of scale that arise from higher growth: GVA per worker is higher in the high growth scenario and lower in the low growth scenario.

Figure 5: UK employment by sector.

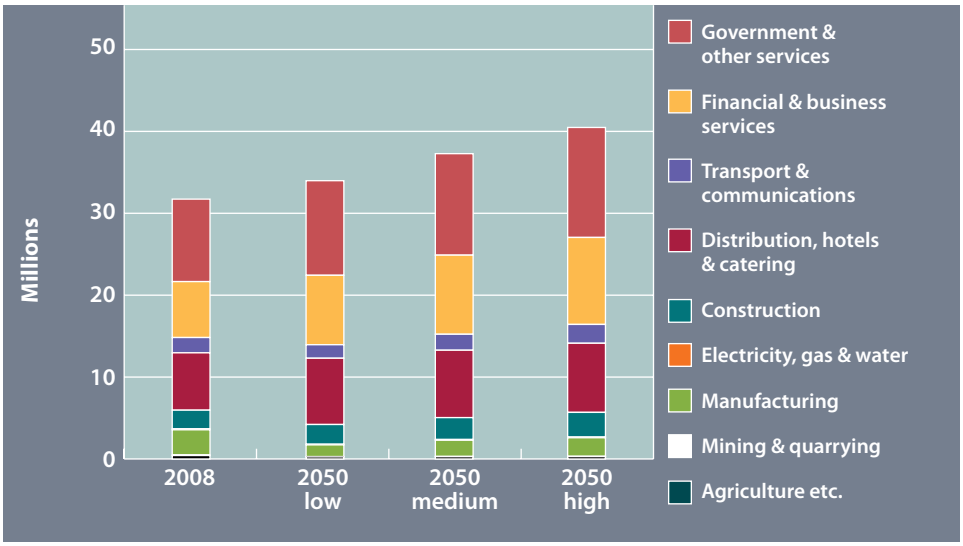


Table 3: UK Employment by sector

	2008 ('000s)	2050 ('000s)			Difference from medium growth in 2050 (%)	
		Low	Medium	High	Low	High
Agriculture etc.	416	263	275	287	–4.4	4.4
Mining & quarrying	67	32	32	32	0.0	0.0
Manufacturing	3066	1432	1981	2266	–27.7	14.4
Electricity, gas & water	123	84	87	91	–3.4	4.6
Construction	2284	2412	2669	3009	–9.6	12.7
Distr., hotels & catering	6997	8090	8228	8437	–1.7	2.5
Transport & comms.	1867	1647	1951	2,95	–15.6	17.6
Fin. & business services	6831	8476	9658	10,624	–12.2	10.0
Government & Other serv.	10,071	11,551	12,388	13,425	–6.8	8.4
Total	31,722	33,987	37,269	40,466	–8.8	8.6

D.8.3 Results by Region and Sector

D.8.3.1 GVA

Historically, there has been a shift in the geography of UK economic activity from the North to the South. In 2008, as measured by GVA, London and the South East were the largest regional economies: London accounted for some 20% of GVA and the South East around 15% (Figure 6, Table 4). All other regions accounted for less than 10%, with three accounting for less than 4% each: the North East, Wales and Northern Ireland. While Financial & business services and Government & other services, the sectors that have been driving UK economic growth in recent times, are the highest GVA sectors in all the regions, the disparities arise because of their relative concentrations. London has by far the highest concentration of Financial & business services and regions located further north have relatively lower concentrations and are thus relatively more dependent on Manufacturing, which exhibits much lower growth in the long run.

Trend growth in the medium growth scenario exacerbates the so-called North-South divide as growth in services continues to drive UK economic growth; the shares of GVA accounted for by London, the South East, the East of England and the South West are higher in 2050 compared to 2008, at the expense of the other regions. These regions contribute most to overall UK GVA growth. These trends lead to widening disparities in GVA per capita across UK regions.

Across scenarios, in 2050, changes in the assumptions on world economic conditions are evident in the results, with regions with large exporting sectors (such as Financial & business services) affected relatively more than those with smaller concentrations of such sectors. The variance in regional GVA also shows something of a North-South divide.

Figure 6: GVA by region.

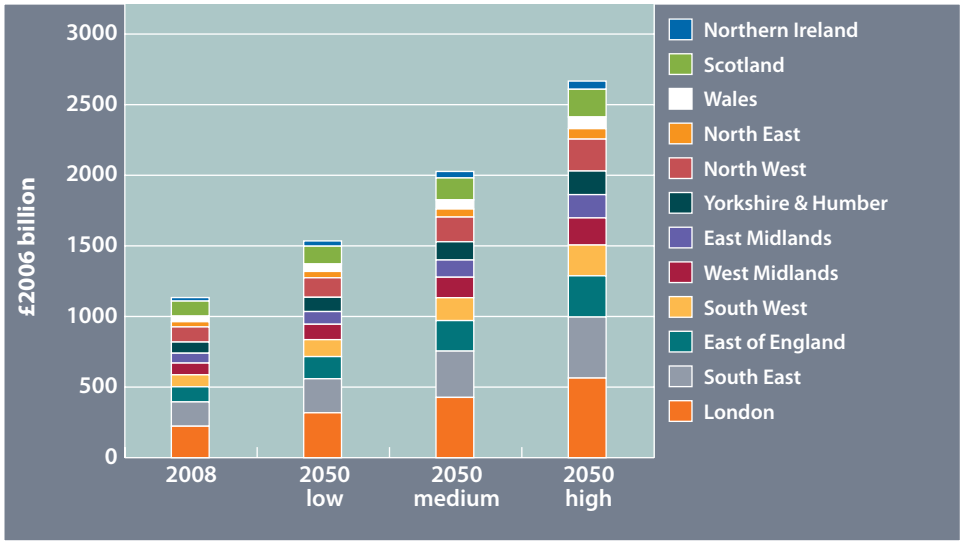


Table 4: GVA by region						
	2008 (£2006bn)	2050 (£2006bn)			Difference from medium growth in 2050 (%)	
		Low	Medium	High	Low	High
London	223	318	427	564	–25.6	31.9
South East	172	241	328	432	–26.7	31.6
East of England	107	157	216	292	–27.1	35.3
South West	85	120	162	218	–25.7	34.5
West Midlands	83	109	145	192	–24.5	32.5
East Midlands	70	90	122	165	–26.4	35.5
Yorkshire & Humber	79	101	129	167	–21.9	29.5
North West	107	138	175	226	–21.0	29.0
North East	37	45	57	74	–21.7	28.9
Wales	40	53	65	83	–19.3	26.7
Scotland	106	126	155	196	–18.8	26.4
Northern Ireland	25	37	46	58	–19.0	26.8
Total	1134	1535	2028	2 666	–24.3	31.5

D.8.3.2 Employment

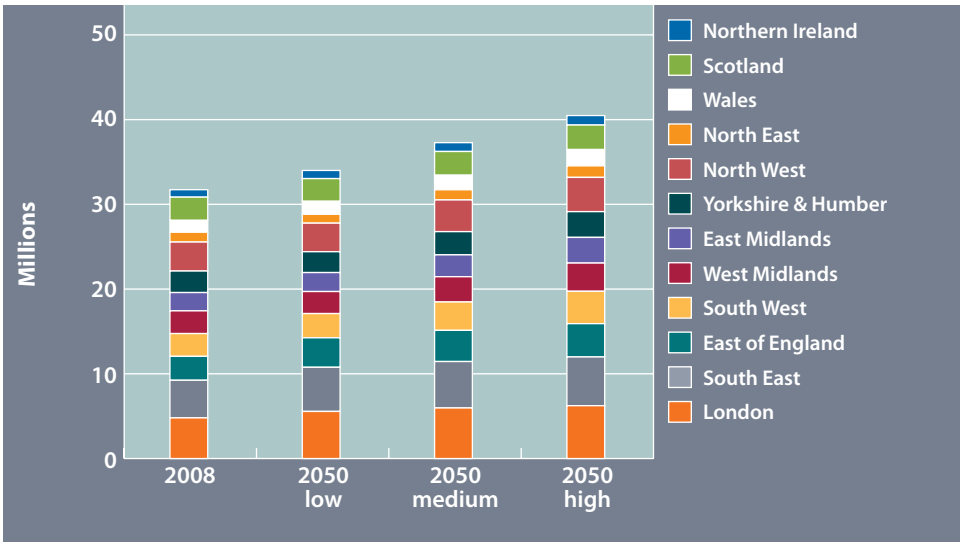
The employment results from the scenarios follow the direction of the GVA results: higher GVA is associated with higher employment and lower GVA with lower employment (Figure 7, Table 5). This holds true at the regional level, but the differences in concentrations of high and low value-added sectors (which have differing levels of labour productivity) mean that the impacts of high and low UK economic growth on regional GVA and employment differ.

In the high growth scenario, the following regions saw increases in GVA in 2050, relative to the medium growth scenario of more than 30%, owing to greater representation of export-oriented, high-value sectors:

- London
- South East
- East of England
- South West
- West Midlands
- East Midlands

Of the above, the employment effects are large in the South West, West Midlands and East Midlands, but comparatively modest in London, the South East and the East of England (of the 12 MDM-E3 regions, only Scotland sees a smaller employment impact than these three). This indicates differences in average labour productivity by region.

Figure 7: Employment by region.



The three regions that see the largest employment impacts have higher concentrations of sectors with relatively low labour productivity. The South West, West Midlands and East Midlands are relatively more dependent on public services than private financial and business services than London, the South East and the East of England. While both sectors are key drivers of long-run UK economic growth in the scenarios, the former is more labour intensive than the latter and employment will tend to follow GVA more closely in public services, despite the general increase in labour productivity over time, and with higher growth.

The same explanation holds for the regions relatively less affected in GVA terms by higher and lower UK economic growth. The North East, Wales and, to a lesser extent, Yorkshire & Humber, see relatively larger employment impacts than the North West, Scotland and Northern Ireland owing to lower shares of higher value-added industries.

Table 5: Employment by region						
	2008 ('000s)	2050 ('000s)			Difference from medium growth in 2050 (%)	
		Low	Medium	High	Low	High
London	4797	5556	5968	6235	–6.9	4.5
South East	4437	5211	5479	5754	–4.9	5.0
East of England	2823	3482	3678	3925	–5.3	6.7
South West	2694	2864	3350	3822	–14.5	14.1
West Midlands	2677	2599	2979	3329	–12.8	11.7
East Midlands	2164	2237	2581	3032	–13.3	17.5
Yorkshire & Humber	2537	2458	2737	3036	–10.2	10.9
North West	3416	3365	3738	4040	–10.0	8.1
North East	1161	1047	1198	1362	–12.6	13.7
Wales	1398	1529	1719	1928	–11.1	12.2
Scotland	2740	2681	2802	2887	–4.3	3.0
Northern Ireland	877	960	1040	1117	–7.7	7.4
Total	31,721	33,989	37,269	40,467	–8.8	8.6

D.8.4 Demand for Infrastructure Services

D.8.4.1 Households

In the medium growth scenario, household expenditure on water services increases modestly over the projection period, by 0.5–0.75% pa. (Figure 8). Differences in the level of household income across scenarios lead to differences in household expenditure and, in turn, differences in water consumption. GDP and income are higher in the high scenario, leading to 15.5% higher water consumption in 2050 compared to the medium growth scenario. Conversely, water consumption in the low growth scenario is 24.6% lower in 2050 relative to the medium growth scenario. MDM-E3 contains no explicit mechanisms (beyond demographic drivers of consumption patterns and changes in price) for improving household water efficiency over time, hence the more obvious differences in consumption across scenarios compared to energy (see below).

Figure 8: Household demand for infrastructure services: water.

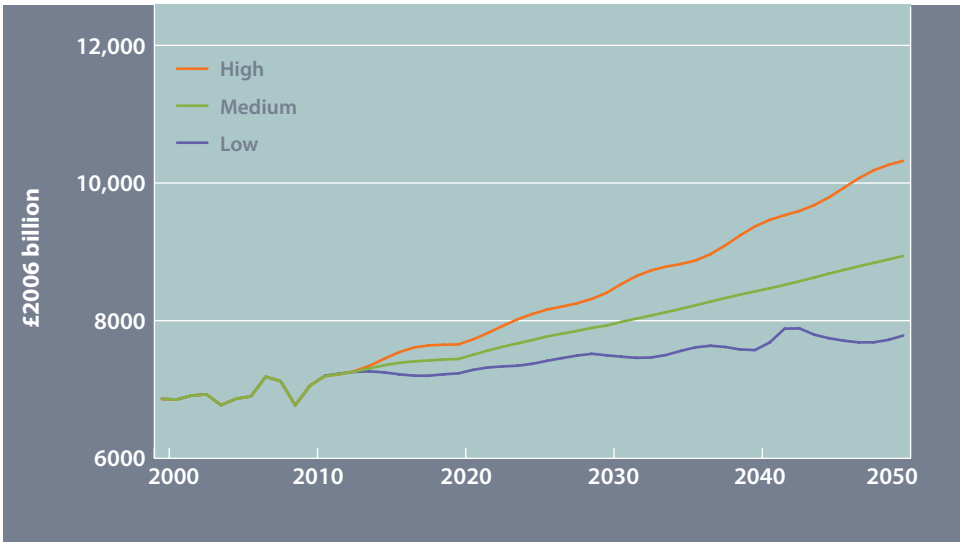


Figure 9: Household demand for infrastructure services: electricity.

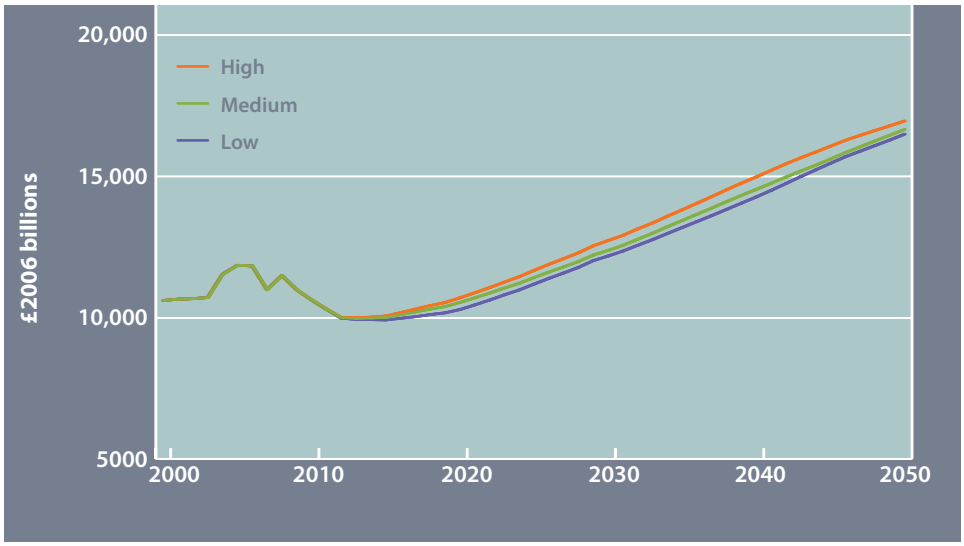
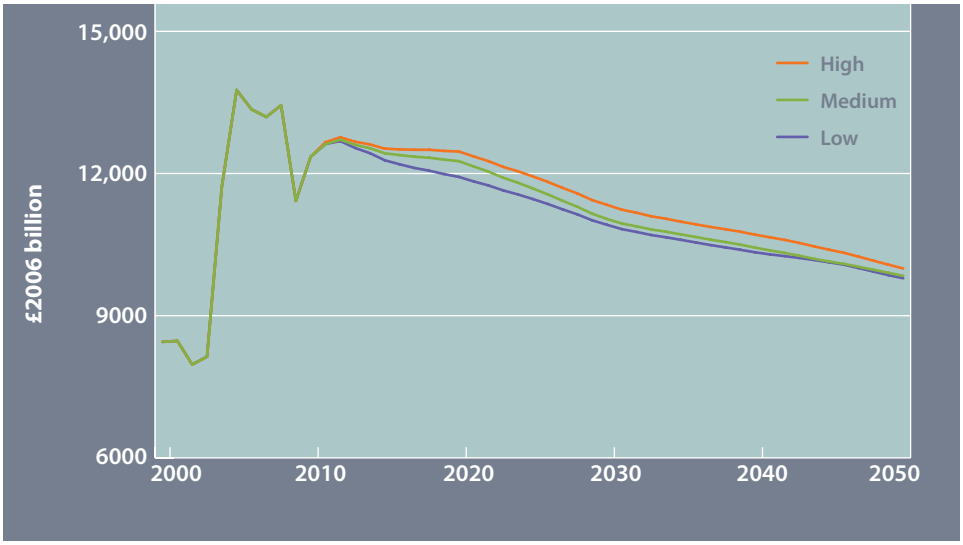


Figure 10: Household demand for infrastructure services: gas.



The MDM-E3 equation for aggregate energy demand from households shows energy demand to be quite inelastic in the long term (Figure 9); other things being equal, a 1% increase in household expenditure leads to an increase in energy demand of around 0.13%. Moreover, higher investment in dwellings in the high growth scenario compared to the medium growth scenario (and relatively lower investment in the low growth scenario) leads to greater energy efficiency. A low elasticity on activity and increasing energy efficiency through wealth/investment leads to modest differences in energy demand of +1.6% in the high growth scenario in 2050 and –0.7% in the low growth scenario, when compared to the medium growth scenario. However, the breakdown of this energy demand changes over time.

The medium growth scenario projection shows a shift towards greater electrification in the residential sector. Electricity demand grows by 1.5–2% over 2015–2030. The rate of growth slows thereafter and, towards the end of the projection period, grows steadily at around 1.25% pa.

Conversely, gas demand (Figure 10) falls over the projection period, by 0.25–1.25% pa to 2030 and by less than 1% thereafter. The long-run rate of decline in the medium growth projection is around 0.5% pa.

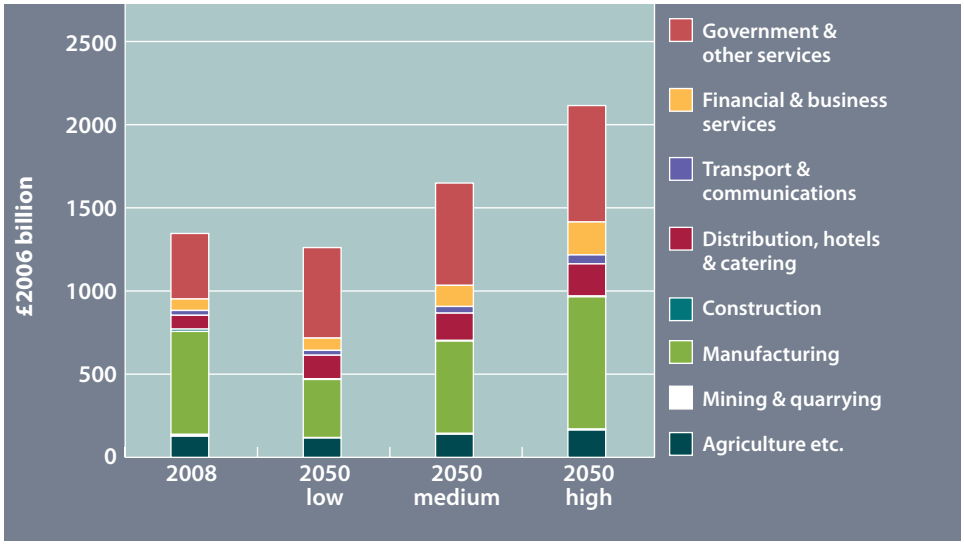
Across the three growth scenarios, the variation in the energy demand profiles is quite slight, owing to satiation/decoupling in energy demand.

D.8.4.2 Industry

To varying degrees, water services are an input to production and thus linked to trends in industrial production and the relative water intensities of industries (Figure 11). At the level of sectoral detail in MDM-E3, water constitutes a small share of the inputs to production. The most intensive industrial users of water services are Manufacturing (accounting for 46% of industrial water demand in 2008) and Government & other services (29%).

In the scenarios, output increases in all but Mining & quarrying to 2050 but the relative contributions of each sector to long term economic growth differs; there is a shift towards services. Despite its much higher water intensity, Manufacturing is outstripped by public services as the largest industrial consumer of water by value in the medium growth scenario. Government & other services' share of consumption in 2050 rises to over 37%. The shares of other services also rise (owing to their strong growths in output), but the increase is smaller because these other service sectors are less water intensive.

Figure 11: Industrial demand for infrastructure services: water.



The high and low growth scenarios have their most direct effects through changes in world economic conditions and thus exports. The changes in the inputs to the scenarios affect the relatively export-heavy Manufacturing sector more than they affect public services. Differences in demand for water services in Manufacturing drive most of the change in demand in 2050 across scenarios.

In the medium growth scenario, industrial demand for electricity and gas services grows modestly over 2008–2050 (Figures 12 and 13), and at a slower rate than the growth in output, owing to higher energy efficiency through both economies of scale and technical progress (higher investment leads to higher energy efficiency in addition to the less than one-for-one increase in energy demand with output).

Differences in energy demand between scenarios in 2050 are driven by Financial & business services (low energy intensity, but large changes in output) and Manufacturing (higher energy intensity but relatively smaller changes in output).

Figure 12: Industrial demand for infrastructure services: electricity.

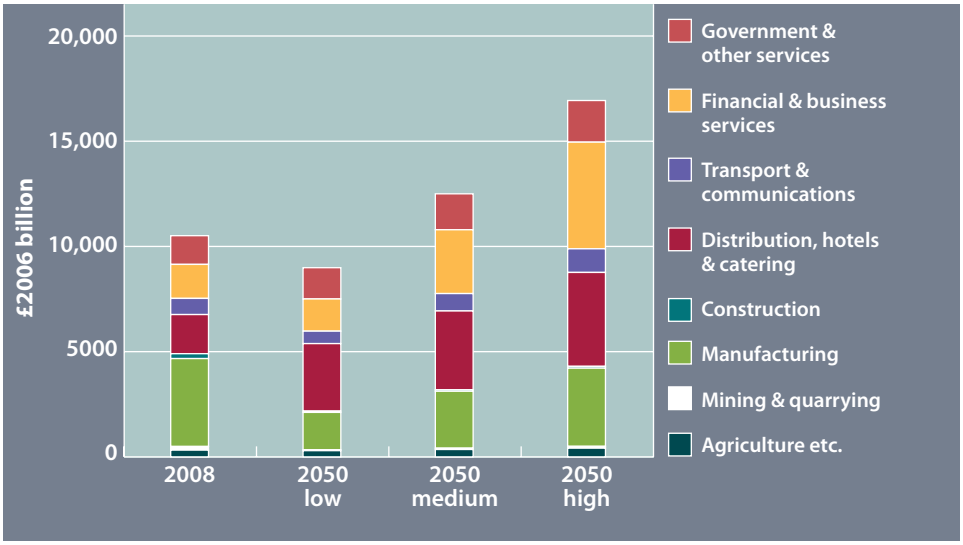
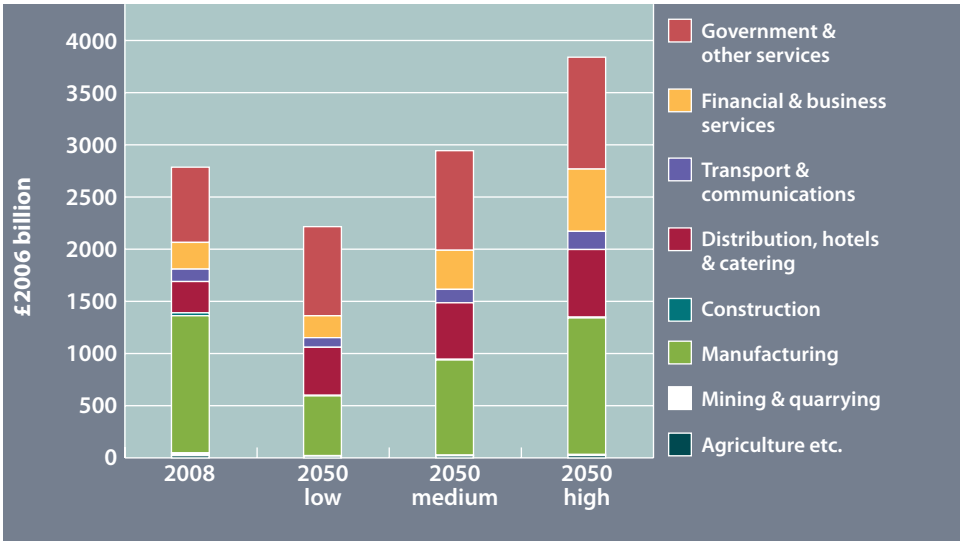


Figure 13: Industrial demand for infrastructure services: gas.



D.8.5 Energy and emissions results

D.8.5.1 Energy

Compared to the medium growth scenario in 2050, total UK energy demand (for primary and final use) is 5.3% higher in the high growth scenario and 4.9% lower in the low growth scenario (Figures 14–16). This implies an economy-wide income elasticity for energy demand of around 0.2: a 1% change in output/income leads to a 0.2% change in energy demand in the same direction.

Over the projection period, total energy demand shows a very slight upward trend from increases in primary energy demand for power generation (to meet higher electricity demand) and Transport (driven mainly by growth in air transport).

Total energy demand from Households and Commerce is relatively flat while in Industry there is a gentle fall over the projection period. The fall in Industry comes from both a general increase in energy efficiency over time (technological as well from economies of scale), but also a general shift away from more energy-intensive industries to relatively less energy-intensive ones.

Figure 14: UK energy demand – medium growth scenario.

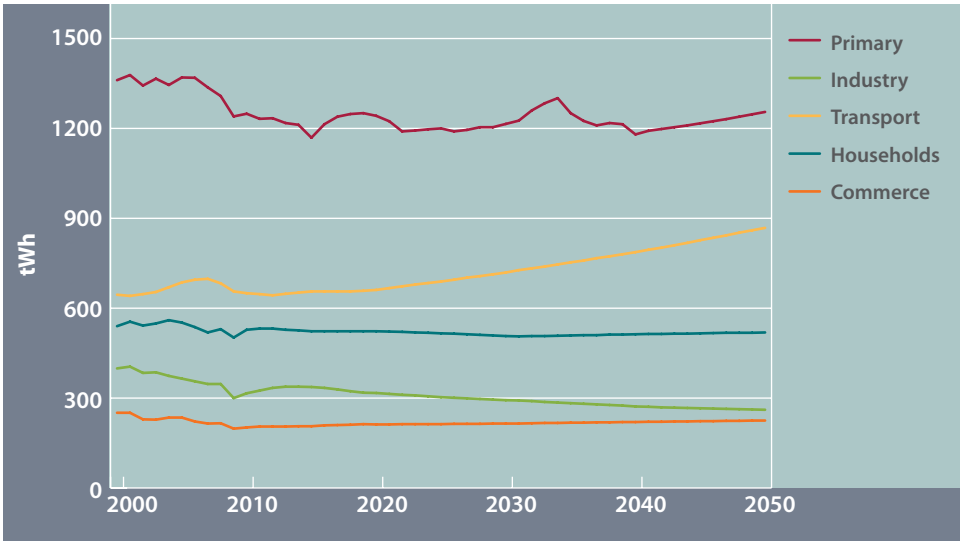


Figure 15: UK energy demand – high growth scenario.

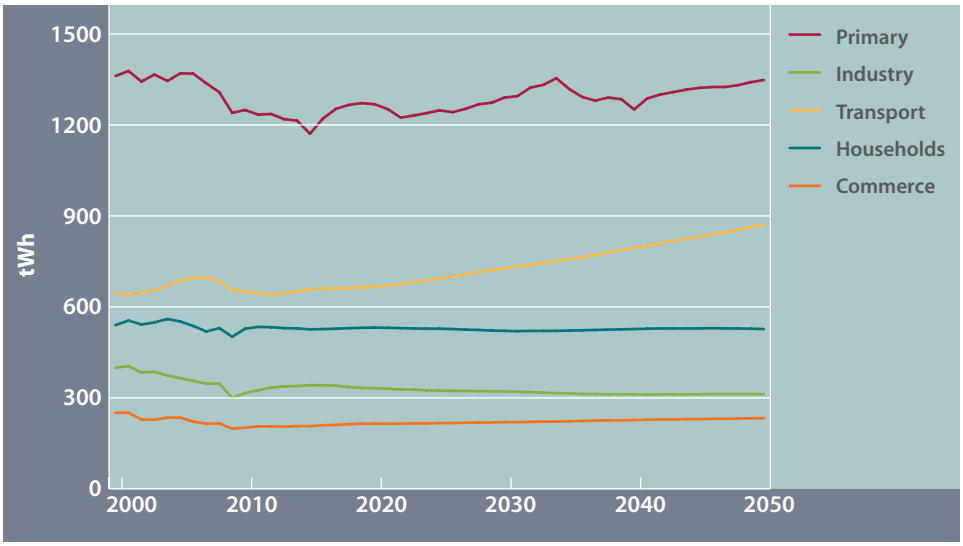
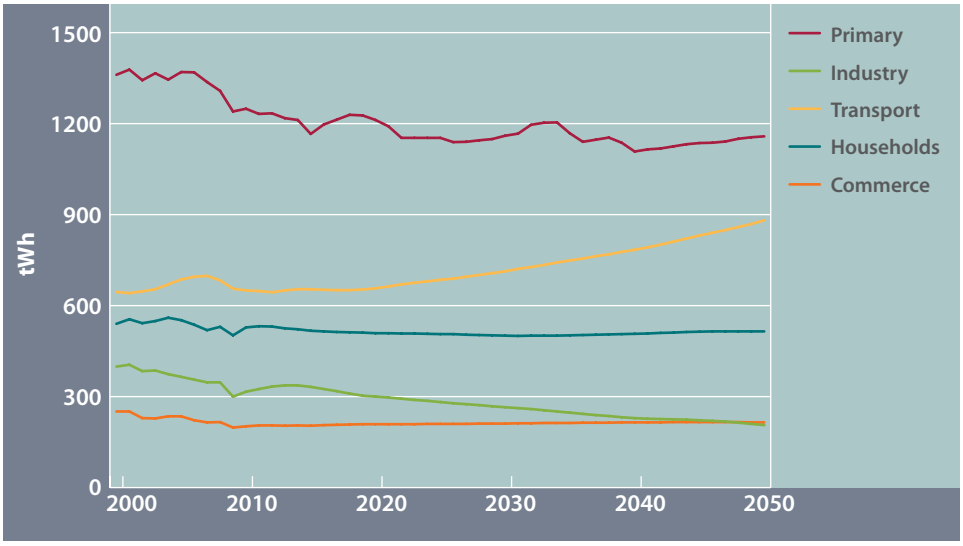


Figure 16: UK energy demand – low growth scenario.

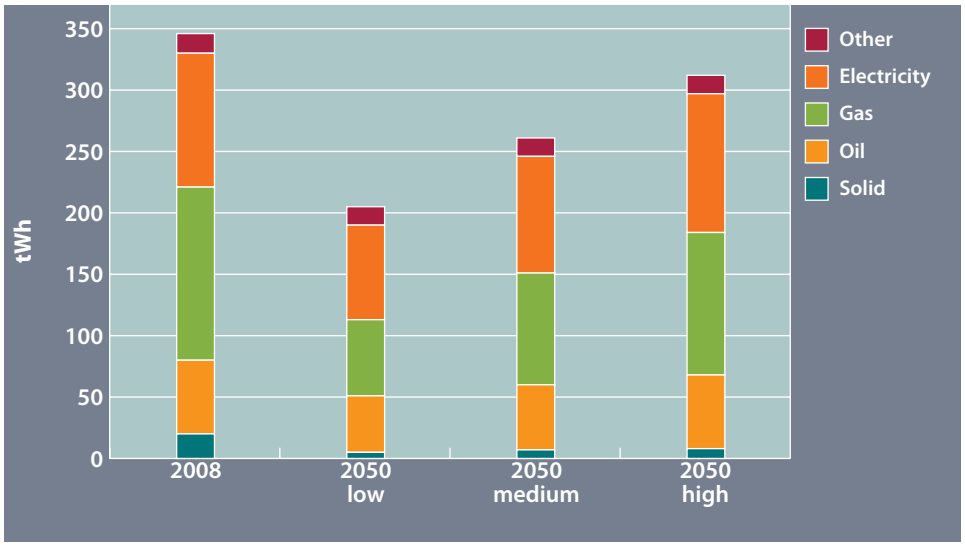


As previously mentioned, across scenarios, higher economic growth tends to lead to higher energy demand and lower growth to lower energy demand, with an implied economy-wide income/output elasticity of 0.2, implying substantial decoupling of economic growth and energy demand.

By sector, energy demand from Industry (Figure 17), the most energy intensive broad user, is most volatile across scenarios with the changes in world activity driving changes in the composition of industrial output, according to the differing export ratios of the sectors. A number of more energy-intensive sub-industries are affected, leading to the observed changes in energy demand.

Even so, the differences in Industry energy demand are still smaller than the changes in output, indicating decoupling over time.

Figure 17: UK final energy demand: industry.



Increases in engine efficiency over time from EU policies on fuel efficiency and emissions limits lead to falling demand for road transport fuel for a time, but sustained income growth in the long term (driving an increase in travel demand) offsets this effect in the medium growth scenario (Figure 18). Continuing past trends, diesel becomes more prevalent in the fuel mix. The Renewable Transport Fuel Obligation (RTFO) is imposed by assumption, requiring that 5% of transport fuel is sourced from renewables by 2013–2014. The share is held constant thereafter (no additional policy or behavioural response is modelled).

A feature of the scenario results is that Road Transport demand for fuel is lowest in 2050 in the medium growth scenario and higher in the high and low growth scenarios. This result occurs because demand for private road travel is driven by income per household, which is lowest in the medium growth scenario in 2050 and higher in the high and low growth scenarios.

In the low growth scenario, there is a smaller UK population and thus fewer households and in the high growth scenario a larger population and thus a greater number of households. In the high growth scenario, UK income increases by more than the increase in the number of UK households. This leads to greater income per household and, in turn, higher travel demand. Higher demand for fuel to facilitate the transport demands follows.

In the low growth scenario, the fall in income is less than the decrease in the number of households. Consequently, income per household in the low growth scenario is higher than in the medium growth scenario, driving slightly higher travel and fuel demand.

Energy demand from Households and Commerce is stable both across scenarios and through time, indicating lower energy intensity per unit of output/consumption (Figures 19 and 20).

Figure 18: UK final energy demand: transport.

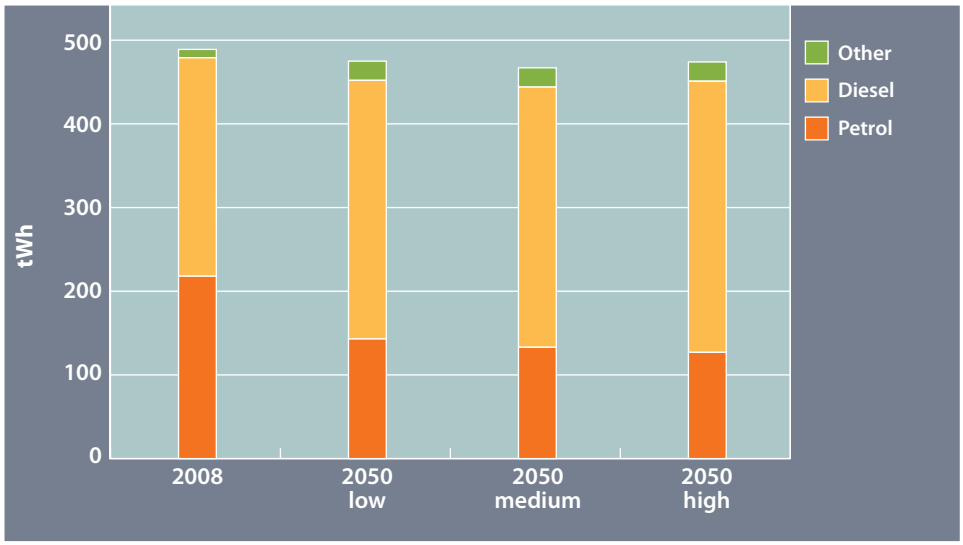


Figure 19: UK final energy demand: households.

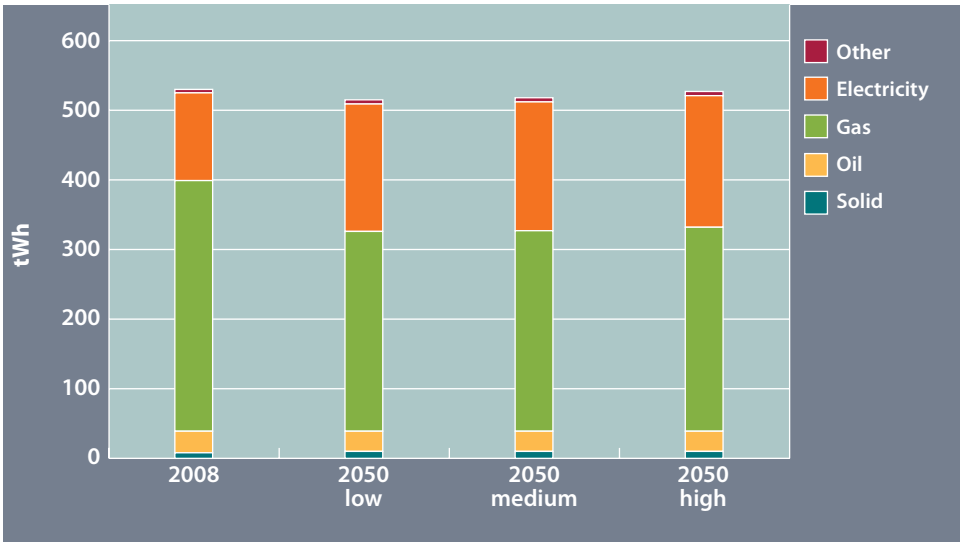
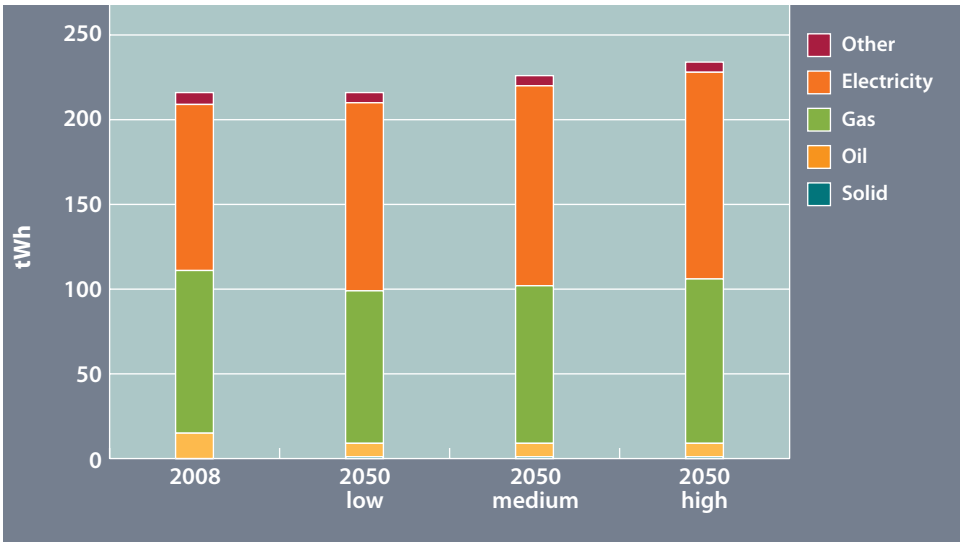


Figure 20: UK final energy demand: commerce.



D.8.5.2 Emissions

In the medium growth scenario (Figures 21 and 22), there is a general trend away from higher carbon-content fuels (solid fuels and oils) towards cleaner fuels (gas and electricity). This is driven mainly by investment (technology) and relative price (including carbon-price) effects. The emissions intensity per unit of final energy consumed falls over time. The shift to more electricity increases primary energy requirements of power generation, but even in this sector, some degree of decarbonisation takes place, with gas-fired generation displacing coal and, in turn, being displaced by increasing amounts of wind power as the gas plant is subsequently retired. Thus, CO_2 and GHG emissions fall over time.

Figure 21: UK CO_2 emissions – medium growth scenario.

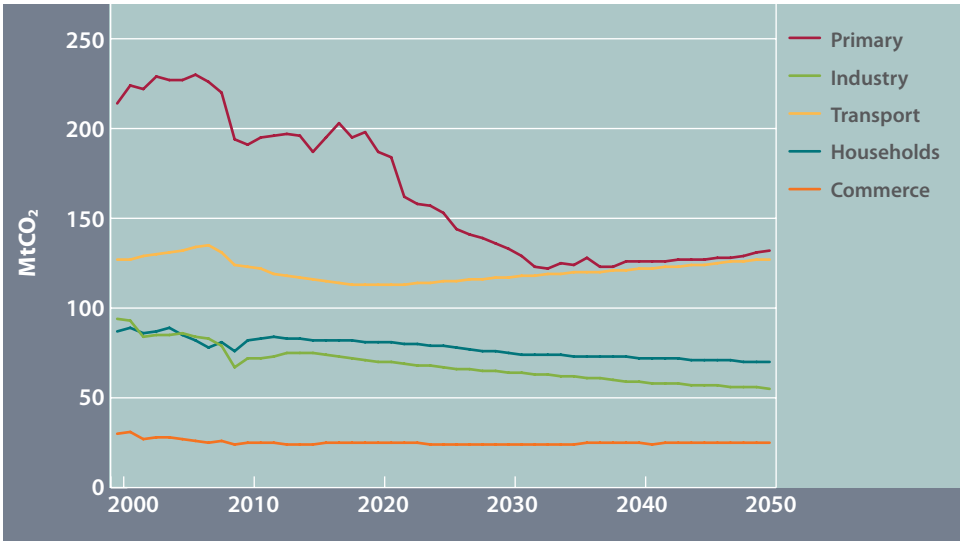


Figure 22: UK GHG emissions – medium growth scenario.

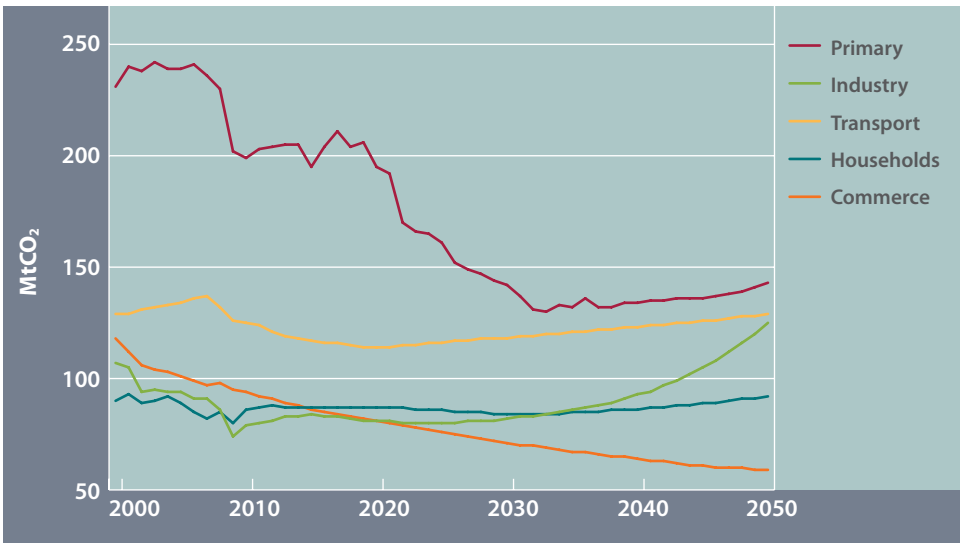


Figure 23: UK CO_2 emissions – high growth scenario.

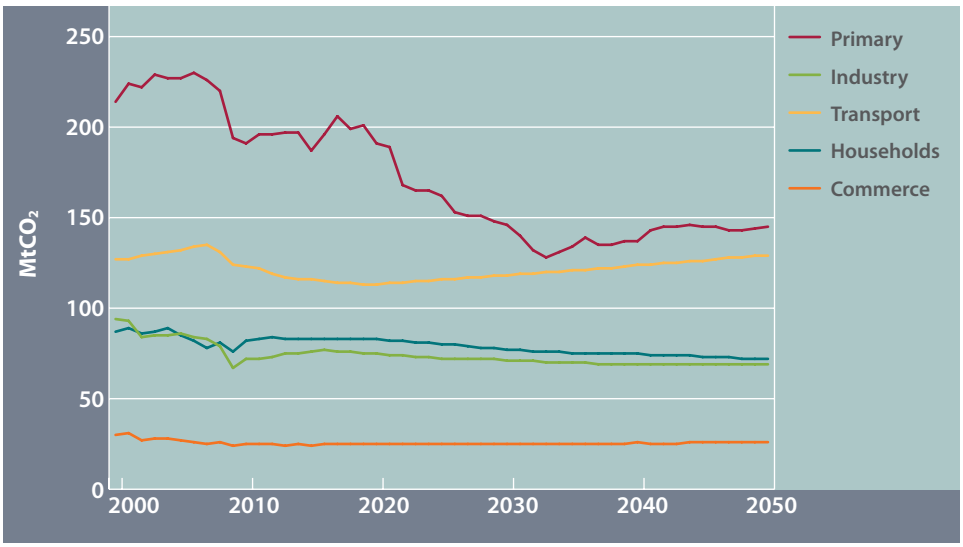
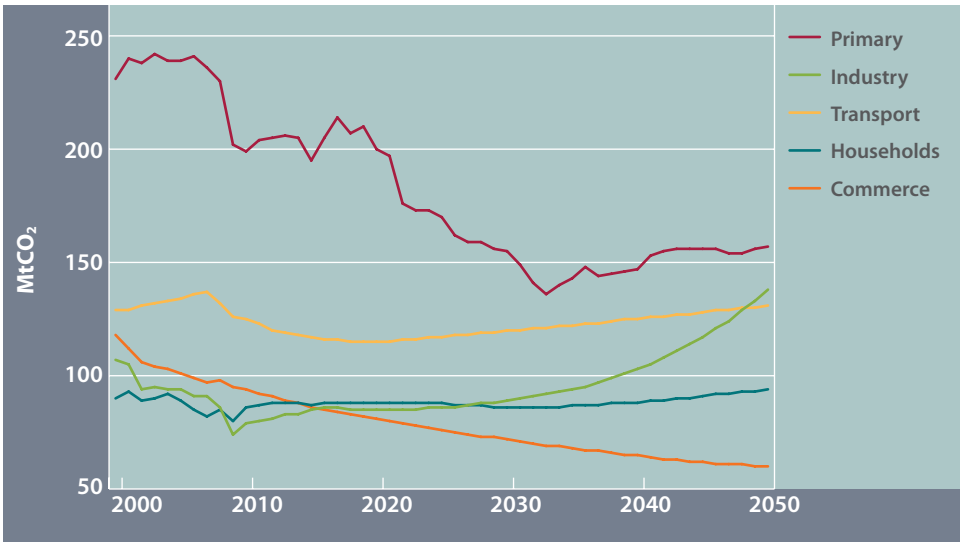


Figure 24: UK GHG emissions – high growth scenario.



Higher economic activity in the high growth scenario (Figures 23 and 24) leads to higher energy demand and thus somewhat higher emissions and, conversely, lower economic activity in the low growth scenario (Figures 25 and 26) ultimately leads to somewhat lower emissions. The increase in energy demand from an increase in output is less than one-for-one, leading to lower energy intensity in the economy, per unit of output, in the high growth scenario relative to the medium growth scenario and relatively higher energy intensity in the low growth scenario. Similarly, the differences in emissions are smaller across the scenarios than the differences in economic activity. Emissions intensity (per unit of output) is relatively lower in the high growth scenario and higher in the low growth scenario.

Figure 25: UK CO_2 emissions – low growth scenario.

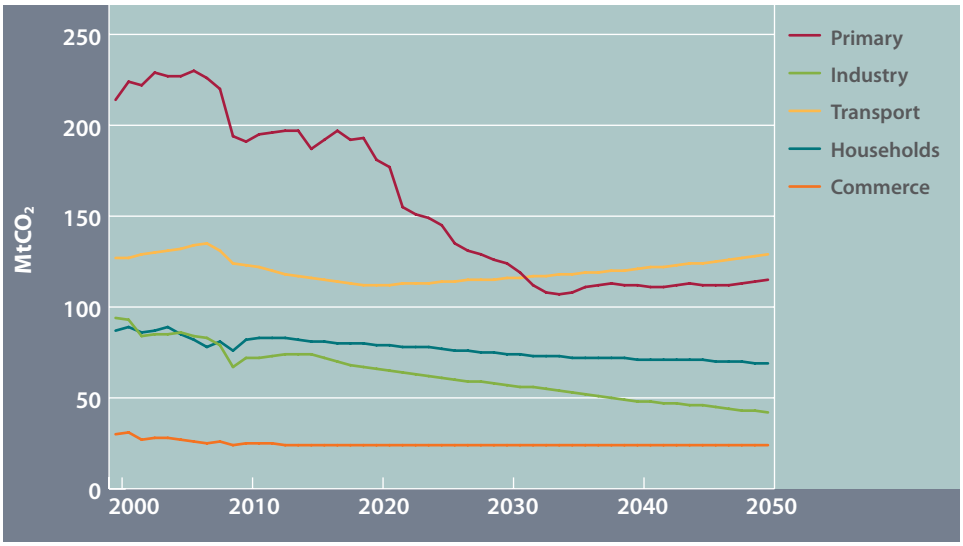
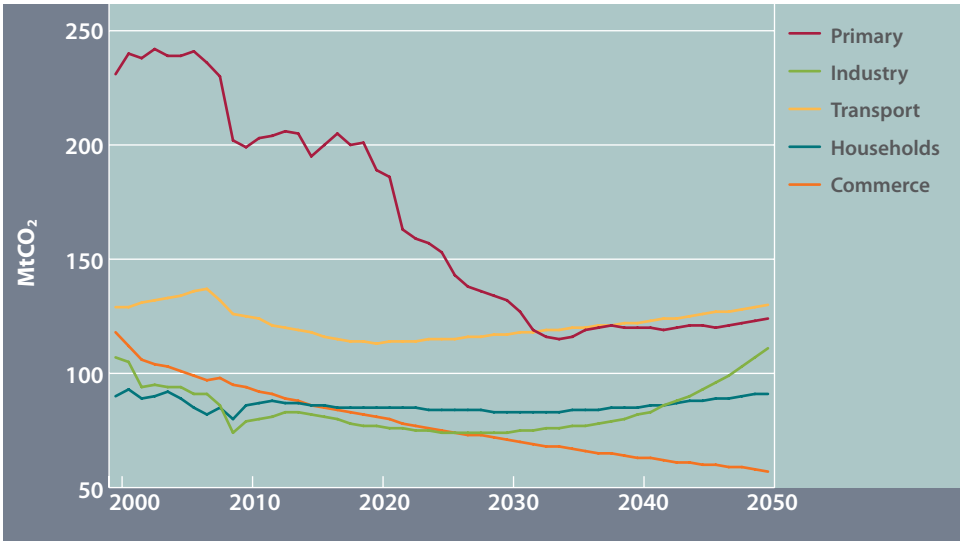


Figure 26: UK GHG emissions – low growth scenario.



D.8.6 Prices and wages

A model result that appears, on the face of it, unusual is that price and wage inflation is lowest in the high growth scenario and highest in the low growth scenario. Within the MDM-E3 framework this is an internally-consistent result that arises from growing economies of scale over time. UK firms face lower costs per unit of output, leading to lower end-user prices and lower nominal wages.

In the scenarios modelled for the FTA, a proportion of higher or lower UK GDP growth (on top of the changes in the demography, energy-price and government assumptions) comes about from an exogenous change in global demand for UK production. In the case of an increase in world demand, UK production must increase to meet the higher export requirements. One direct consequence of the increase in UK output requirements is an increase in employment, although by less than one-for-one in the current set of equation parameters in MDM-E3.

The less-than one-for-one increase in employment relative to output immediately implies an increase in labour productivity (output divided by employment) and thus indicates increasing returns to scale/economies of scale in production.

The wage system in MDM-E3 operates according to a wage-bargaining model in which workers bargain for wage increases according to economic factors such as:

- Inflation, to cover increases in the cost of living
- Unemployment; in times of lower unemployment, the labour supply is more constrained and replacing workers is more difficult
- Worker productivity; workers wish to be compensated for increases in skill/output

As already mentioned, in the high growth scenario, worker productivity improves, leading to workers bidding up their real wages. Higher real wages increase employment costs to firms and act as a compensating factor in response to the effect of increased output on employment.

In the scenarios, the output effect (driving employment up) outweighs the wage effect (pushing employment down) and the result is an increase in employment that outweighs the increase in average wages (slower wage growth compared to employment growth).

Remembering that the increase in output is the largest of all the effects, the cost of labour, per unit of output, falls in the high growth scenario relative to the medium growth scenario. Conversely, per-unit labour costs are highest in the low growth scenario.

In the high scenario, lower labour costs lead to lower production costs. MDM-E3 forms prices as a mark-up on production costs so a lower level of production costs, other things being equal, leads to a lower retail price. The nature of the economies of scale means that UK firms become more profitable. As outlined above, inflation is one of the drivers of higher wages; if prices are lower, workers find it harder to bargain for higher nominal wages. There is a tendency for both prices and wages to be lower in the high scenario and higher in the low scenario for similar reasons.

The logic above maps out the main drivers of the price and wage results in the scenarios. There are other compensating factors, but these are small relative to the main effects.

Technical progress in MDM-E3 is endogenous and derived from investment. Higher investment leads to increases in product quality that are reflected in increases in prices. The investment effect is relatively small across scenarios with some degree of offsetting from investment in energy-efficiency measures, leading to lower energy consumption per unit of output (lowering the cost of energy inputs to production; there is greater decoupling of output and energy demand in the high scenario).

We would expect periods of above-trend economic growth to lead capacity constraints because the economy is producing beyond its so-called 'normal' level of output. MDM-E3 does reflect this in the short run, but the scenarios represent states of the world in which the long-run trend rate of economic growth permanently changes. Over the 40-year projection period, firms adjust their expectations for future economic growth leading to less binding limits on capacity; the price effect in the long term is negligible.

In summary, labour and energy costs are lower in the high growth scenario relative to the baseline due to economies of scale. Demand for these inputs, per unit of output, is lowest in the high growth scenario because of greater labour productivity and energy efficiency. Conversely, low scenario shows the highest labour and energy costs owing to relatively lower realised economies of scale. The differences in the input costs explain the differences in prices across the scenarios.

As defined, the results from the MDM-E3 scenarios are internally- (i.e. model-) consistent outcomes given the inputs. One arguably counter-intuitive implication is that the UK faces no issues of scarcity in productive inputs and capacity. It is possible that sustained higher growth, on a global scale should lead to increasing resource depletion and scarcity. In turn, we would expect the prices of such commodities to rise, leading to higher prices for UK production. This is a mechanism that the model results fail to reflect and something that may be worth exploring further in the Work Stream 1 analysis.

One possible addition to the scenarios is an increase in world trade prices to reflect increasing scarcity of (imported) global resources. However, this addresses only part of the effect we would expect to see in such an event; the cost of domestically-produced inputs would also rise, but this would not be represented in an MDM-E3 scenario without further intervention.

D.9 CONCLUSION

This technical annex describes in more detail the economic modelling for the FTA, providing further information on the features of MDM-E3 and the model developments specific to the ITRC research programme. The annex continues by detailing the specification of the three FTA scenarios and provides additional detail on the drivers of these results as well as highlighting areas that may warrant further exploration and consideration for the analysis planned for Work Stream 1. In particular, for the given input assumptions, the model gives the result that higher levels of economic growth are associated with lower price and wage inflation. While an entirely model-consistent result given the inputs, the model perhaps fails to reflect physical constraints on higher growth that manifest themselves as resource depletion continues unabated.

Given the input assumptions, the model also shows that road transport fuel demand is higher in both the high and low growth scenarios compared to the medium growth scenario, further highlighting the different effects alternative trajectories of economic growth can have on income.

Other than the above, the model results are quite intuitive. BaU growth (the medium growth projection) comes mainly from services, a continuation of trends in pre-recession recent history. Regions that see the largest growth are those with the highest concentrations of such services and higher economic output gives rise to higher employment, with the scale of the effect dependent on changes in labour productivity over time.

Under different trajectories of UK GDP growth, the main differences come from the different assumptions about global economic activity leading to changes in export demand. Sectors with higher export ratios are affected more in both output and employment terms and the regions in which these sectors are located affected relatively more in output terms. The employment effects at the regional level depend on the nature (specifically, the labour productivity) of the sectors that make up each region's economy.

Economies of scale grow over time in all the projections, with more economies of scale realised as output growth increases. This leads to increasing decoupling between energy and economic growth, leading to substantially smaller percentage differences in energy and emissions across scenarios relative to the changes in activity.

The fuel mix in UK sectors evolves over time, becoming less carbon intensive. Final users switch to cleaner fuels, including electricity (which has no direct emissions as far as these fuel users are concerned). The increase in electricity demand must be met by increased power generation and the generation mix becomes cleaner over time, first with a shift to more gas-fired generation and then to wind power.