



The economic burden of Long Covid in the UK

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Authors

Eva Alexandri – ea@camecon.com

Alice Brooke – amb@camecon.com

Chris Thoung – ct@camecon.com

Ruairidh Milne - R.Milne@soton.ac.uk

Contributors

Rebecca Elliott – re@camecon.com

Project director

Chris Thoung – ct@camecon.com

Contact person

Eva Alexandri – ea@camecon.com

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Summary

Long Covid is prevalent in the UK population.

- While Long Covid remains inadequately understood, the evidence is clear on the adverse effects on people's lives. The most recent ONS estimates from early March 2023 suggested that there were almost 2m people living with Long Covid in the UK, representing some 3% of the UK population. While diverse in its symptoms, around 80% of people reported Long Covid as affecting their ability to carry out day-to-day activities in at least some way. For those more severely affected, people have reported being unable to live alone without assistance and either a reduced ability to work or having to leave work altogether. The financial implications for individuals and families may be substantial.
- Early hopes that Long Covid might prove to be short-lived have not been realised and at this point, Long Covid should be considered a long-term condition that requires investment in long-term solutions. UK government commitments to addressing Long Covid remain uncertain, with current funding in England of clinics for assessment and rehabilitation only recently extended to March 2025, with no commitment to longer-term support.

Long Covid has long-term economy-wide implications.

- With Long Covid now established in the population and clearly affecting health and livelihoods, there are questions about what Long Covid means in the longer term for the UK economy. This report takes the available evidence to examine future scenarios of Long Covid to 2030, considering trends such as future prevalence, effects on the ability to work and the costs of Long Covid treatment.
- Using our E3ME macroeconomic model to simulate a Long Covid future, the results suggest that Long Covid may have macroeconomic costs of some £1.5bn of GDP each year, with the impacts increasing if future prevalence were to rise. The main driver of this result is the way in which Long Covid reduces people's ability to work, leading to lower household incomes and lower economic growth overall. Lower employment of around 138,000 by 2030 follows as a consequence. The pattern of these impacts across the economy reflects a mix of sectors in which more people have Long Covid, leading to reductions in and exits from work; and lower economic activity, which tends to affect market services in an economy such as the UK.
- While GDP and employment are lower as a result of Long Covid, these impacts are likely greater than the numbers would first suggest, because the composition (quality) of that GDP has also changed. In the analysis, the assumption is that total government spending remains the same in the Long Covid scenario, such that any expenditure on Long Covid-related healthcare involves a reduction in some other item(s) of public spending, whether in health or more widely. In the current fiscal environment, this represents a trade-off. As seen early in the pandemic, COVID-19 placed acute pressure on a health system already struggling with mounting waiting lists and deteriorating performance. Our analysis suggests that Long Covid, if it proceeds according to current knowledge and trends, may represent a further source of chronic (i.e. systemic) pressure and a drag on economic growth.

Table 1: Macroeconomic impacts of Long Covid in 2030

	Impact in 2030	Comment
GDP (£2023bn)	-£1.5bn	Impact if Long Covid cases remain at 1.9m people pa. GDP impact increases to -£2.7bn if cases rose to 4m people by 2030.
Household income (£2023bn)	-£1.3bn	Impact if Long Covid cases remain at 1.9m people pa. Impacts increase to -£2.1bn if cases rose to 4m people by 2030.
Long Covid health expenditure (£2023bn)	£4.2bn	Impact if Long Covid cases remain at 1.9m people pa. Expenditure could increase to £9.3bn if cases rose to 4m people by 2030.
Employment	-138,000	Impact if Long Covid cases remain at 1.9m people pa. Employment impact increases to -311,000 if cases rose to 4.0m people by 2030.

Note(s): £2023bn refers to monetary values reported in real terms. Impacts are reported relative to a baseline without Long Covid. Impacts are for 2030 only (i.e. not cumulative).

- There are two ways of thinking about the health system implications of Long Covid, both of which represent new pressures on or demands of the system. Management and treatment costs need staff and funding. Based on UK employment trends, the analysis suggests a need for some 46,000 public healthcare workers to support Long Covid treatment. If government expenditures do not increase to accommodate this, then one possible outcome is that spending and staffing for other public services may have to fall. The UK health system is, however, already under strain. Another possibility is that health expenditures relating to Long Covid lead to further reductions in elective care, in the form of longer waiting lists and reduced service. Either situation would be exacerbated by higher future prevalence and there are policy choices to be made in this regard. The analysis also does not consider the possibility of resorting to private care, which would further raise the monetary cost on people and their families.
- There is some evidence of overlap between Long Covid and deprivation, with a higher prevalence of Long Covid among people who are more likely to be on benefits or to live in social housing. Our macroeconomic modelling results suggest employment effects also impact lower-income households *without* direct experience of Long Covid, with the pattern of wider employment losses including retail and hospitality, which are typically lower paid. Workers in other services sectors are relatively more affected. These sectors are also those with higher proportions of women.
- Two further reasons to think that the societal impacts of Long Covid might be larger than the macroeconomic impacts set out above concern the following, both of which lie outside of the scope of the current assessment:
 - the (monetary) value of the disease burden, i.e. in terms of quality-adjusted life years, which is likely substantial but lies outside of the boundary of a macroeconomic assessment
 - the impact of Long Covid on informal carers, whose time is not captured in GDP and whose (potential) income losses are not explicitly captured in the analysis

By the above, the overall impacts on welfare, health and wellbeing may well be larger than is implied by the reductions in GDP and employment alone.

- This analysis draws on a range of published sources to inform the modelling. However, with the situation continuing to evolve and new research emerging, some of the assumptions, such as the impact of Long Covid on income, are based on data from earlier stages of Long Covid. Research into Long Covid continues and outputs from ongoing studies tend to suggest that longer-term impacts could be higher than has been assumed in this report. If this is the case, the results reported here may prove to be a lower estimate of the macroeconomic consequences.

Funding to support Long Covid is possible, and future treatments could also help.

- Our analysis sheds light on the macroeconomic consequences of Long Covid, which go beyond and magnify the effect of Long Covid on people's ability to work and earn income. Wider economic activity and employment suffers as a consequence.
- The final part of our analysis considers alternative tax options for government funding of healthcare, rather than reallocating existing government expenditure. This analysis shows that Long Covid treatment can be funded on top of existing government expenditures, although the choice of tax instrument does itself have macroeconomic impacts. Income taxes tend to have a slightly more negative impact than, for example, higher national insurance contributions on the part of employers.
- Moreover, the government health expenditures considered in this analysis focus on how Long Covid is currently treated (i.e. patterns of healthcare utilisation by people with Long Covid). Research into Long Covid continues to explore options for more effective treatment and management. Should these prove effective, healthcare costs might increase initially, before potentially decreasing in the long run.

Inaction on Long Covid is as much a policy choice as concerted action.

- Focusing on the UK macroeconomy to 2030 we estimate that Long Covid is likely to reduce GDP by £1.5bn and around 140,000 jobs each year. Were the number of cases to rise from current estimates of around 2m people per year to 4m people per year, these negative impacts would be larger, as more people become ill and less able to work. For example, were cases to double by 2030, the negative impacts would also increase, to £2.7bn of GDP and 311,000 jobs.
- Expressed specific NHS England funding for Long Covid is confined to Long Covid clinics and this support is due to end in March 2025. Nevertheless, the health needs of those with Long Covid must still be met. As seen in the early, acute phases of the pandemic, this stands to put more pressure on a healthcare system that is already under strain. Healthcare resources are needed regardless and, if total government spending remains unchanged, spending on other public services may need to fall. A continuation of the current situation is as much a policy choice as concerted action.

1. Introduction

1.1 Overview

Long Covid refers to prolonged symptoms of COVID-19 beyond the acute period of four weeks. Symptoms associated with Long Covid are wide and varied, including respiratory issues, cardiovascular symptoms, neurological problems and physical ailments. Rather than being a single condition, Long Covid may actually describe several distinct syndromes (collections/clusters of symptoms).

Given the pace of global COVID-19 infections, and the subsequent rise of Long Covid, the situation with respect to prevalence and consequences is rapidly evolving. Nevertheless, the (now-lapsed) UK Coronavirus (COVID-19) Infection Survey suggests that Long Covid prevalence, on a self-reported basis, rose to 1.9m people by March 2023. This represents almost 3% of the UK population. For reference, there are 4.3m people (6% of the population) in the UK living with a diagnosis of diabetes, and perhaps a further 850,000 living with diabetes without having been diagnosed.

Long Covid affects all groups but there have been more cases among those aged 35-69 as well as women. Cases also appear higher among people living in more deprived areas and those with other pre-existing long-term health conditions. By sector, Long Covid cases are higher among people working in social care, education, and health and social care.

Severity varies but, of the estimated 1.9m people living with Long Covid, a high proportion report being limited in some way in their day-to-day activities, whether 'a little' (59% by March 2023) or 'a lot' (20%).

1.2 Objectives

Given the rise and symptoms of Long Covid, and the impact of these symptoms on people's ability to work, the potentially chronic nature of Long Covid is of long-term macroeconomic concern.

This report sheds light on the macroeconomic implications of Long Covid, considering the effects on the ability to work whether leading to:

- withdrawal from the labour market
- partial withdrawal from a reduction in working hours owing to Long Covid

The impact of Long Covid on the ability to work goes on to affect labour supply, production and incomes, leading to wider macroeconomic impacts on GDP and employment beyond the economic effects on those living with Long Covid.

It is important to bear in mind that Long Covid remains inadequately understood and the evidence base continues to evolve. As such, the analysis presented in this report seeks to draw on the available evidence as much as possible in an evolving situation, while also acknowledging the ongoing uncertainty about the future effects of Long Covid as a now long-term condition.

1.3 Structure of this report

This report consists of three further chapters. Chapter 2 provides an overview of current evidence as it relates to the macroeconomics of Long Covid. Chapter 3 presents the assumptions and results from the macroeconomic modelling. The report concludes in Chapter 4. Chapter 5 lists references and the appendix gives a brief overview of the macroeconomic model applied in this analysis, Cambridge Econometrics' E3ME model.

2. Long Covid in the UK

This chapter provides a brief summary of the evidence on Long Covid in the UK as it relates to a macroeconomic assessment, as presented in Chapter 3. This current chapter discusses estimates of Long Covid prevalence and symptoms and implications for work and healthcare costs.

As noted throughout, research on COVID-19 and Long Covid is ongoing and the situation thus continues to evolve. This is a challenge to any assessment and it should be borne in mind that new studies are published frequently, shedding new light on different aspects of Long Covid.

2.1 Long Covid prevalence

While there remains no formally agreed definition, the term Long Covid commonly refers to symptoms that either continue or develop after a period of acute COVID of up to four weeks (see, for example, Barber *et al.*, 2021).¹ NICE (2024) provides clinical case definitions that further identify ongoing symptomatic COVID-19 as signs and symptoms that last for 4-12 weeks and post-COVID-19 syndrome as those that continue for more than 12 weeks. NICE (2024) notes that both ongoing symptomatic COVID-19 and post-COVID-19 syndrome are commonly referred to as Long Covid.

From the UK Coronavirus (COVID-19) Infection Survey, covering the four weeks to 5 March 2023, the UK Office for National Statistics (ONS) (2023) estimated that 1.9m people were experiencing self-reported Long Covid symptoms.² This represents almost 3% of the total UK population. To give a sense of scale, this estimate compares to 4.3m (over 6% of the UK population) living with a diagnosis of diabetes, and perhaps a further 850,000 who could be living with diabetes but who have not been diagnosed (Diabetes UK, 2023). The majority of those suffering with long Covid are of working age. The ONS (2023) data suggest that 85% self-reporting symptoms (an estimated 1.6m people) were aged between 17 and 69. An earlier analysis by the Institute for Fiscal Studies (IFS) (Waters and Wernham, 2022), based on the 2021 UK Household Longitudinal Study, was consistent with ONS findings at the time. The total number of people affected by Long Covid is important as it gives an indication of the size of healthcare resources needed to manage and treat the illness, while the prevalence among people of working age has direct implications for economic growth. Working age people represent potential workers in an economy, and thus also represent productive potential for future growth. Both numbers (1.9 m people with Long Covid and 1.6m of which are working

¹ Most definitions in use tend to agree on the persistence of symptoms, differing more in the duration of symptoms before being considered as Long Covid. For example, the World Health Organization (WHO) (2022) defines Long Covid as ‘the continuation or development of new symptoms 3 months after the initial SARS-CoV-2 infection, with these symptoms lasting for at least 2 months with no other explanation’.

² As in ONS (2023), self-reported Long Covid is defined as symptoms lasting for more than four weeks after the first or suspected infection, and not explained by something else. This is consistent with a definition of Long Covid that encompasses both ongoing symptomatic COVID-19 (signs and symptoms lasting 4-12 weeks) and post-COVID-19 syndrome (lasting more than 12 weeks).

age) are important in the macroeconomic assessment, as explained in Sections 2.4 and 3.2 of this report.³

Other interesting findings around the prevalence of Long Covid in the population are around gender. The same ONS (2023) data indicate that women appear somewhat more likely to have Long Covid, accounting for 58% (1.1m) of those with Long Covid⁴, a finding also corroborated by the IFS study (Waters and Wernham, 2022).⁵ The prevalence of long COVID in the UK economy is higher in sectors that have a higher percentage of women employed, as hinted by the ONS survey (2023). Interestingly, the most sectors indirectly impacted by Lon Covid (because of the income impacts) are those that also employ a larger share of women, as discussed further in Chapter 3.

Long Covid seems to be more common among those with pre-existing long-term health conditions and living in social housing (Waters and Wernham, 2022). People with Long Covid were also more likely to be claiming benefits, with Waters and Wernham (2022) pointing out that a high proportion of Long Covid sufferers were recorded as receiving disability benefits for (the aforementioned) long-term health conditions. These findings hint that Long Covid could have implications on the distribution of economic impacts, with more vulnerable households suffering the brunt of the impacts. While this is outside the scope of the current analysis, it is briefly touched on in Chapter 3 and may warrant additional investigation.

2.2 Long Covid symptoms

Long Covid describes several distinct syndromes (collections/clusters of symptoms), rather than being a single condition (as in, for example, National Institute for Health and Care Research [NIHR], 2021). These symptoms can change (including relapse) over time, as can their severity (NICE, 2021, and Brown and O'Brien, 2021; in Kwon *et al.*, 2023).

The symptoms of Long Covid vary in severity, with many people reporting experiencing symptoms severely enough for them to affect their day-to-day activities. The same ONS (2023) analysis cited above, reported that 59% of people with self-reported Long Covid were adversely affected 'a little' in their day-to-day activities; while 20% were adversely affected 'a lot'. Of an estimated number of people with Long Covid at the time of 1.9m, this breaks down to 1.1m and 0.4m people, respectively.⁶

The ONS (2023) analysis is consistent with evidence from other research on Long Covid. Sivan *et al.* (2023) suggest that the burden and disability associated with Long Covid may be worse than what is currently estimated in literature for other chronic conditions such as Diabetes Mellitus, COPD, Heart Failure and

³ UK Coronavirus (COVID-19) Infection Survey for the four weeks to 6 March 2021.

⁴ This share of 58% of people with Long Covid being women compares to women accounting for 51% of the UK population, according to mid-2021 estimates by the ONS (2022b).

⁵ The finding for women was not statistically significant in the IFS analysis.

⁶ From ONS (2022a), the corresponding figures for the four weeks to 5 March 2022 (between the two years reported in the main text) suggest that 1.7m people were experiencing self-reported Long Covid. Of those 1.7m, 48% said that Long Covid affected their ability to undertake day-to-day activities 'a little' and 19% reported the effect to be 'a lot'.

Multiple Sclerosis. Initial results of the study revealed that most patients in the sample had experienced a deterioration of health over 18 months since Long Covid, with no signs of recovery in the imminent future. Ziauddeen *et al.* (2022) also found that a high proportion of people reported that Long Covid has affected their ability to carry out a range of activities, including domestic chores, leisure and social activities, work, self-care and caring responsibilities. Even at this relatively early stage of the pandemic, people were reporting functional limitations and almost one-third reported that they were unable to live alone without any assistance.

Another study, jointly by the Trades Union Congress (TUC) and Long Covid Support (2023) and based on a survey, found that 63% of surveyed people had their ability to carry out normal day-to-day activities in substantially impacted by Long Covid, with a further 33% saying their ability had been limited to some extent. That is, almost all people surveyed reported some adverse effect of Long Covid.

With symptoms persisting (and possibly continuing to deteriorate) with no complete resolution or full recovery, Sivan *et al.* (2023) conclude that Long Covid should be considered as a Long-Term Condition, with all the implications that carries in terms of national investment in its management and the financial costs this may imply. The proportion of people who are substantially affected by Long Covid in their day-to-day activities has direct implications for UK employment and productivity, as further highlighted in Sections 2.3 and 3.2 of this report.

2.3 Long Covid and work

From the earlier section, the ONS (2023) data suggest some 1.6m people of working age in the UK are living with Long Covid. With a variety of symptoms identified, and with people reporting how Long Covid affects their day-to-day activities, there are clear implications for the ability to work. Various studies point to these effects.

For example, Sivan *et al.* (2023) found that just 21% of people had been able to maintain their previous roles prior to Long Covid infection. A much larger proportion (62%) had been affected, either by having to take sick leave, reducing their hours, changing roles or quitting altogether.

Studies have also noted the accompanying losses of income, which has welfare implications. Early survey data (Ziauddeen *et al.*, 2022; in November 2020) reported lost income by 37% of people with Long Covid. A follow-up survey one year later (Ziauddeen *et al.*, 2023; in November 2021) recorded 47% of people reporting lost income. The later TUC and Long Covid Support (2023) survey over September-October 2022 found that 14% of people said that they had lost their job because of reasons connected to Long Covid and 50% were having to use savings to support themselves financially.

These earlier estimates of income losses may have been temporarily offset by various Covid- and wider employment-related policies. More recent evidence points more strongly to income losses, with various papers noting financial hardship for those with Long Covid. Kwon *et al.* (2023) estimated income losses from a sample of Long Covid patients referred to specialist Long Covid care clinics. The average reduction in annual incomes was found to be £12,897, with much variation by sector. People suffering with Long Covid for longer (more than two years) were more likely to see larger income losses. At individual/household level, these income impacts appear substantial, both immediately, but also have longer term implications with respect to economic security, standards of living and pension pots.

While the evidence points strongly to income losses from Long Covid, existing literature appears quite uncertain as to the precise numerical size, though financial hardship is certainly noted in various papers. At individual/household level, these impacts are potentially substantial both immediately (in terms of lost income) but also longer term with respect to their economic security, standards of living and pension pots. How economic factors drive wider determinants of health and wellbeing are also well known.

2.4 Health costs of Long Covid

At an individual level, cost estimates of Long Covid treatment are now emerging with Mu *et al.* (2023) finding a cost per person with Long Covid of £3,350. This cost estimate is higher than for most other comparison groups considered over the period (January 2020 to January 2023). This figure is also higher than the estimated costs of Chronic Fatigue Syndrome/Myalgic Encephalomyelitis (CFS/ME), which might otherwise have offered some proxy value for the costs. Nearly half of people with Long Covid are thought to suffer from CFS/ME (Salari *et al.*, 2022) and the Optimum Health Clinic Foundation (2017) estimated health costs of £1,370 per person per year. Compared to other chronic conditions, the cost per person with Long Covid is slightly higher compared to per person expenditure needed for those suffering from coronary heart disease (£2,995), diabetes (£2,364) or hypertension (£2,706), but below the per person cost of those with COPD (£4,114). The comparison costs for coronary heart disease, diabetes, hypertension and COPD cover primary, secondary and prescription costs and are based on data published by Public Health England (2020) and adjusted by inflation (ONS, 2023, dataset ID: MM23) to reflect 2023 prices.

Of further possible concern is that Mu *et al.* (2023) note that health system utilisation is elevated for primary care but also emergency departments. The first may be understandable if initial efforts are devoted to diagnosis but the second potentially raises concerns about the ability of current arrangements to help manage Long Covid effectively. Mu *et al.* (2023) also found that pre-pandemic appointments/admissions were higher than during/after. It is not clear precisely what explains that result though some combination of more limited healthcare resources and changing patient behaviour (to avoid healthcare) are put forward as plausible explanations.

At this stage, the direction that future healthcare costs might take is unclear.

3. Long Covid and the UK economy

The previous chapter gave a sense of the current state of knowledge about Long Covid, highlighting a continually evolving situation and areas of uncertainty. This chapter goes on to present a macroeconomic assessment of how persistent Long Covid might affect the UK economy to 2030.

The aim of the analysis is to assess the macroeconomic and labour market implications for the UK economy of Long Covid. This focuses on how the ability to work (and earn income) on the part of those with Long Covid might lead to wider macroeconomic effects. The analysis necessarily abstracts to a macro level.

The approach involves comparing different projections (alternative futures) to a baseline case i.e. an assessment of how the UK economy might fare in the different scenarios once compared to a baseline scenario (implicitly, of no Long Covid). Given the only differences between the scenarios arise from explicit policy changes and other assumptions, the difference between the scenarios can be taken as an indication of the likely impacts of the assumption made about Long Covid and possible policy responses..

The sections that follow describe the approach to the macroeconomic analysis, the assumptions that make up the various scenarios considered, and present the results from both the main scenario and a series of sensitivity analyses (to account for the uncertainty about various aspects of Long Covid).

3.1 Approach

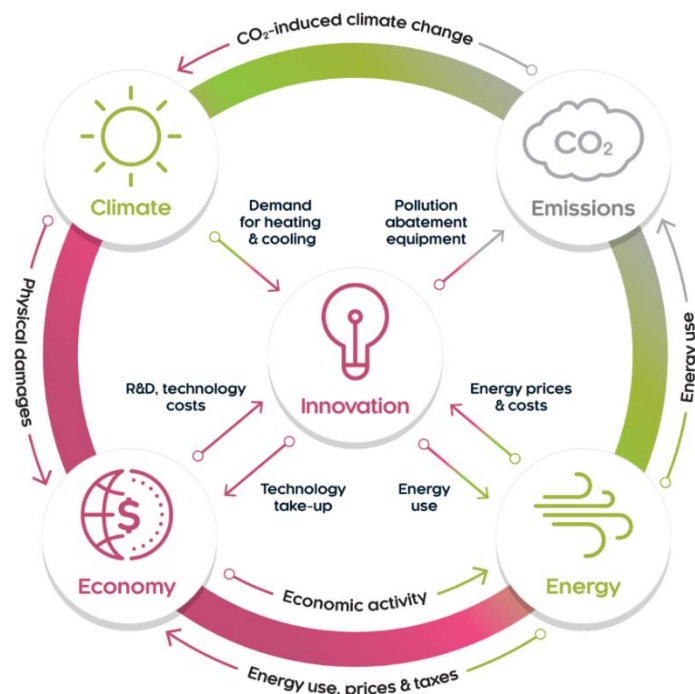
To assess the implications of Long Covid on the economy, Cambridge Econometrics' E3ME model was used to simulate different possible futures for the UK economy. Introducing assumptions about future prevalence of Long Covid and its effects shows how the rest of the economy reacts, going beyond the initial effects of Long Covid to trace out wider macroeconomic impacts.

E3ME is an econometric model of the global economy, designed to replicate the movements (dynamics) of a modern economy, as observed in historical data. The model is frequently and most typically used for *ex ante* assessment of future scenarios and policies, providing a tool with which to examine the economic consequences of a range of different futures.

E3ME distinguishes the UK as a distinct economy among 71 others. The UK is the economy of focus in the analysis that follows. The model has a high level of sectoral disaggregation, identifying 70 sectors, from agriculture to a range of manufacturing sectors, utilities, construction and an array of public and private services. A brief description of the model is in the appendix of this report, with a full technical description available online (Cambridge Econometrics, 2022).⁷

Figure 3.2 shows E3ME's core economic structure for a single country, depicting the main economic flows in the model. Most of the economic variables shown in the figure are broken down by sector. The model includes both accounting identities (e.g. GDP as the sum of the different components of expenditure) and behavioural relationships (such as the relationship between household income and spending). These interact, creating several feedback loops in the model. An initial impact may be either amplified or dampened depending on the relative strength of the various effects.

Figure 3.1: The E3ME model



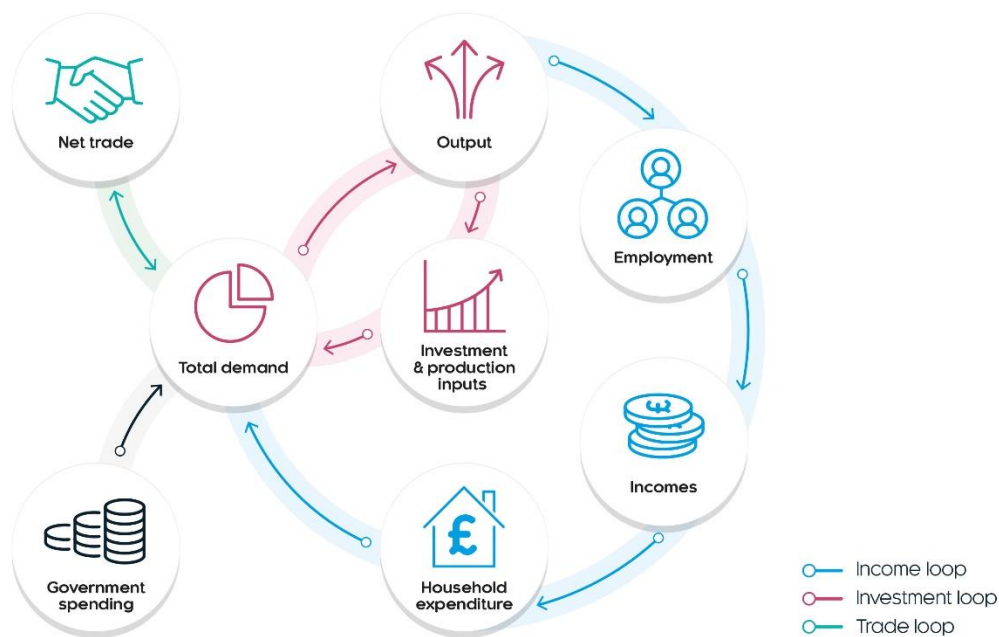
Source(s): Cambridge Econometrics.

The main feedback loops in the model are:

- Between sectors:** If one sector increases production it will buy more inputs from its suppliers who will in turn purchase from their suppliers. This is the link between output, investment and production inputs, and total demand in the figure.
- Income:** If a sector increases output, it may also increase employment, leading to higher incomes and additional consumer spending. This in turn feeds back to the economy through expenditure, requiring further production. In the figure this is represented by the link between employment, incomes, and expenditure leading to higher demand.
- Investment:** When firms increase output (and/or expect higher levels of output in the future) they must also increase productive capacity, requiring investment. This creates demand in sectors that produce investment goods (e.g. construction, engineering) as well as their supply chains, by the sectors loop above.
- Trade:** Some of the increases in demand in a country will be met by imported goods and services. This leads to higher demand and production in other countries, which in turn may stimulate further activity in the original country, from new export demand. As a result, there is also a link between countries through international supply chains, which is also affected by relative international competitiveness.

⁷ For more information, see: <https://www.e3me.com/>

Figure 3.2: The structure of the economy in E3ME



Source(s): Cambridge Econometrics.

The approach is to then to link existing information on Long Covid to the economic framework presented in Figure 3.2 to simulate a range of future scenarios out to 2030 and see how different assumptions about Long Covid might lead to outcomes that differ from a baseline case without Long Covid. The range of assumptions that can be explored is limited by the information on Long Covid impacts available and which can be measured and linked to macroeconomic variables.

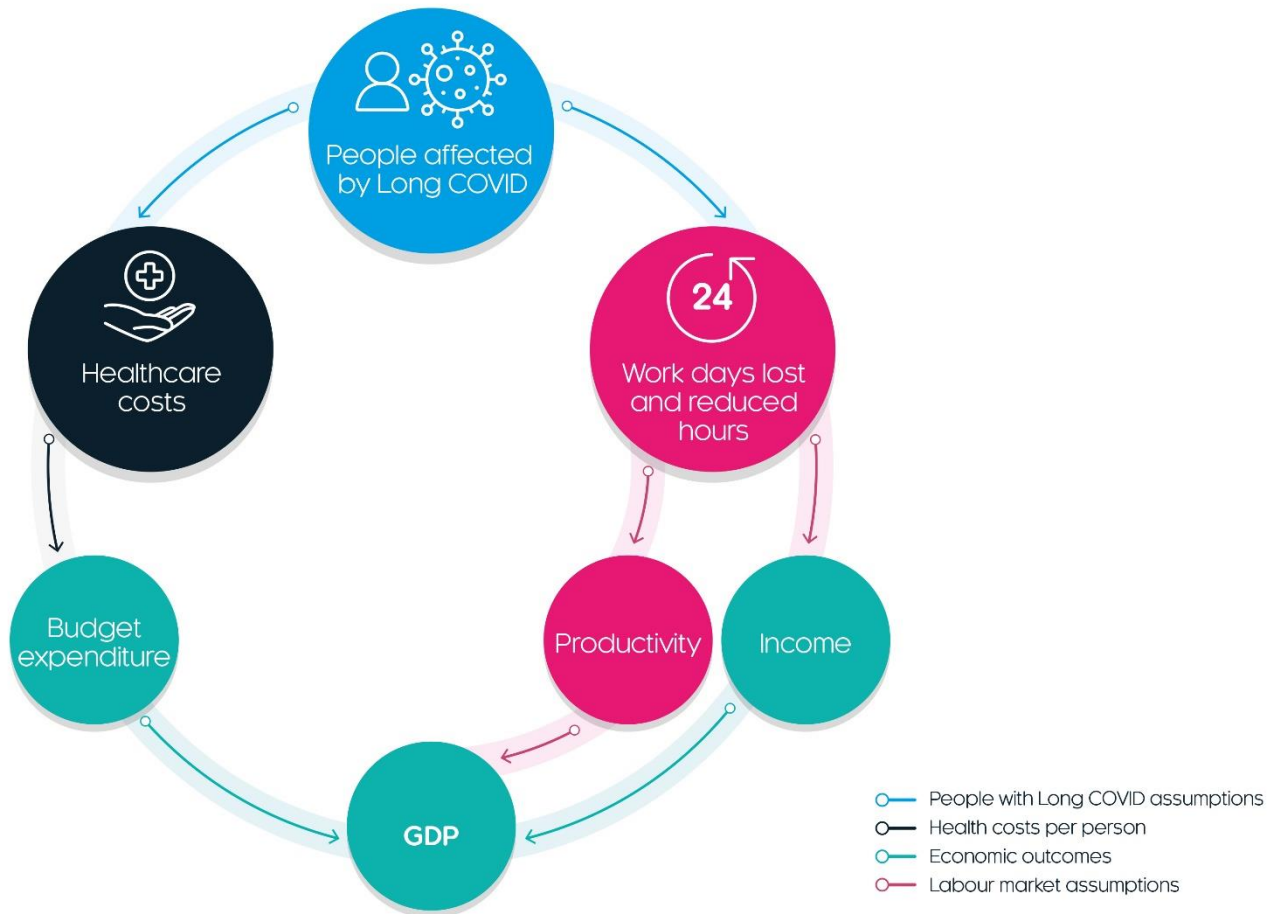
The economic logic of Long Covid therefore rests on assumptions about:

- The prevalence of Long Covid in the population, as the starting point for the further assumptions: the more people with Long Covid, the larger the changes in the Long Covid scenarios.
- The labour market implications of Long Covid (a function of its severity) in terms of:
 - the number of people no longer able to work, who must therefore withdraw from the labour force
 - the extent to which others are still able to work, but not as much as previously, leading them to reduce their hours
- The healthcare costs of Long Covid diagnosis and treatment, which may involve the reallocation of

resources from other public services or different funding strategies.

Figure 3.3 summarises how these assumptions link to E3ME’s economic structure. The numerical values used for these assumptions are summarised in Section 3.2.

Figure 3.3: Economic logic of Long Covid



The assumptions on people unable to work or working reduced hours feed directly into the income loop detailed above, leading to changes in incomes and household expenditure. This has direct welfare implications for households. The people leaving the labour market may make it more difficult for firms to fill job vacancies, potentially leading to lower productivity. Lower productivity may in turn affect domestic production. This may mean higher imports (as per the trade loop above) and/or changes in investment and sector patterns (as highlighted in loops between sectors and investment in Figure 3.2). As the loops repeat themselves, the overall impacts are of a much larger scale than the original loss of productivity and jobs attributed to Long Covid in the original assumptions.

The assumptions on the cost of healthcare of Long Covid are represented by the potential impact on public spending and GDP. Government expenditure is a component of GDP and affects overall economic activity. As such, the way this expenditure requirement is handled has implications on the economy.

The role for policy concerns government finance decisions to support people with Long Covid. While in England no further funding has been explicitly committed to Long Covid beyond March 2025, the assumption is that healthcare is necessary and thus a required (non-discretionary) expenditure on the part of the government. That is, higher healthcare utilisation of people with Long Covid places a demand on healthcare that is met as part of general healthcare expenditures (higher demand for GP, inpatient and outpatient services and emergency departments).

While it remains an option to incur more debt to cover these health expenditures, i.e. on top of other existing public spending, the current political environment is very much focused on fiscal prudence. As such, the underlying assumption in the scenario is that health spending to support those with Long Covid involves the government providing the necessary support. This means that the value of total government expenditure in Figure 3.2 remains unchanged compared to the baseline, but the change in composition (to healthcare expenditure for other types), may have macroeconomic effects and, as discussed, the composition of spending also reflects wider (i.e. non-economic or, at least, not immediately) effects on the UK population. The analysis also explores some alternative financing mechanisms to see how results could differ with explicit government action.

All of the above assumptions generate a range of economic and distributional effects. Furthermore, all of the above assumption are dependent on the number of people with Long Covid, meaning that the size of the effects are directly link to the prevalence of Long Covid in the future.

Factors that are out of scope in the analysis, linked directly to the Long Covid assumptions as well as broader implications of the illness include:

- The macroeconomic impacts only capture the effects of the information currently available on long COVID (e.g. costs, number of people affected).
- Because of the macroeconomic view the analysis takes, microeconomic impacts, such impacts on different household types and other groups, are not represented. The macroeconomic approach does not account for broader societal impacts such as quality of life and family members who become carers for people affected by Long Covid.
- There is a high level of uncertainty around longer-term impacts that is not reflected in the analysis. In particular, the issue of pension impacts for people that are no longer able to work. Other longer-term implications around productivity and the evolution of the illness are also not reflected in the analysis.

3.2 Assumptions

Understanding of Long Covid continues to grow and there remains high uncertainty as to how a future of Long Covid might play out. Nevertheless, the evidence in Chapter 2 shows how Long Covid has evolved and this provides some basis with which to develop a set of medium-term assumptions to 2030.

Drawing on the evidence presented previously and the approach presented in Section 3.1, the modelling consists of a main scenario that adopts the central assumptions, along with further sensitivities that vary these assumptions to acknowledge the uncertainties in the current evidence. These sensitivities help to gauge the potential range of outcomes. Table 3.1 below sets out the assumptions for the scenario and sensitivities.

The assumptions that underpin the scenarios concern:

- the future prevalence of Long Covid in the UK population and, from a macroeconomic point of view, the prevalence in the working age population, especially
- the labour market effects of Long Covid in terms of its effects on the ability to work at all and the ability to work as many hours as previously
- the healthcare costs associated with Long Covid

As outlined earlier in the economic logic of Long Covid, the key drivers of the results concern the number of people with Long Covid, the effects on the labour market (their labour supply, which also affects their own incomes) and healthcare costs.

Table 3.1: Long Covid scenario assumptions

Assumption	Impact/Mechanism	Main	Sensitivities			Source(s)	Comment
			1	2	3		
1	Population living with Long Covid	Basis for the further assumptions (linked to per person assumptions)	1.9m, held constant to 2030		Grow to 4.0m by 2030	Main: ONS (2023) Sensitivity 3: See comment	Main scenario assumes the number of people with Long Covid each year remains constant (i.e. the stock). Sensitivity test is of a more-than-doubling to test a more extreme outcome in the face of (high) uncertainty.
2	Working age population living with Long Covid	Basis for the further assumptions (see below)	1.6m, held constant to 2030		Grow to 3.2m by 2030	ONS (2023) Sensitivity 3: See comment	Growth to 3.2m follows proportionally from the higher number of people with Long Covid (as Assumption 1, immediately above).
3	Proportion of people with Long Covid unable to work	Withdrawal from the labour market among those of working age Lower labour supply but also lower employment leading to lower incomes	10%	20%	10%	Main: Waters and Wernham (2022) Sensitivity 3: Ziuaddeen <i>et al.</i> (2023)	Main assumption derived from Waters and Wernham (2022). While the survey method used limits generalisability, Ziuaddeen <i>et al.</i> (2023) find a higher rate of labour market withdrawal, close to 20%. This is tested in Sensitivity 2 as a higher bound.
4	(Average) reduction in hours worked by people with Long Covid	Of those with Long Covid who do not stop working, some may have to work reduced hours Lower labour supply but also lower hours worked leading to lower incomes	2.4 hours per week per (working) person with Long Covid	3.6 hours per week per (working) person with Long Covid	2.4 hours per week per (working) person with Long Covid	Main: Waters and Wernham (2022) Sensitivity 2: See comment	Main assumption derived from Waters and Wernham (2022). Similar logic as Assumption 2 above about possible higher impacts. Tested as a 50% increase in Sensitivity 2.
5	(Average) healthcare costs per person with Long Covid	Government expenditure redirected to support Long Covid i.e. assume (initially) no commitment of new resources	£3,350 pa per person with Long Covid	£3,350 pa, growing to £5,000 pa by 2025 and then held constant to 2030	£3,350 pa per person with Long Covid	Main: Mu <i>et al.</i> (2023) Sensitivities: See comment	Mu <i>et al.</i> (2023) analyses individuals between January 2020 and January 2023, yielding an estimated cost of £3,350 per person with Long Covid. Given other uncertainties (as above), cost escalation was also tested, in the sensitivities.

Note(s): Shaded cells highlight differences between the sensitivities and the main scenario.

Source(s): Various (see two rightmost columns).

The main scenario arguably reflects some conservatism in the assumptions, with the idea that the sensitivities then explore that range as a way to address the uncertainty in the current situation and state of the evidence. Specifically, the main scenario assumes:

- no change in the number of people with Long Covid each year: 1.9m
 - of those 1.9m people, the proportion who are of working age is assumed to be the same as in the most recent ONS data (from March 2023): 1.6m people
 - while the number of people with Long Covid is unchanged, this does not necessarily mean that the same people have Long Covid over the period; rather, the number of those recovering from Long Covid is roughly the same as the number who contract it
- various labour market effects arising from Long Covid, relating to the way in which Long Covid reduces people's ability to carry out their day-to-day activities, including work:
 - Long Covid leads to some people withdrawing entirely from the workforce (in line with the analysis in Wernham and Waters, 2022)
 - for those affected by Long Covid, not all will necessarily withdraw from the workforce, but they may have to reduce their hours
- healthcare costs in line with Mu *et al.* (2023), of £3,350 pa per person with Long Covid.

In the main scenario, the assumption is that the number of people with Long Covid (the stock) remains at its March 2023 level, of 1.9m people. Of those, 1.6m are of working age. Of course, given the early state of these numbers, it is possible that the number of people with Long Covid could increase. Indeed, the March 2023 numbers (the last ONS release) on which this assumption is based is around one year old at this point.

With this in mind, Sensitivity 3 considers a situation in which Long Covid cases increase to 4m by 2030. This represents an eventual more-than-doubling in cases compared to the main scenario. This brings the share of people with Long Covid at any one time in the UK up to around 6%.

While there is good evidence of people having to leave work, as discussed previously, the evidence on the degree of this happening is more uncertain, with earlier analyses likely clouded by the effect of COVID-19 policies (e.g. furlough) as well as the absence from work policies on the part of employers. The progression of ONS (2021, 2022a and 2023) figures on prevalence and severity also at least hints at the idea that more people with Long Covid are affected in their day-to-day activities, which would very likely affect their ability to work. As such, while the Waters and Wernham (2022) estimate (from 2021 data) is of 10%, assuming no clear path to recovery (of which there is little evidence; as in, for example, Sivan *et al.*, 2023), it seems somewhat more likely that the rate of withdrawal would be higher, rather than lower. Consequently, we test a sensitivity in which the rate of withdrawal is double: 20%. While Ziauddeen *et al.* (2022) highlight the difficulty in generalising their result (and which was still derived some time ago, in late 2021), the 20% is in line with this figure and may be reasonably treated as towards the (current) upper end.

The reasoning behind using Waters and Wernham (2022) as the basis for the estimated reduction in hours worked follows similar reasoning, drawing on established (general) longitudinal studies while accepting that these results are relatively early in the analysis of what is proving to be a long-term condition. With little

other evidence to go on, we opted to test a larger reduction, of 50% on top of the main assumption.⁸

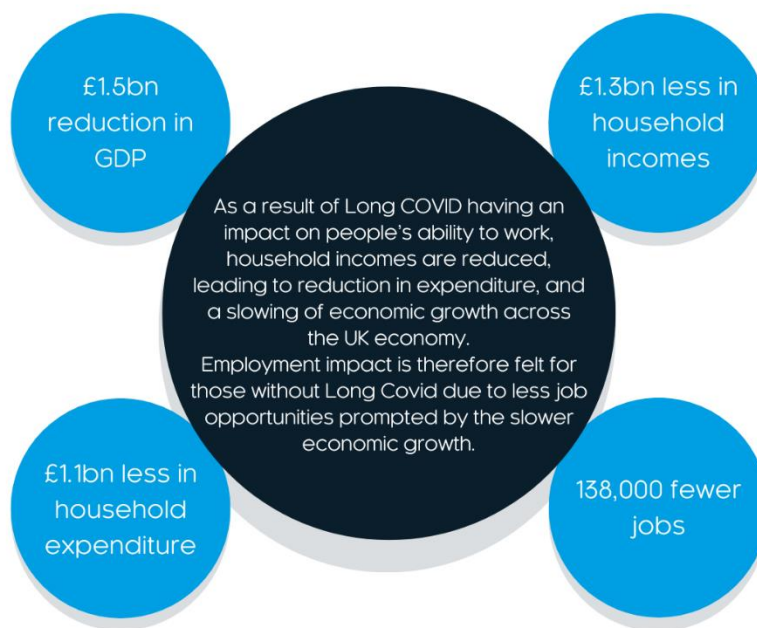
Healthcare costs are taken from Mu *et al.* (2023) and, again, were increased in the sensitivity analysis to see how higher costs might affect the overall outcomes.

As well as the model runs set out below, we also considered the macroeconomic implications of funding the healthcare provision, as a further set of model runs. These model runs are indicative, to give a sense as to the dynamic implications of funding Long Covid (in contrast to the main scenarios of diverting resources).

3.3 Results

Compared to a case without Long Covid, the results from the main scenario suggest that UK GDP could be reduced by around £1.5bn each year over the period to 2030. However, if Long Covid cases are substantially higher at 4m people by 2030, in Sensitivity 3, the GDP impact would be more severe, growing over time to reduce UK GDP by £2.7bn in 2030.

Figure 3.4: Macroeconomic impacts of Long Covid by 2030



The main scenario estimates the health costs of Long Covid to be £4.2bn each year. This is significant and, to give a sense of scale, represents 2.7% of the 2022/23 NHS England budget (NHS, 2022). By comparison,

⁸ As the later discussion of results will show, higher values are not likely to substantially affect the final conclusions.

this is around double what the NHS would expect to spend on COPD (estimated at around £1.9bn⁹) but below the estimated health costs for cardiovascular disease in England, of around £7.4bn (Public Health England, 2019).

Most of the negative impact comes from Long Covid reducing people's ability to work, thus lowering household incomes. This in turn reduces household spending and activity in the UK economy, lowering GDP. Lower employment follows, as a consequence of the lower economic activity. In the main scenario with Long Covid, there are almost 140,000 fewer jobs by 2030 than in the scenario without Long Covid. This figure includes people without Long Covid who are affected by the reduction in economic activity leading to fewer jobs. A higher prevalence of Long Covid would magnify this effect, with 310,000 fewer jobs if the number of people with Long Covid were to rise to 4m by 2030.

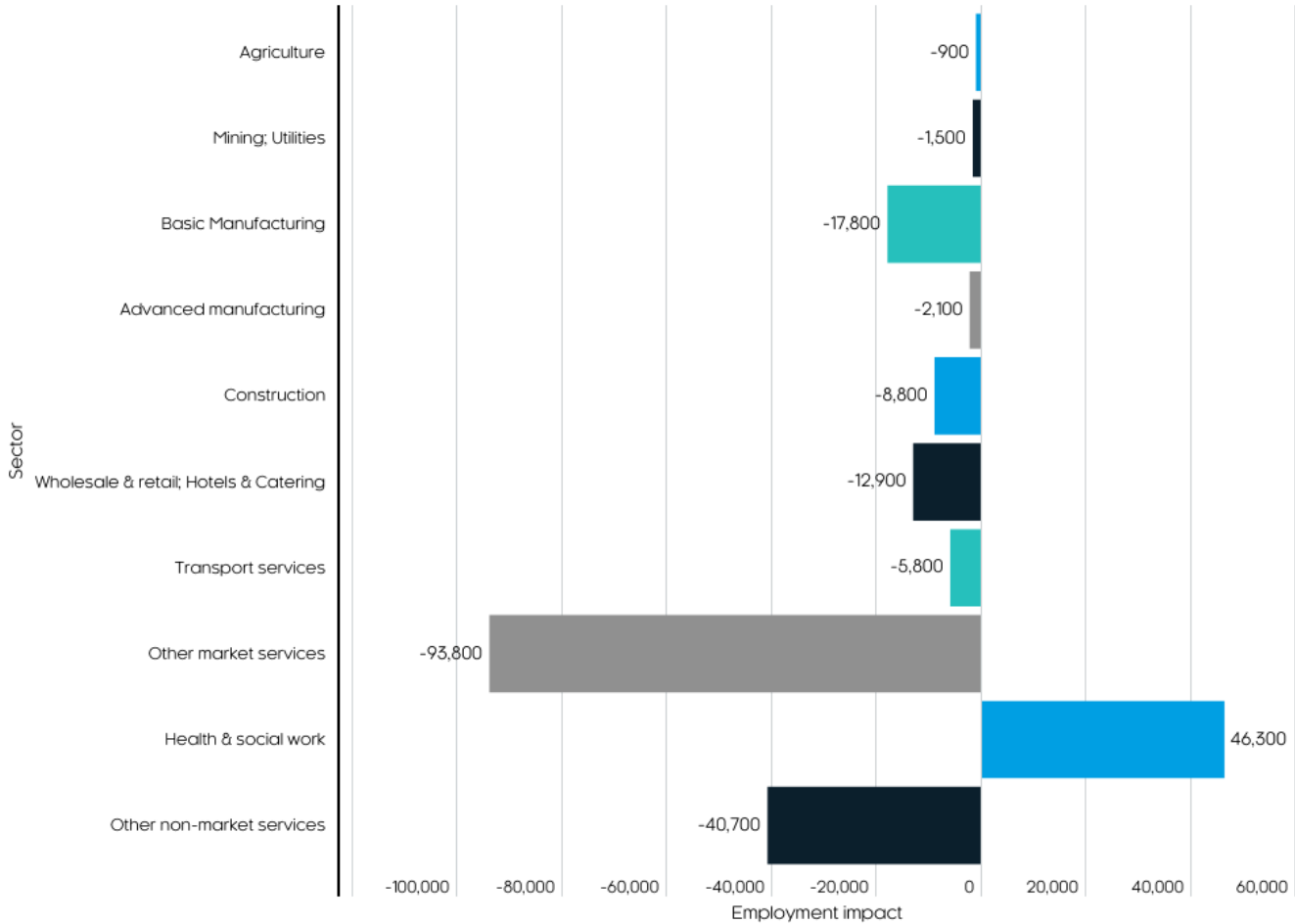
Given the socioeconomic patterns of Long Covid described in the earlier chapters, the pattern of Long Covid in the population is such that those on lower incomes and/or benefits appear more affected. The main scenario results suggest that the wider impacts may also fall more on lower-income households. Distributional results from the model suggest slightly larger impacts on poorer households, which is consistent with more of the impacts falling on sectors with relatively lower average wages compared to the UK average, such as 'Wholesale & Retail; Hospitality and Catering', which leads to relatively larger loss of income for lower income households compared to higher-earning ones.

Employment in service sectors is expected to be the most impacted; a direct result of the prevalence of Long Covid in these sectors and an outcome of lower household expenditure.

The sectoral employment effects reflect both the pattern of Long Covid infections across sectors and the sectoral composition of the UK economy, as shown in Figure 3.3. In both cases, the impacts are concentrated in service sectors (almost 80% of the job losses would be in these sectors); and especially Other market services such as IT, legal and accounting, architecture and real estate. Wholesale & retail and Hotels & catering also suffer, accounting for a further 13,000 fewer jobs by 2030. Both Other market services and Wholesale & retail and Hotels & catering are sectors with relatively higher shares of women: 44% and 72%, respectively; compared to no more than 25% elsewhere, excluding non-market (i.e. public) services. Were resources diverted from other public services to support additional health care, employment in Health & social work would be expected to increase in line with the increase in government expenditure in the sector required for the treatment and management of Long Covid.

⁹ <https://www.england.nhs.uk/ourwork/clinical-policy/respiratory-disease/>

Figure 3.5: Employment impacts by sector in 2030



Note(s): Employment impacts are reported as absolute differences from 2023? baseline. Other market services refers to service sectors not individually included in the graph and includes sectors such as IT, legal and accounting, architecture, real estate and security. Advanced manufacturing = Electronics; Mechanical & electrical equipment; Transport Equipment.

Again, were more people to suffer from Long Covid each year, these employment impacts (including by gender) would be accordingly more severe, with even greater job losses in the sectors mentioned previously.

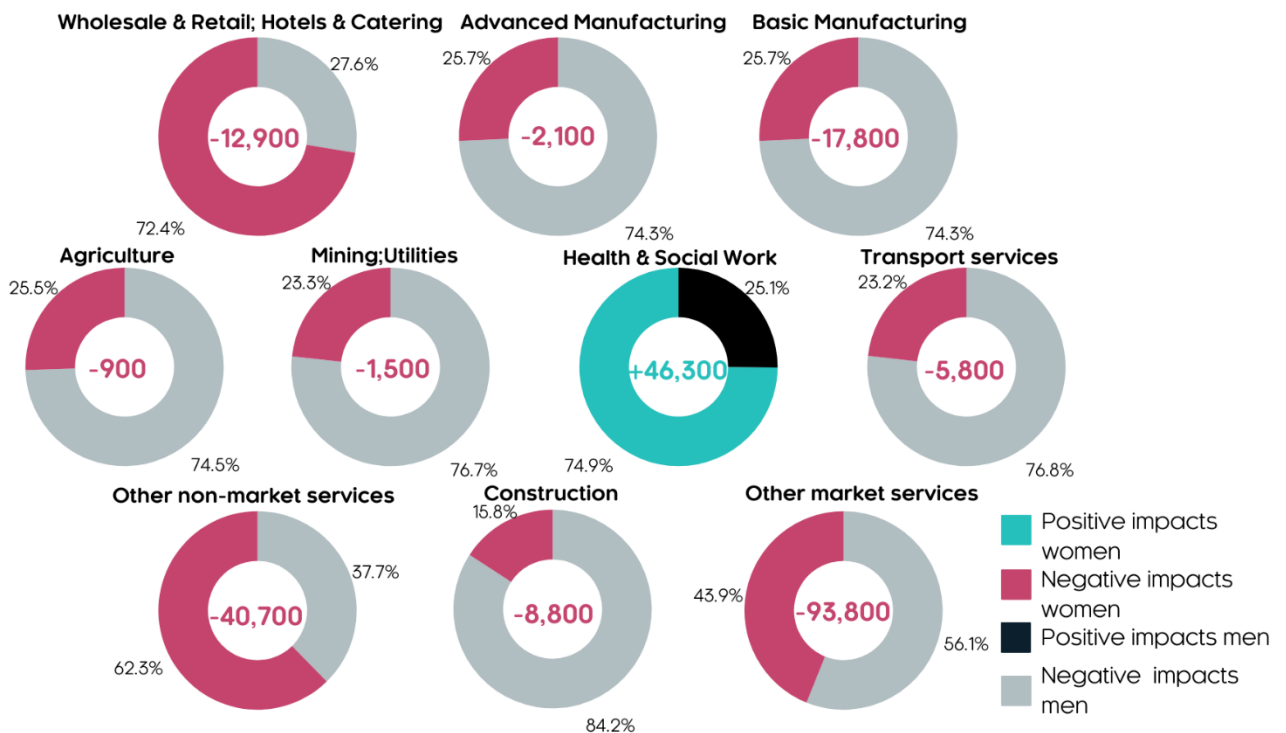
While public sector employment appears to be less impacted than other sectors as a result of Long Covid it is worth noting that, in our analysis, total public spending is assumed unchanged. Instead, the costs of Long Covid treatment are met by shifting funds away from other public services and towards Long Covid treatment. This would be consistent with current positions on UK government budgets. The employment impacts follow the same logic, with staff expanding in healthcare in line with the increased expenditure but leading to reductions in other public services. An alternative outcome would be that the resources are actually reallocated within healthcare such that employment in each of health and non-health public services is unchanged. This would not meaningfully change the macroeconomic results but would represent a case in which Long Covid care leads to lower provision of other health services. This is plausible as an alternative

and would be consistent with a situation in which Long Covid adds additional pressure to a health system that has been under strain for some years. Were health workforce challenges to persist, new health needs may lead to longer delays in elective care, lengthening waiting lists and reducing service quality. In this sense, whereas the early years of COVID-19 showed how acute pressure can squeeze health systems, Long Covid may represent a source of new chronic pressure.

Long Covid is expected to have a disproportionate impact by gender.

Given the sectoral pattern of the results, the overall employment effects by gender are roughly 50:50 (with women accounting for slightly less). This reflects the pattern of economic impacts as an outcome (rather than the pattern of Long Covid), with more of the macroeconomic effects eventually falling on sectors with higher proportions of women such as Wholesale & Retail: Hotel & Catering. However, this effect is partly mitigated by a possible increase in demand for workers in the Health & Social work sector (a direct reflection of the additional healthcare requirements), a sector where women account for around 75% of the jobs. Manufacturing, Construction and Transport services, all sectors with a significant male workforce, are also expected to decrease in employment in 2030

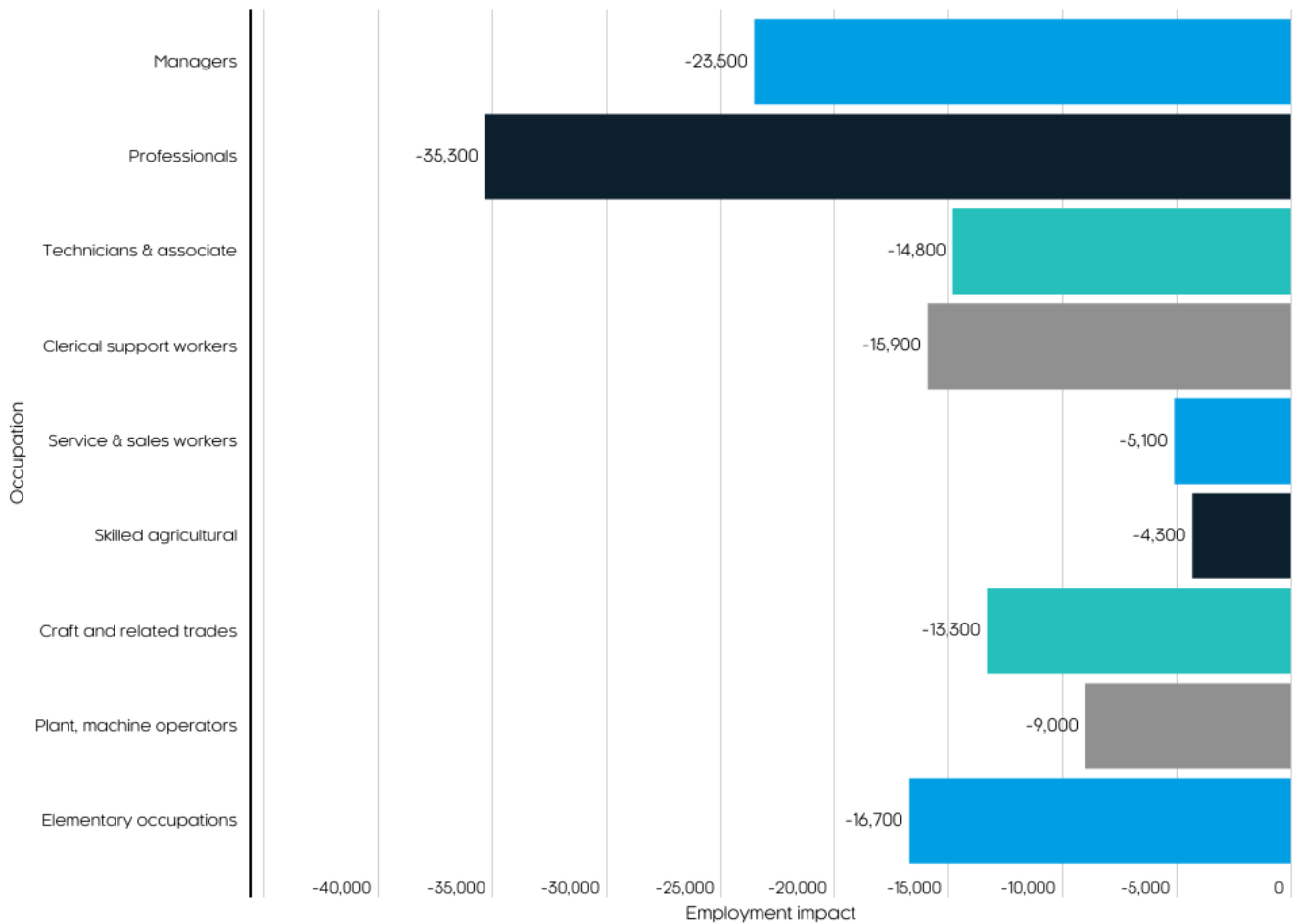
Figure 3.6: Employment impacts by Gender in 2030



Long Covid has employment impacts on all occupational levels

Given both the health and sectoral effects of Long Covid, relatively more of the job losses are projected to be among managers and professionals: almost 60,000 (43%) of the roughly 140,000 jobs lost by 2030. Losses among other occupations are milder, at around 15,000 each of: technicians and associate professionals; clerical support workers; craft and related trades; and elementary occupations. There are impacts at all occupational levels (see Figure 3.7).

Figure 3.7: Employment impacts by occupation in 2030



Note(s): Employment impacts are absolute differences between the main scenario and the baseline.

Source(s): Cambridge Econometrics.

3.4 Sensitivity analysis

The three sensitivities previously introduced in Section 3.2 explored the assumptions regarding the number of people in employment affected by Long Covid and the cost of diagnosing and treating Long Covid.

1. Increased treatment cost: One variant looked at the impact of increasing the treatment cost from £3,350 to £5,000 per person, with all other scenario assumptions remaining the same.
 - Little to no impact on a macroeconomic level, but redistribution of government resources would be expected and subsequently, similarly to the main scenario, would lead to more resources moved towards healthcare services and away from other government service areas.

2. **Increased treatment cost and increased economic inactivity:** A further variant explored the impact of the cost increase together with increasing the share of people with Long Covid unable to work from 10% to 20%.
 - GDP would be £2.7bn lower compared to baseline in 2030, as opposed to £1.5bn lower compared to baseline in the main scenario.
 - Job losses would also increase to 334,600; 194,600 more than the main scenario where it assumed treatment cost and economic inactivity remains the same.
3. **Increased number of people with Long Covid,** growing from 1.9m to 4m by 2030. This leads to an almost doubling of the negative GDP impacts compared with the main scenario, to £ 2.7bn.

Alternative financing

The results from the main scenario suggest some wider impacts on the economy beyond those directly affected by Long Covid, with various concerns about sectoral/distributional impacts and potential job losses leading to further income reductions.

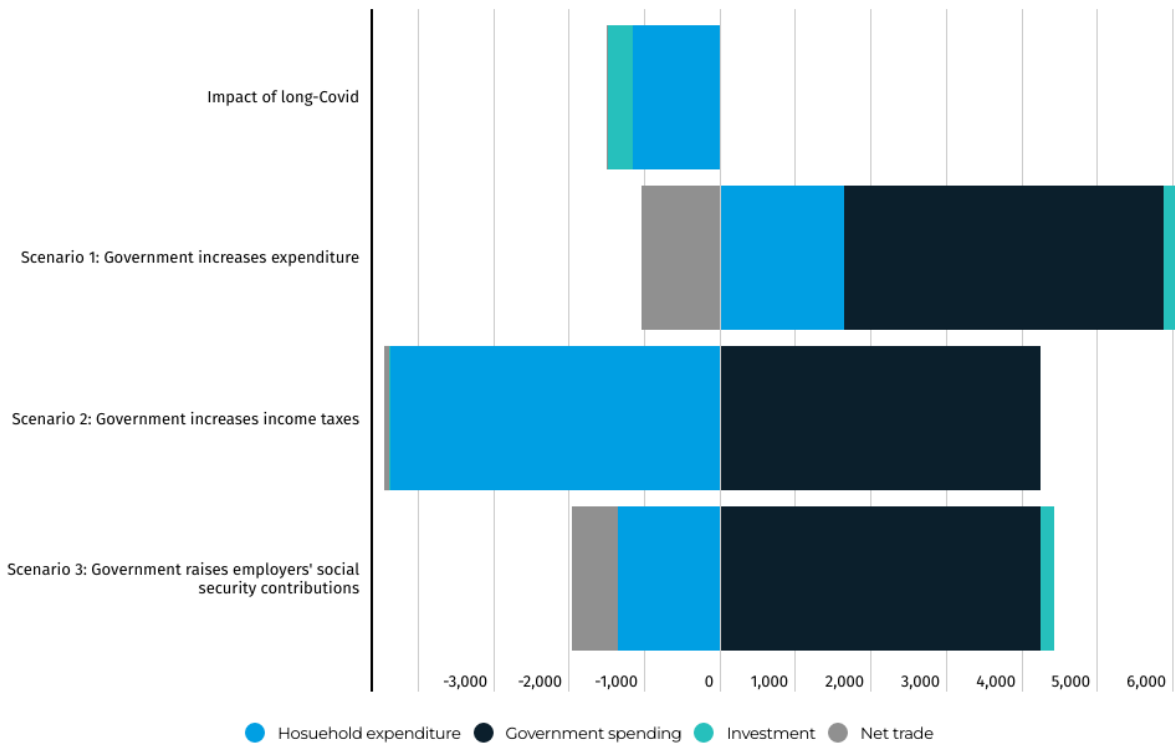
The analysis focuses largely on the prevalence and costs of Long Covid, under the assumption that, with current fiscal constraints as well as workforce challenges, the amount of government spending would have to be largely unchanged. The implication is that support necessary for Long Covid involves a diversion of resources from other forms of government spending. This is not unprecedented given, for example, how resources for elective care were diverted to respond to the early waves of the COVID-19 pandemic.

In contrast to the main analysis, which assumes no change in government efforts to raise revenues to cover this expenditure, this section explores outcomes through variants to the main scenario in terms of funding options:

1. **Financing through increased health expenditure, without reallocation of resources:** cover the additional requirements to diagnose and treat Long Covid, increasing public debt in the process:
 - Here, the impact on GDP is positive, by £5.1bn in 2030 compared to the main scenario. However, this is not sufficient to overcome the overall negative employment impacts from the reduced ability to work. (Though, depending on how other policies including benefits are setup, there may still be ways to help alleviate stresses on these people.)
 - By itself, this approach leads to higher debt, which is, for the most part, ruled out by current political parties.
2. **Financing through increased income taxation:** Government increases expenditure to cover the additional requirements to diagnose and treat Long Covid, but also raises income taxes to finance this increase:
 - Negative GDP impacts, particularly if income taxes are raised, because this directly reduced households' incomes. As a result, households' expenditure is expected to decrease even further, leading to lower demand for goods and services and, consequently, lower employment.
3. **Financing through employer social security contributions:** Government increases expenditure to cover the additional requirements to diagnose and treat Long Covid, but also raises employers' social security contributions to finance this increase.
 - Employment impacts are of a slightly less negative compared to the income tax sensitivity.

- Positive impact on GDP, because, while households remain worse off, government expenditure offsets the lower household consumption.

Figure 3.7: GDP impact of alternative financing options for healthcare expenditure, 2030



Source(s): Cambridge Econometrics.

3.5 Limitations

The main limitation of this study is related to the uncertainty of the future evolution of Long Covid. Current evidence shows no clear path to recovery for those with Long Covid such that longer-term improvement or deterioration cannot easily be determined. As such, it is difficult to gauge the longer-term effects on the affected population, particularly in terms of support requirements and what this means for healthcare and other support. This also leads to uncertainties regarding the assumptions linked to labour market participation.

A key constraint concerns the information available on Long Covid that can be translated to numerical inputs for macroeconomic modelling. The impacts of the analysis are directly linked to the assumptions: the number of people with Long Covid, the extent to which their ability to work is impacted and the healthcare costs associated with Long Covid. The sensitivity analysis offers some insight into the potential range of outcomes, but it is entirely possible that new evidence may suggest that certain impacts actually lie outside of these ranges.

The report seeks to answer questions about macroeconomic impacts and, as such, is confined to macroeconomic impacts. The analysis cannot look into very detailed issues, such as the composition of households affected by Long Covid, and likely impacts on specific types of individuals or firms. Such elements are dealt with on an average basis. The analysis also cannot say anything about things not measured in macroeconomic terms, such as quality of life, or the value of unpaid work resulting from Long Covid, such as volunteering or people caring for relatives with Long Covid.

4. Conclusions

Long Covid is now established in the UK population. ONS data (March 2023) suggests that there are almost 2m people living with Long Covid in the UK, representing some 3% of the UK population. The majority of people affected are of working age. With Long Covid affecting their ability to carry out day-to-day activities, Long Covid has implications on people's lives but also on the UK economy. People more severely affected have reported being unable to live alone without assistance, having to leave their jobs or reduce their paid working hours, leading to substantial financial implications.

Long Covid and the long-term macroeconomic implications

Our modelling estimates that Long Covid may lead to a decrease in GDP of around £1.5bn each year, with net job losses of around 138,000 by 2030. The drivers behind this outcome reflect the decrease in people's ability to work, leading to lower household incomes and lower economic growth overall. This is under the assumption that the government does not increase public spending, requiring reallocation of resources either within the health system or from other public services. The size of the macroeconomic impacts is affected by future prevalence of Long Covid, with the future impacts likely to be greater? more negative if prevalence rises. This will also put more pressure on health services.

Health & social work

Many people with Long Covid have considerable need for health care. The current cost estimate of £3,350 pa per person as well as the potential number of people affected are both uncertain but could lead to additional annual healthcare costs of some £4.2bn by 2030, if prevalence remains around 1.9m people. Were these health needs to be met by an expanded health service this could require an additional 46,000 public healthcare workers. The alternative (as was seen in the early period of COVID-19) is that funding constraints and workforce shortages create additional pressure that leads to ever lengthening waiting lists for elective care and service quality suffering.

Given the current fiscal environment and with the healthcare system already struggling with long waiting lists and deteriorating performance, it is likely that Long Covid risks becoming a further source of chronic pressure on the health system as well as a drag on economic growth.

Impact on society

The report focuses on the impact on the UK macro-economy, however it did capture some information on specific trends within society.

There is evidence of overlap between Long Covid and deprivation, with higher prevalence among people on benefits or living in social housing. Evidence from our modelling suggests wider economic impacts may reinforce this inequality, with employment effects impacting lower-income households including those not necessarily suffering from Long Covid, with job losses more likely to occur in market services and lower-paid sectors such as retail and hospitality. Because employment impacts are concentrated more in service sectors, who traditionally employ a higher share of women, gender impacts see a slightly more

disproportionate on women in service sectors but overall gender impacts across all sectors is about 50:50 ().

What the analysis does not capture

As a macroeconomic impact assessment, the analysis does not capture other societal impacts. These impacts are outside the scope of this work, but have significant implications on the magnitude of Long Covid impacts on UK society:

- the (monetary) value of the disease burden, i.e. in terms of quality-adjusted life years, which is likely substantial but lies outside of the boundary of a macroeconomic assessment
- the impact of Long Covid on informal carers, whose time is not captured in GDP and whose (potential) income losses are not explicitly captured in the analysis

The analysis also does not capture the impact of Long Covid if those affected resort to private healthcare services (e.g. paid carers) in the absence of public sector alternatives, nor the monetary burden of those with Long Covid needing to access private health care.

Given the above, the impact of Long Covid is certainly greater than implied by the estimated GDP reductions alone.

This analysis draws on a range of published sources to inform the modelling. However, with the situation continuing to evolve and new research emerging, some of the assumptions, such as the impact of Long Covid on income, are based on data from earlier stages of Long Covid. Research into Long Covid continues and outputs from ongoing studies tend to suggest that longer-term impacts could be higher than has been assumed in this report. If this is the case, the results reported here may prove to be a lower estimate of the macroeconomic consequences.

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Appendix: E3ME

The analysis in this report applies Cambridge Econometrics' E3ME model to examine alternative futures about Long Covid to see how different assumptions lead to different macroeconomic outcomes.

E3ME is a computer-based model of the world's economic and energy systems, and their links to the environment.¹⁰ The model was originally developed through a succession of European Commission research framework programmes with a pedigree that can be traced back to work to develop a computer model of the British economy, as part of the Cambridge Growth Project at the Department of Applied Economics, University of Cambridge.

E3ME

Structure and data

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, including both voluntary and involuntary unemployment. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, government spending and international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

The E3ME model includes historical data and projects forward annually to 2050, taking into account potential effects of COVID-19 and the war in Ukraine. The main data sources for European countries are ONS, Eurostat and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. For regions outside Europe, additional sources for data include the UN, OECD, World Bank, IMF, ILO and national statistical agencies. Gaps in the data are estimated using customised software algorithms.

Although E3ME can be used for forecasting, the model is more commonly used for evaluating the impacts of an input shock through a scenario-based analysis. The shock may be either a change in policy, a change in economic assumptions or another change to a model variable. The analysis can be either forward looking (ex-ante) or evaluating previous developments in an ex-post manner. Scenarios may be used either to assess policy, or to assess sensitivities to key inputs (e.g., international energy prices). The scenarios represent alternative versions of the future based on a different set of inputs. By comparing the outcomes to the baseline (usually in percentage terms), the effects of the change in inputs can be determined.

E3ME is often compared to Computable General Equilibrium (CGE) models. In many ways the modelling approaches are similar; they are used to answer similar questions and use similar inputs and outputs. However, underlying this there are important theoretical differences between the modelling approaches. In a

¹⁰ For more information, see: <https://www.e3me.com/>

typical CGE framework, optimising behaviour is assumed, output is determined by supply-side constraints and prices adjust fully so that all the available capacity is used. In E3ME the determination of output comes from a post-Keynesian, demand-driven accounting framework and it is possible to have spare capacity in the economy. It is not assumed that prices always adjust to market clearing levels. The differences have important practical implications, as they mean that in E3ME regulation and other policy may lead to increases in output if they are able to draw upon spare economic capacity.

The econometric specification of E3ME gives the model a strong empirical grounding. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis and rebound effects, which are included as standard in the model's results.

E3ME can produce a broad range of economic indicators, including GDP and its aggregate components, sectoral output and GVA, prices, trade and competitiveness effects, international trade by sector, employment, wage rates and labour supply.

Strengths

The key strength of E3ME can be summarised as follows:

- The close integration of the economy, energy systems and the environment, with two-way linkages between the economy and energy system.
- The detailed sectoral disaggregation in the model's classifications, allowing for the analysis of similarly detailed scenarios.
- Its global coverage, while still allowing for analysis at the national level for large economies (71 regions in total).
- The econometric approach, which provides a strong empirical basis for the model and means it is not reliant on some of the restrictive assumptions common to CGE models.
- The econometric specification of the model, making it suitable for short and medium-term assessment, as well as longer-term trends.

Limitations

As with all modelling approaches, E3ME is a simplification of reality and is based on a series of assumptions. Compared to other macroeconomic modelling approaches, the assumptions are relatively non-restrictive as most relationships are determined by the historical data in the model database. This does, however, present its own limitations, for which the model user must be aware:

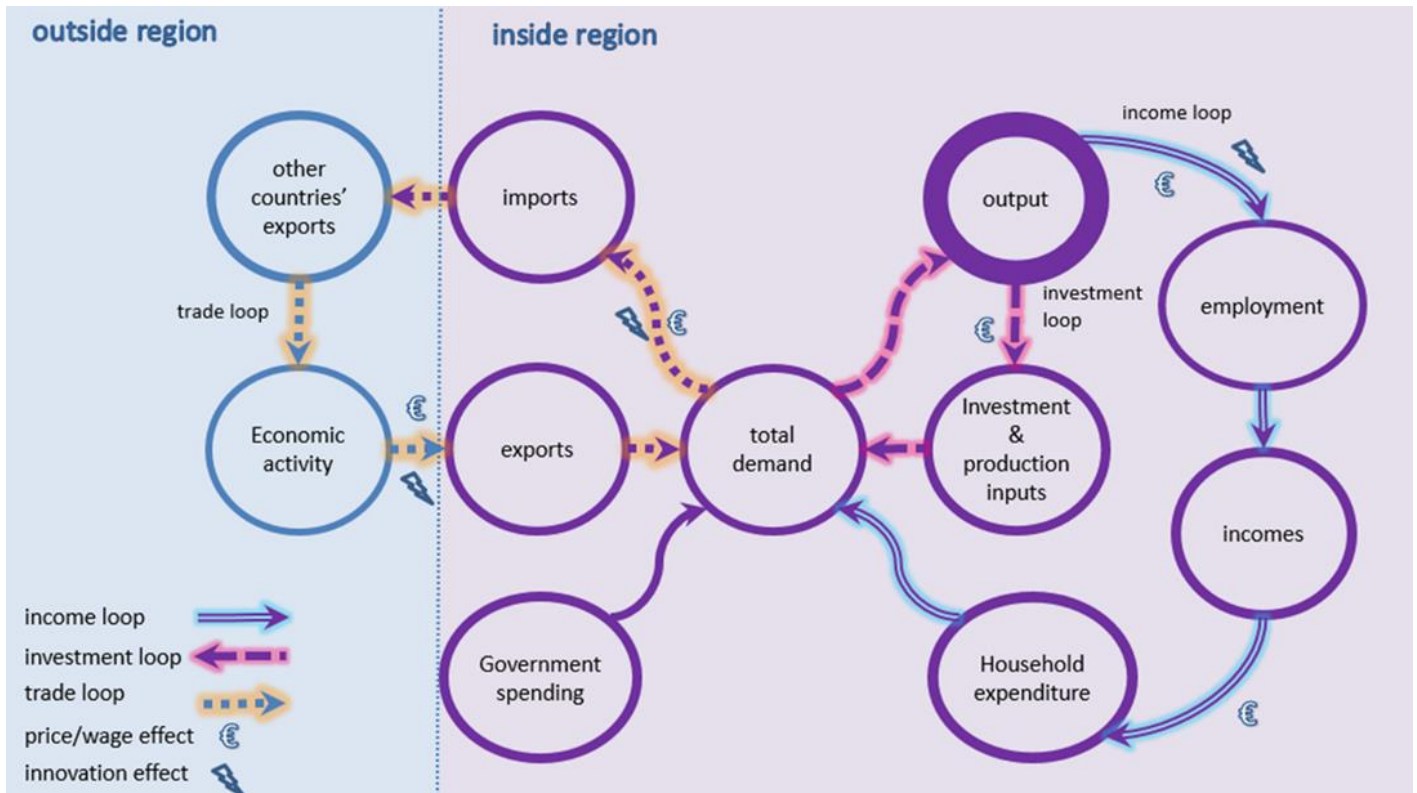
- The quality of the data used in the modelling is very important. Substantial resources are put into maintaining the E3ME database and filling gaps in the data. However, there is some uncertainty in results due to the data used.
- Econometric approaches are also sometimes criticised for using the past to explain future trends. While the E3ME parameters are based on long timeseries to provide sufficient data points for robust estimations, in cases where there is large-scale policy change, the 'Lucas Critique', which suggests behaviour might change, can be applicable. There is no solution to this argument using any modelling approach (as no one can predict the future or behavioural responses by economic agents), but we must

always be aware of the uncertainty in the model results.

Economy

Appendix Figure 1 shows how E3ME's economic module is solved for each region, illustrating the main flows in the model. Most of the economic variables shown in the chart are solved at the sectoral level. The whole system is solved simultaneously for all sectors and all regions, although single-country solutions are also possible.

Appendix Figure 1 Economic structure of E3ME



As highlighted above, E3ME entails both an investment and a trade loop. In the former, when firms increase output (and expect higher levels of future output) they must also increase production capacity by investing. This creates demand for the production of the sectors that produce investment goods (e.g., construction, engineering) and their supply chains. In the latter, an increase in demand is met by imported goods and services. This leads to higher demand and production levels in other countries. Hence there is also a loop between countries.