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Macroeconomic implications of a basic income

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Contents

1 Introduction

This paper sheds light on the macroeconomics of basic income

This paper presents the results of a research project to investigate the macroeconomic implications of basic income. In recent years there has been renewed interest in basic income as a possible policy instrument. Accompanying this wave of interest is a growing body of research. Much of that research has either looked empirically at small basic income-like pilots/schemes or conducted simulation exercises (i.e. modelling) to assess the distributional effects (at an individual/household level) of re-engineering the tax and benefits structure of an economy. The contribution of this research is to better understand how basic income might operate at scale i.e. at the level of a macroeconomy (an economic system), accounting for dynamic effects (feedbacks). To do this we apply a macroeconomic model, E3ME, to examine a range of basic income schemes in the UK.

Areas of focus concern scheme design, automation and debt-free sovereign money

As well as shedding light on the macroeconomic effects of basic income, the research considers, in particular:

- how macroeconomic effects are relevant to an assessment of basic income, because of wider behavioural responses on the part of households, especially with respect to consumption patterns and labour supply
- the importance of scheme design in developing a basic income policy i.e. the other policies that accompany the basic income payment, to fund it
- the possible application of basic income at scale, in response to a high automation, high unemployment future in which household incomes are severely depleted through lack of jobs
  - in this regard, we turn our attention to the potential for debt-free sovereign money (DFSM) as a way to fund such a basic income

Our approach applies a macroeconomic model for policy simulation

In considering the above, we develop a series of macroeconomic simulations (scenarios) in which we test different schemes over a future 15-year period. In the case of a large-scale basic income, we test a scheme under conditions of high automation to see whether a DFSM-funded basic income can return key macroeconomic variables to baseline levels. In doing so, we consider and compare a range of macroeconomic indicators to judge the relative performance of different scheme designs.

The remainder of this paper provides some (brief) background to the work and its motivation (in Chapter 2); sets out the approach to applying a macroeconomic model and the scenario design (Chapter 3); before presenting the results (Chapter 4). The paper concludes in Chapter 5. The accompanying appendices provide further detail on the E3ME model and on more detailed aspects of the scenario design.

2 Background

Basic income

Contemporary challenges have spurred renewed interest in basic income

Basic income (in various guises) is not a new idea. However, recent renewed interest in basic income has been spurred by a variety of concerns including:

- inequality in the wake of the financial crisis and, more recently, the differential impacts of the COVID-19 pandemic
- the (punitive and intrusive) nature of recent tax and welfare reforms
- a possible future of widespread technological unemployment brought about by automation reducing aggregate labour income, thus requiring new sources of income (likely 'unearned income') to take their place, if households' standards of living are to be maintained

With the above in mind, there have been various proposals for a basic income in the UK, with analyses of how the existing tax and benefits structure might initially be adjusted away from current, targeted measures and towards the universal and unconditional payment of a basic income.[1] Such schemes are put forward as feasible (in both practical and fiscally neutral terms) re-orientations of the system, particularly as routes to addressing the first two concerns above.

The risks of adverse automation futures suggest a role for basic income

The other prominent concern that has piqued interest in basic income is automation. There is a great deal of uncertainty as to how automation might reshape economies, for better or for worse. The potential role of a basic income comes from a concern that automation will occur in such a way that it renders many jobs obsolete, depriving people of their sole/principal source of income. In the absence of such work, people will need some other form of income to support consumption. It is here that basic income enters as a possible solution, providing 'unearned' income as a replacement for the lost 'earned' income.[2] In this regard, if there is some non-negligible risk of widespread unemployment from automation, and basic income is a possible solution to that unemployment, then research is needed to better understand the macroeconomics of basic income.

However, in the face of large-scale automation and a possible requirement for large-scale basic income, the funding mechanisms typically proposed become less viable. In particular, a basic income funded by income tax (i.e. a basic income scheme that is largely redistributive in nature) makes little sense in a world in which the tax base (those earning income from work) is diminishing. There is a requirement for other ways of funding such policies, with taxes on wealth, carbon and land put forward as options.

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[1] See, for example, as indicative of the literature: for the UK, Painter and Thoung (2015) and Torry (2019); and, for Scotland, IPPR and the Fraser of Allander Institute (2020).

[2] Crocker (2020) argues that this is a longer-standing phenomenon, and that technological change has for some time been the cause of a widening gap between labour (earned) income and consumption. This has in turn created a growing reliance on sources of unearned income. By this argument, a basic income becomes necessary, crucially accompanied by a stable funding mechanism.

In contrast to conventional fiscal measures based on taxation and public debt issuance, sovereign money creation involves new money created by the central bank to fund public spending. This circumvents traditional public debt management and, in this case, could fund a basic income that also alleviates debt-financed household consumption. This will likely have very different macroeconomic impacts to other funding mechanisms.

Macroeconomic modelling

Macroeconomic modelling as a tool to understand larger-scale interventions

However, there are relatively few examples of basic income or basic income-like policies at scale. This limits the evidence with which to form a comprehensive account of a potentially transformational policy intervention. Moreover, beyond the level of the basic income *payment* (that is, the unconditional, non-withdrawable payment to individuals), there are many candidate designs for a basic income *scheme*, not least the mechanism(s) by which the payment is funded.

Because an *ex ante* assessment of basic income is not straightforward, there is a growing body of research that uses computer models to simulate the effects. To date, the prevailing modelling approach has been microsimulation to analyse the distributional impacts of shifting taxes and benefits towards a basic income. The results are static, providing a before-after comparison of whether different household types end up better or worse off in income terms after the policy change. These analyses typically consider fiscally neutral policy changes and are thus mostly an examination of the initial (first-round) effects of an income redistribution.

Microeconomic models have the advantage of high levels of individual-/household-level detail…

The clear advantage of microsimulation exercises is their ability to assess distributional impacts in detail. Drawing on survey data, such models can, for example, understand differential effects on households of differing types/demographics and economic circumstances. However, as static analyses, microsimulation exercises do not typically go on to consider how households might react to changes in income (e.g. consumption and economic activity) or, indeed, broader behavioural responses to a permanent stream of basic income (e.g. in the labour market). Wider (and dynamic) macroeconomic analysis of these follow-on effects, or the accompanying fiscal implications, has been comparatively less explored. These wider effects become increasingly relevant as the size of the basic income payment increases because the nature of the funding mechanism itself also has macroeconomic implications.

…while macroeconomic models are better-suited to tracing out system-level effects

Macroeconomic modelling can thus fill an evidence gap by considering how other theorised effects of a basic income might play out at the level of a socioeconomic system. For example (and these may differ according to the level of the basic income):

- payments to people on lower incomes may have stronger consumption effects, increasing aggregate demand and economic activity
- different funding mechanisms may differ in their consequences e.g. alternative forms of taxation, sovereign money etc

- the economic security of basic income could affect labour market decisions e.g. strengthen wage bargaining, investment in education/training, potential withdrawal from the labour market etc

A macroeconomic model provides a consistent framework with which to examine these consequences but also to consider interactions with other phenomena. Of particular interest here is the extent to which a basic income might ameliorate the potential negative impacts of large-scale automation. Moreover, at such levels of basic income (i.e. increasingly as income replacement rather than income supplement), options for funding become increasingly relevant to policy design. Candidate funding mechanisms include existing and commonly proposed tax measures (e.g. income, wealth, environmental etc) as part of a conventional fiscal management framework, but also, for example, more radical measures such as sovereign money creation.

In the next chapter we set out in more detail the design of the scenarios by which we assess the macroeconomic implications of basic income.

3 Approach

To assess the possible impacts of UBI schemes, we rely on macroeconomic modelling. A model-based approach allows for the simulation of counterfactual scenarios and policy proposals using a computer representation of the economy. Most modelling efforts to date limited their analysis to static calculations estimating the redistributive effects of proposed UBI schemes. However, to capture the complexity of feedback loops from income and employment to expenditure, trade, investment and prices, a dynamic modelling exercise is required. Dynamic macroeconomic modelling emulates these relationships to reflect how economic actors would change their behaviour in response to changing economic conditions and incentives. Such an exercise yields a system-level assessment of UBI.

For this analysis we use CE's E3ME model, an econometric model of the world's economic and energy systems, and the environment.[3] E3ME is structured along post-Keynesian lines, and countries/regions are modelled at a high level of sectoral detail, linked through trade. The model is frequently applied for impact assessment (e.g. for the European Commission and UK government) as well as research studies (e.g. for the Economic and Social Research Council, European Commission H2020 programme and predecessors). More information about E3ME and the explanation as to how the scenario assumptions have been translated into E3ME model inputs is available in the appendices to this paper.

As a macroeconometric model with the express purpose of simulating national economies (and in a global context), E3ME is well-suited to examining the macroeconomic impacts of various UBI schemes under different economic conditions. The scenarios are designed to provide the analysis of:

- A typical UBI scheme proposed in the literature, subtracting benefits and raising taxes to re-distribute income; and for comparison, a DFSM-funded UBI scheme, effectively injecting new money into the economy;
- A large scale DFSM-funded UBI scheme designed to address the potential loss of incomes in a scenario in which a large number of jobs are lost to automation.

Table 3.4 presents a brief overview of the assumptions for each of the scenarios, which concern, principally: basic income payments and funding (where relevant), and the accompanying labour supply response (see Appendix B for further details); and automation assumptions.

1. Baseline

The baseline (Scenario 1) is a business-as-usual projection which assumes no UBI intervention and no automation impact. It is a status quo projection which serves as a point of reference to understand the impact of UBI policies, or the impact of automation. Impacts of alternative UBI schemes, therefore, can be estimated as the difference in the value of particular economic variables

[3] https://www.e3me.com/wp-content/uploads/2019/09/E3ME-Technical-Manual-v6.1-onlineSML.pdf

compared to these baseline levels. The impacts of automation can be measured in a similar way.

2. Fiscally neutral UBI schemes

Scenario 2 and variants model fiscally neutral UBI schemes with small-scale UBI payments, in line with the existing policy proposals for the UK. The amounts of UBI are assumed to differ by age (Table 3.1). Also in those the proposals in the literature, UBI replaces certain benefits, as set out in Appendix B. While the withdrawal of existing benefits covers a part of the cost of the UBI scheme, the remaining cost must be covered in other ways. The typical scheme design involves changes to the tax system, through increases in income tax rates and/or social security contributions. Scenario 2 assumes financing via income tax and employee social security contributions (Table 3.2). The design thus represents an initial redistribution of existing financial resources across different income brackets (within the household sector), but no direct stimulus. However, due to a higher marginal propensity to consume across lower income groups, this can still indirectly raise consumption, with wider economic effects. The magnitude of the overall effect on the economy will also depend on the magnitude of an opposing effect, arising as a result of changes to work incentives due to tax changes and unearned income changes. We estimate that the combined effect across all quintiles will reduce labour supply by 3%, composed of a 2% reduction in hours worked and a 1% reduction in the labour force participation rate (details on this calculation are available in Appendix B).

As the later analysis shows, the nature of the UBI scheme design may matter, with a further sensitivity (variant) of this scenario considering how switching part of the funding to employers' social security might affect outcomes.

3. DFSM UBI

Scenario 3, DFSM UBI, does not impose a constraint of fiscal neutrality. Instead, the cost of UBI payments is met with Debt-Free Sovereign Money (DFSM); as set out, for example, by Crocker (2020). This scenario assumes small-scale UBI payments of a size similar to the level of UK government support provided to households in 2020/21 during the COVID-19 pandemic, amounting in total to £82bn, or close to £1,200 per person annually (see Appendix B for further discussion of this calculation).

In contrast to Scenario 2, this scenario does not impose fiscal neutrality through changes in tax rates or benefits. The UBI in Scenario 3 serves as a top-up source of income funded through issuance of DFSM. DFSM-funded UBI effectively provides a stimulus without removing/redistributing resources in the economy (as an income tax might).[4] The effect of DFSM-funded UBI is to increase incomes for all income groups and therefore boost aggregate expenditure in the economy. Nevertheless, increased incomes are assumed to have secondary impacts on incentives to work. We enter these into the model

[4] The rationale for funding this level of UBI rests on the observation by van Lerven *et al*. (2021) that UK government borrowing in 2020/21 was of a similar amount to net purchases of government bonds by the Bank of England that same year. From this, van Lerven *et al*. (2021) go on to say that this amounts, effectively, to public sector borrowing being funded by newly created money i.e. in a way that resembles DFSM. With household support forming just one part of the overall support package, our analysis considers the macroeconomic effects of sustaining a DFSM-like income-support policy over a longer period.

as a 0.8% reduction in labour supply, in equal parts made up of lower labour force participation rate and fewer hours worked (detailed in Appendix B).

Table 3.1 Annual UBI payments per person: income tax-funded UBI and DFSM-funded UBI (£2018 per year)

Age group:	2. Income tax-funded UBI	3. DFSM-funded UBI
0-15	2,609	1,224
16-64	4,174	1,224
65+	9,392	1,224

Source(s): Cambridge Econometrics assumptions.

Table 3.2 Total cost and sources of financing of the UBI schemes (£2018 per year)

	Fiscally neutral UBI	DFSM UBI
Cost of UBI payments	-321	-81
Covered by:		
Withdrawal of the existing benefits	154	0
Income tax revenue increase	93	0
Employers' social security contributions	75	0
Debt-free sovereign money	0	81

Note(s): The estimates are approximate, based on the analysis of average income and tax payments in different quintiles and other simplifying assumptions.
DFSM UBI payments are calculated from 2020/21 reported COVID-19 expenditure rescaled to 2020 population (for input to E3ME).

Source(s): Cambridge Econometrics analysis of ONS data, UKMOD.

4. Automation

Scenario 4, automation, is a non-UBI scenario designed to demonstrate the estimated future impacts of automation on household incomes. In the results section we compare the results to those in the baseline scenario to illustrate the potential impacts of high automation on the UK economy. This scenario assumes a gradual loss of jobs, as humans are replaced by robots. We assume that 15% of UK jobs are lost by 2035, although job losses vary by sector (Table 3.3). In turn, this leads to a decline in labour incomes. Simultaneously, the economy sees increased capital investment in robots, and productivity gains as a result of efficiencies brought by that automation (explained in more detail in Appendix B). We assume that the automation-supported workforce is 50% more productive and that a single robot will replace 3.3 workers. These assumptions are reflective of the available evidence but remain subject to uncertainty (and debate). Nevertheless, these assumptions are sufficient to define an automation future that erodes household incomes. The precise numerical assumptions are not the object of focus. Instead, the purpose of these assumptions is to create a scenario that serves as a precursor to an assessment of the possible role of UBI. This is the focus of the study.

For the purposes of this exercise, which focuses on the UK, we do not fully model a global automation scenario in which different parts of the world see differing job losses according to the structure of their own economies. This would be a larger exercise requiring region-specific assumptions for all regions captured in the model. However, we also cannot only represent UK automation in isolation because this has implications for trade. Without similar effects in the rest of the world, increased UK competitiveness from automation raises demand for UK exports, affecting the overall results. To strip out this effect, we adjust UK trade volumes (exports and imports) to remove the influence of these price changes i.e. *as if* the UK's competitive position were unchanged, approximating comparable automation elsewhere in the world. This allows us to focus on the implications of automation on UK household incomes (through which there can still be trade effects e.g. on imports).

In the results section we compare the results to those in the baseline scenario to illustrate the potential impacts of high automation on the UK economy.

Table 3.3 Sectoral job loss assumptions in the automation scenario (percentage difference from baseline) 2035

Sector	Estimated job losses by 2035
Agriculture, forestry & fishing	-9.4%
Mining & manufactured fuels	-14.3%
Basic manufacturing	-22.5%
Engineering & transport equipment	-22.5%
Electricity supply	-15.9%
Other utilities	-26.2%
Construction	-11.5%
Distribution & retail	-21.0%
Transport	-28.2%
Communications, publishing, accommodation	-28.2%
Business services	-15.5%
Public & personal services	-8.2%

Source(s): Cambridge Econometrics analysis of PwC (2017) and PwC (2018).

5. Combined automation and income-compensating DFSM UBI

Scenario 5 combines Scenario 4 (automation) with a proposal for a DFSM-funded UBI. The level of UBI payments is identical for all age groups and is set at such levels to compensate for labour income lost due to automation. Effectively, this means that, as automation results in lower household incomes (from job losses) over time, the compensating UBI payments will increase to make up for those losses to bring total household income back to the level consistent with the baseline scenario. In practice this means that in 2035, the UBI rate would be £2,231 per person per annum. This scenario tests whether a DFSM-funded UBI scheme could be viable as a policy to support household incomes in the face of high technological unemployment and decreasing labour demand.

While it is the large reduction in labour demand that drives this scenario, for the completeness of the economic simulation, the labour supply response to the UBI is calculated within the model by the same approach as in Scenarios 2 and 3. According to these estimates, by 2035 the labour supply would decline by 1.4%, in equal parts made up by reduction in the labour force participation rate and in hours worked.

Table 3.4 Scenarios modelled

<table>
<tr><th colspan="2">Scenario</th><th>UBI payments and changes to benefits</th><th>UBI scale</th><th>UBI funding source</th><th>Automation</th><th>Household expenditure</th><th>Labour market</th></tr>
<tr><td colspan="2">1. Baseline</td><td>No UBI, no changes to the benefits system</td><td>N/A</td><td>N/A</td><td>None (beyond any implicit in the baseline)</td><td rowspan="5">Follows E3ME consumption function, expenditure responds to assumed initial changes in disposable income. Modelled for individual quintiles</td><td>N/A</td></tr>
<tr><td rowspan="2">UBI implementations</td><td>2. Fiscally neutral UBI</td><td>UBI with selected existing benefits withdrawn</td><td>Small scale, in line with existing policy proposals

Annual payments per person vary with age:
• Children: £2,609
• Adults: £4,174
• Pensioners: £9,392</td><td>Income tax and employee social security contributions</td><td rowspan="2">None (beyond any implicit in the baseline)</td><td rowspan="2">Decreasing labour supply as an initial behavioural response to UBI: lower participation rate and hours worked.

Firms hire more people to keep their labour input as labour productivity is unchanged</td></tr>
<tr><td>3. DFSM UBI</td><td>UBI applied on top of existing benefits system</td><td>Small scale: similar to the UK government's COVID-19 support measures.
Same payments across all ages, at £1,221 per person per annum</td><td>DFSM</td></tr>
<tr><td colspan="2">4. Automation</td><td>No UBI, no changes to the benefits system</td><td>N/A</td><td>N/A</td><td rowspan="2">High-automation, high unemployment scenario</td><td>Automation increases productivity and brings severe job losses</td></tr>
<tr><td colspan="2">5. Combined automation and income-compensating DFSM UBI</td><td>UBI applied on top of existing benefits system</td><td>UBI payments compensating for labour income lost to automation. Constant across all age groups, but varying across years, reaching £2,231 per person per annum in 2035</td><td>DFSM</td><td>As in Scenarios 2, 3, and 4 combined</td></tr>
</table>

Notes(s): A more detailed description of the assumptions is provided in Appendix B.

Performance metrics for UBI schemes

The key metrics of macroeconomic performance for these scenarios are:

- GDP
- employment
- prices (inflation)

The main mechanisms through which UBI affects the economy are stimulated consumer expenditure and changes to incentives to work resulting in changes to labour force participation and hours worked. As a result of a number of feedback loops in the economy, both can affect the GDP and employment.

For example, a fiscally neutral UBI scheme redistributes income to consumers with higher marginal propensities to consume. At the same time UBI also alters the incentives to work as a result of changing marginal tax rates, resulting in dynamic employment changes.

Therefore, the stimulating effect on consumer expenditure can be somewhat moderated, and will depend on a multitude of feedback loops modelled by E3ME, from consumption and employment to trade, investment, prices, and GDP. The relative magnitude of these effects has been a subject of interest for policymakers concerned not only about redistributive impacts of UBI schemes, but also about its impact on the overall performance of the economy.

The effects on prices are of interest from the perspective of macroeconomic stability, as it is a typical concern that UBI schemes stimulating consumer expenditure (or other design aspects of a UBI scheme, including DFSM) could lead to inflation, depending on whether the economy approaches capacity constraints. These mechanisms are also represented in the E3ME model and are described in more detail Appendix A.

Limitations of macroeconomic modelling

Nevertheless, some limitations apply to macroeconomic modelling. Firstly, a macroeconomic model such as E3ME provides only a simplified version of reality. In particular, only a limited number of key relationships and feedback loops can be represented in a model. Similar simplifications were required when translating technical and political assumptions underpinning UBI schemes or the automation scenario into economic variables in the framework of E3ME (Appendix B). Therefore, a number of implicit assumptions exist about which feedback loops were included in our E3ME model and in our scenarios, which may differ significantly from other macroeconomic models. While these choices are grounded in economic theory and empirics, a certain degree of subjectivity arises which overall can have a marked impact on the results (model dependence).

Secondly, many parameters capturing the magnitudes of the relationships represented in E3ME model are estimated statistically. These estimates are based on the past behaviour of the real-world economy. However, a degree of uncertainty exists about the true value of these parameters, since we rely on statistical estimates. Also, these relationships may not hold in the future. This is an especially important limitation, given the likely magnitude of changes brought by large-scale UBI schemes or by the onset of automation.

It is also important to note the trade-off in a macroeconomic modelling exercise such as this. In exchange for a more complete, dynamic analysis of the effects of basic income on the macroeconomy, we sacrifice the household-level detail that characterises (static) microsimulation exercises. In general, the discussion of ‘households’ that follows refers to households as the institutional sector, in macroeconomic / national accounts terms i.e. an aggregate variable. While distributional impacts can be (and are) estimated, the level of detail possible is appreciably lower than might be gleaned from a microsimulation model of individual households. We comment to the extent possible on household-level implications but acknowledge a (future) need to explore this in greater depth, perhaps through linkages with a microsimulation model.

4 Results

This section presents the modelling results covering, in turn, our analysis of:

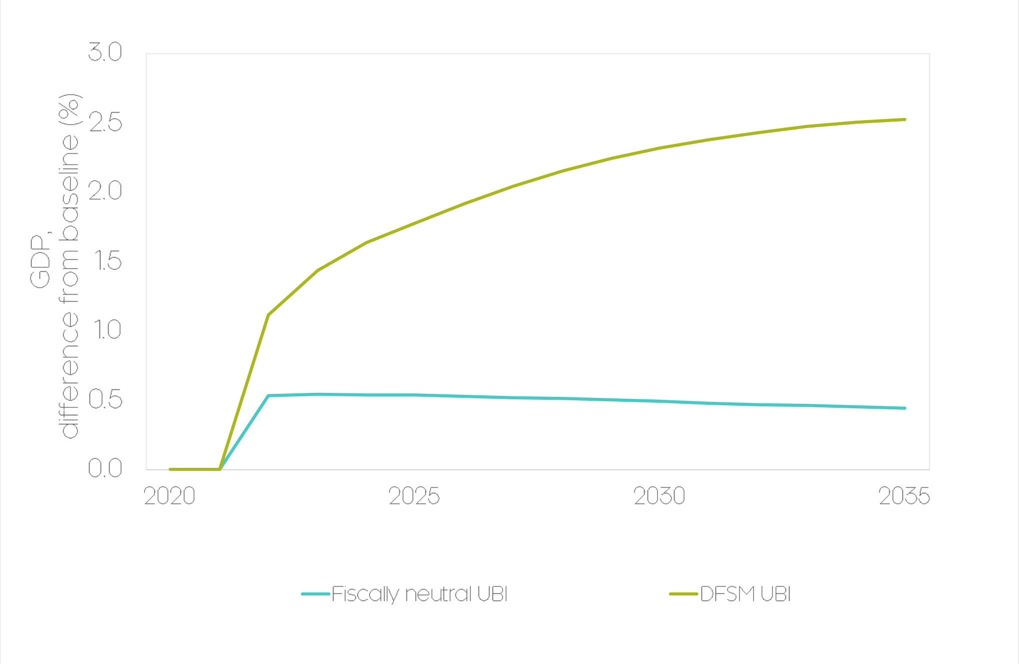
- UBI schemes typically proposed in the UK, in terms of scale and/or design
- large-scale automation and how it might erode incomes, with basic income as a possible solution to counter the potential adverse effects

Small-schemes, fiscally neutral and DFSM-funded

Small-scale UBI schemes can generate (small) positive GDP effects

Figure 4.1 shows how a fiscally neutral basic income scheme (Scenario 2) and a DFSM basic income scheme (Scenario 3) might affect GDP compared to the baseline. Both basic income variants have a small positive GDP impact, with output 2.5% higher than baseline in the DFSM UBI and 0.4% higher in the fiscally neutral case. Note that, beyond the conclusion of a small positive effect, the two schemes are not directly comparable because the size of the income support differs (see Appendix B for further details).

Figure 4.1: GDP impacts of two basic income schemes, difference from baseline (%)

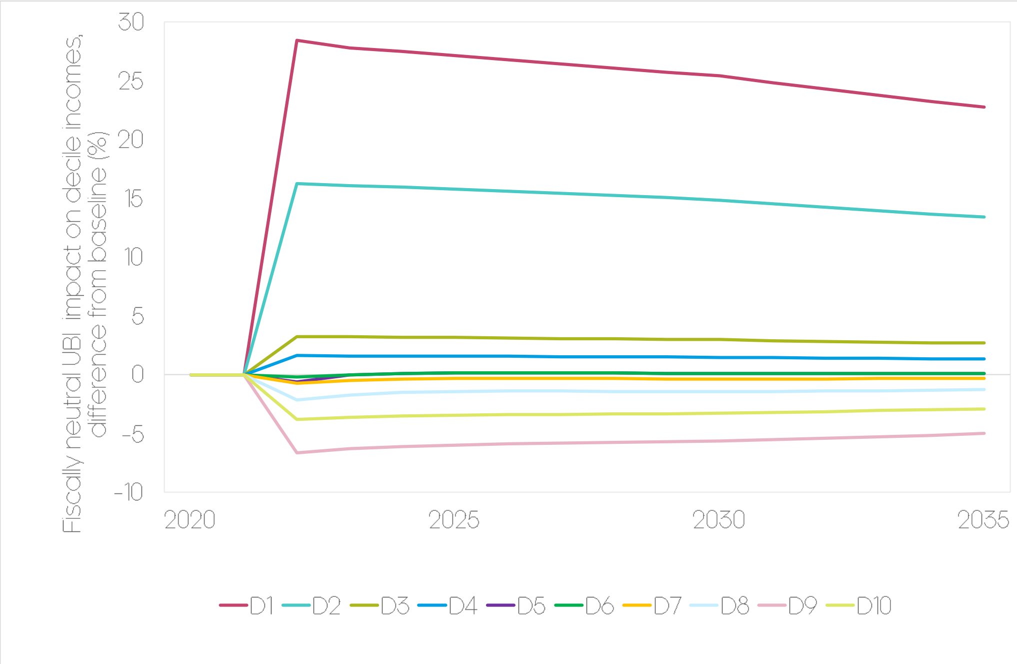


Source(s): Cambridge Econometrics, E3ME model.

Fiscally neutral UBI results

In the ***fiscally neutral basic income scenario***, while more is provided in basic income, these payments are offset (fully funded) by taxes on labour earnings: income taxes and employees' social security contributions. Therefore, overall household income is initially unchanged in this scenario, though funds are redistributed across income groups in the economy, which is relevant to the final macroeconomic outcomes.

Figure 4.2: Changing decile incomes under the revenue neutral basic income scenario, difference from baseline (%)



Source(s): Cambridge Econometrics, E3ME model.

Figure 4.3: Decomposing the GDP effect in the fiscally neutral basic income scenario, difference from baseline (%)

Source(s): Cambridge Econometrics, E3ME model.

Redistribution to lower-income households raises GDP slightly

The main driver of the GDP impacts in this scenario is the redistribution and the consequent increases in consumption. Channelling income towards lower-income households increases total consumption because lower-income groups have higher marginal propensities to consume (to purchase essential goods and services). This redistribution boosts economy-wide consumption because, net, the higher consumption by lower-income households more than offsets reductions in consumption by higher-income households. Figure 4.2 shows the extent of this income redistribution (a combination of the initial UBI changes as well as economy-wide feedbacks). Figure 4.2 shows that the income of the bottom (lowest-income) decile increases by more than 20% compared to baseline, while that of the top (highest-income) decile is 7% lower on the same basis. Figure 4.5 decomposes the GDP effect in the fiscally neutral scenario, highlighting the contribution of higher household consumption, offset slightly by a mild increase in imports (stemming from this same consumption effect). The overall effect is a 0.4% increase in GDP compared to baseline by 2035.

While the basic income scheme does reduce incentives to work initially, higher economic activity leads to overall higher employment

The second impact channel in the fiscally neutral basic income scenario is through labour market dynamics. While the transfer does increase incomes for lower-income households, this may also weaken (at least somewhat) the incentive to work. Moreover, given the design of this scheme, to also raise other taxes to fund the basic income, there are disincentives to work across the distribution, leading to (initial) reductions in labour supply in the face of higher income tax rates, for all households.

In this scenario, we assume that basic income is a disincentive both at the extensive and intensive margins. Extensive margin impacts mean reduced participation rates (fewer workers), while intensive margin impacts result in fewer hours worked by those in employment. We also assume that, with lower average hours worked per worker, firms must hire more employees to sustain the same level of production (to sustain the same level of labour input). Thus, and in lieu of strong evidence to the contrary, the scenarios make no assumption that reducing working hours, by itself, *causally* raises worker productivity, even if there is an observed inverse relationship between GDP per capita and annual working hours per worker (see, for example, Giattino and Ortiz-Ospina, (2020)).

The results are robust to higher labour productivity

Overall, while this scenario incorporates an initial reduction in participation rates and hours (from the basic income and funding mechanism), the need for more workers to sustain a given level of output, along with the stimulus effect of consumption on production drives a 2.3% increase in employment in 2035 compared to the baseline (as shown in Figure 4.8).

The literature is inconclusive as to how working fewer hours affects the labour productivity of employees, and how firms might react to those changes. Some studies (such as Pencavel (2015), and Collewet and Sauermann (2017)) found that a small reduction in hours worked could boost hourly productivity, though these studies are mostly based on small-scale trials in specific industries. Our main scenarios assume no productivity change on the part of workers. Consequently, to produce a unit of output, firms must maintain the same level of (unit) labour input by hiring proportionally more workers to compensate.

Our qualitative result (a modest increase in GDP) is robust to this productivity assumption. Alternative runs which assume labour productivity increases to offset lower hours (such that workers produce and are paid the same but work fewer hours) give broadly similar results. GDP remains slightly higher in the scenarios than in the baseline, albeit with not quite as large an increase. Given the similarity of the results, we do not report them in detail.

At a macroeconomic level, our results are thus not sensitive to the assumption as to whether fewer hours worked raises productivity (or not).

However, the design of the funding mechanism is of macroeconomic importance

Typical (modelled) basic income schemes usually propose further income taxation as a way to fund the payments. This is not the only funding option and various other sources are frequently mentioned, such as carbon, wealth and land taxes.[5] As a further test of the fiscally neutral case, we also ran a version of this scenario in which some of the funding was levied from firms rather than households. In this variant, the additional funding comes from income taxes and employers' (rather than employees') social security contributions, in equal parts.

The same level of basic income but an alternative funding mechanism has a somewhat different impact. Rather than an initial redistribution of income within the households sector, this variant transfers some income (profit) from firms to households. In aggregate, households thus receive more income as the initial direct effect. To households, this increases consumption by more than the income tax-only case. By 2035, GDP is 2.4% higher than baseline for the same level of basic income payment as in the main scenario. As not all costs of the basic income scheme are covered by taxes on labour income, disincentives to work and the reduction of labour supply are also weaker. GDP and employment are thus increased by more than in the main fiscally neutral scenario.

However, this alternative funding mechanism increases firms' costs and, in turn, raises prices, leading to higher inflation.

DFSM UBI results

In the ***DFSM-funded basic income scenario*** (Scenario 3) the effects are more straightforward in that the stimulus raises GDP by providing additional income to households, leading to further consumption. This contrasts with the fiscally neutral case (Scenario 2), which examines a(n initially) redistributive scheme.

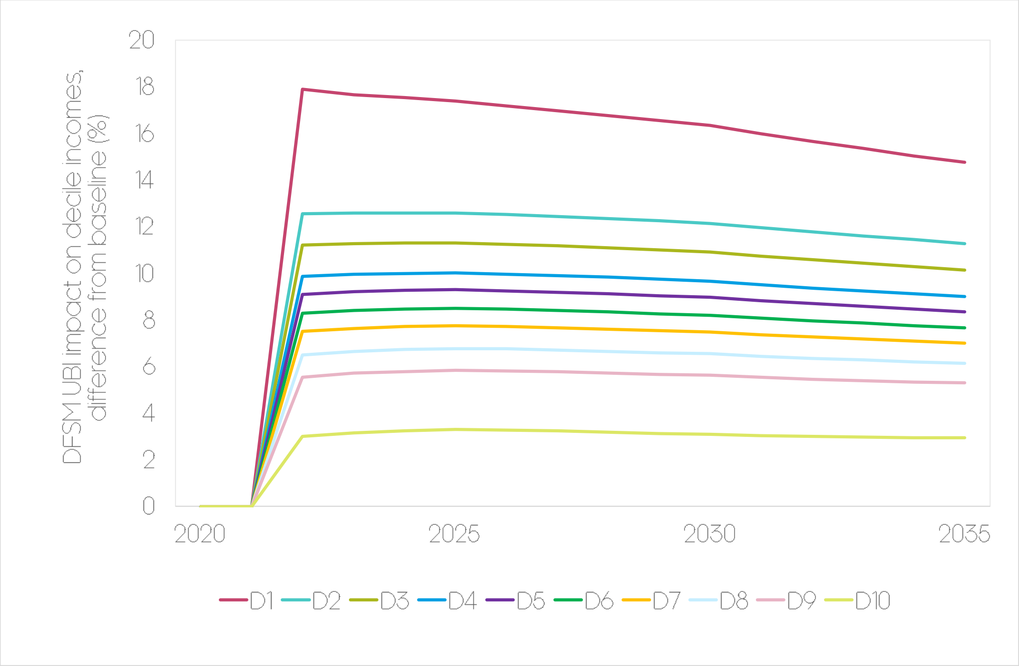
In this scenario the differential impact across the income distribution is weaker as the scheme is only providing new income (and not also redistributing income, from higher- to lower-income households). In percentage terms, lower-income households still benefit more (and contribute more to higher consumption). Because the benefits system and existing income taxes are unchanged, the basic income in this scheme generates weaker disincentives to work. The scenario has 2.3% higher employment level than in the baseline

[5] Income taxes are a convenient and readily available lever in a microsimulation model, which may explain their relatively greater use in UK studies, even if there is stated acceptance that other sources are also viable and legitimate. Depending on their intended purpose, the feasibility and desirability of different tax options can vary e.g. in the tension between revenue raising and emissions reduction (in the case of carbon taxes); administrative complexity; and whether it is feasible to identify a target for the tax base in question.

by 2035, coming from the higher consumption which generates higher product and ultimately higher labour demand (see Figure 4.8Figure 4.).

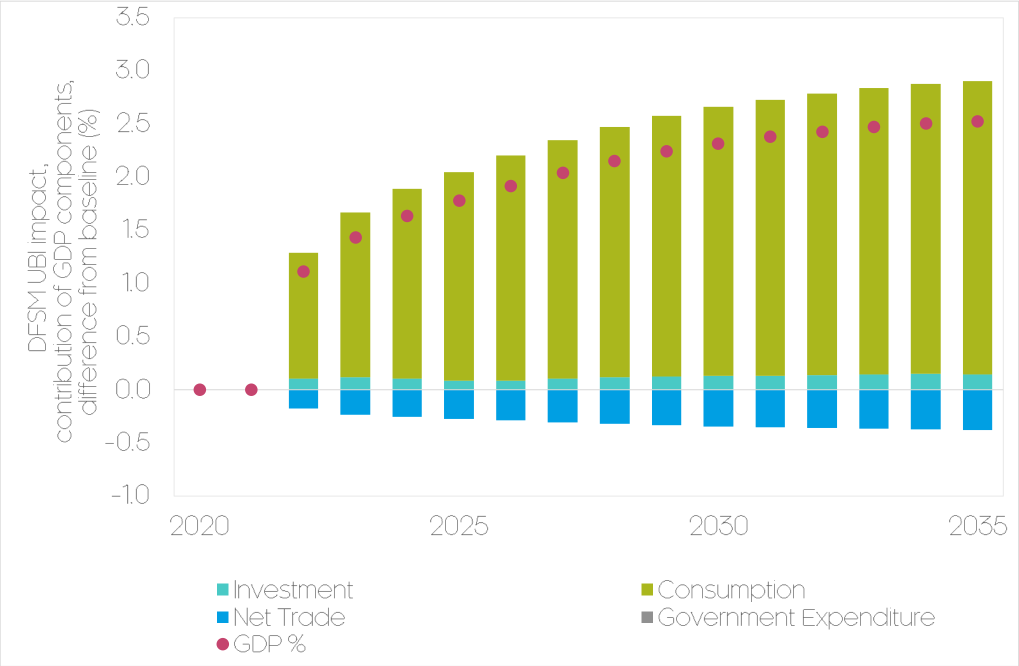
In aggregate, household income increases by 7% above baseline in 2035 from the DFSM UBI, with the lowest-income decile seeing a substantially higher increase than that in percentage terms (see Figure 4.4). Figure 4.5: shows that the higher incomes increase consumption, driving the positive GDP effect. By 2035, GDP is 2.5% higher than in the baseline.

Figure 4.4: Changing decile incomes under the DFSM basic income scenario, difference from baseline (%)



Source(s): Cambridge Econometrics, E3ME model.

Figure 4.5: Decomposing the GDP effect in the DFSM basic income scenario, difference from baseline (%)



Source(s): Cambridge Econometrics, E3ME model.

Impact on inflation

Neither of the small-scale UBI scenarios (fiscally neutral or DFSM) exhibits strong inflationary impacts: the difference in the price level by 2035 is less than 0.01 percentage points when compared to the baseline (Figure 4.9). This is because demand-pull inflation is relatively weak as a factor in E3ME. With no presumption that the economy operates at (or tends towards) full capacity, there remains room in the:

- short run, for production to adjust to meet higher demand through higher capacity utilisation
- longer run, for productive capacity to adjust (through new investment) to support higher expected demand in the future

In the results, the implication is that the economy is able to absorb the (mild) increases in demand generated by the basic income schemes.

As discussed before, we modelled sensitivity around the funding mechanism of the fiscally neutral basic income scheme. In this variant, basic income has strong inflationary impacts through the cost-push channel (0.7 percentage points higher price levels compared to the baseline in 2035). This highlights the importance of wider scheme design i.e. beyond simply the level of basic income payment. For the same level of basic income payment, different scheme designs can perform differently in macroeconomic terms. In this case, it is possible to design more or less inflationary income schemes.

Impact on public finances

The real-economy effects of UBI can also translate into impacts on government finances. E3ME provides a simplified treatment of government finances, in which many government revenues and expenditures are modelled endogenously. In general, higher levels of economic activity result in higher government revenues, as E3ME calculates government revenues largely on the basis of tax rates applied to items such as employee earnings, company profits and household consumption. Government expenditures are also estimated endogenously, for example to fund the output of public sectors (such as healthcare, education, public administration and defence), or the linkage to the cost of social security payments and going wage rates in the economy (as these payments are typically indexed).

In scenarios assuming DFSM UBI, the cost of UBI is met with issuance of DFSM. DFSM does not create liabilities for the government and, therefore, does not add to the public deficit and debt stock. However, in our calculations we assume that all other components of the primary balance continue to be financed as is, with primary public deficits being financed by new public debt issuances, adding to the stock of debt and incurring interest payments.[6,7]

Our analysis shows that the additional economic activity as a result of both fiscally neutral and DFSM-funded UBI schemes results in an improvement to government finances (see Figure 4.6). Our estimates show that in the fiscally neutral UBI scenario the debt-to-GDP ratio would be approximately 1 percentage point (pp) lower than in the baseline scenario. In line with the

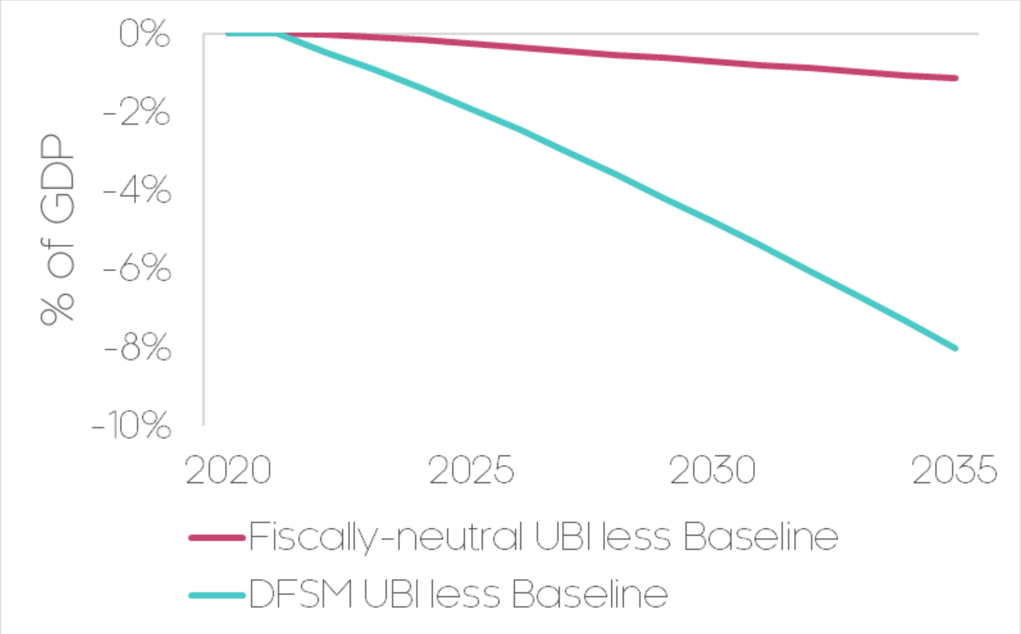
[6] The primary balance in this context is the difference between government revenues and government expenditures excluding DFSM.

[7] In this simplified treatment, we make an assumption that the cost of interest payments on any additional debt is met with further debt issuances. In practice, the government could rely on various alternatives to cover the financing needs, such as cuts to expenditure or tax increases.

assumed nature of DFSM-funded UBI and its greater stimulus effect, it is estimated that by 2035 the UK's debt-to-GDP ratio would be around 9 pp lower than in the baseline scenario.

Under the assumption that the interest rates on government debt will remain at similar levels to currently (about 2.8%), in the fiscally neutral UBI scenario the public debt interest payments in 2035 would be lower by £1.2bn compared to the baseline (equivalent to less than 0.1% of 2035 GDP in the baseline scenario). Under the DFSM-funded UBI scenario this difference would amount to £8bn in 2035, or 0.2% of GDP projected for that year. For comparison, over the past decade the average UK public debt interest payments stood at about 2.4% of GDP (or £40bn in 2020).[8] Therefore, the impacts on the cost of servicing debt are modest, but serve as an example of how different methods of financing UBI could affect public finances.

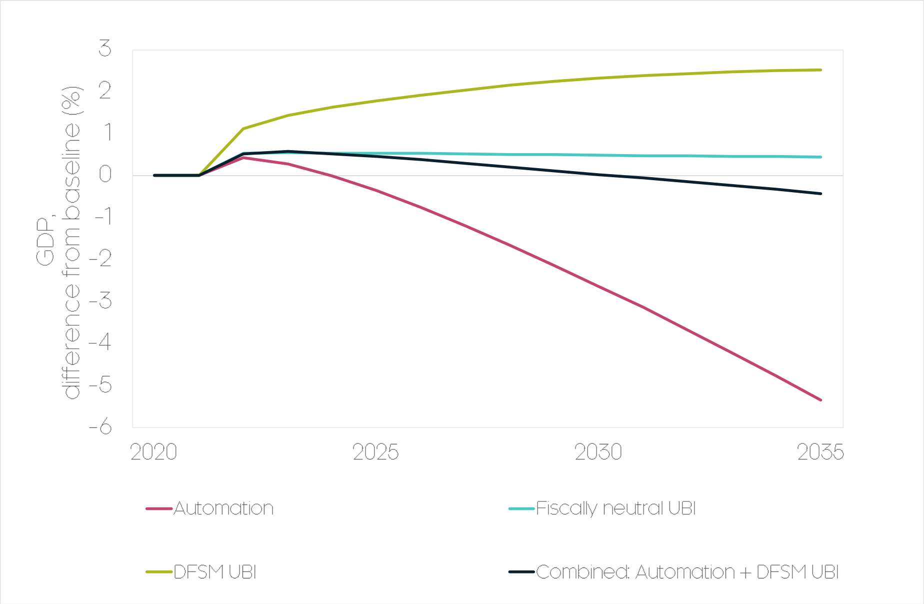
Figure 4.6: Impact on public debt stock – fiscally neutral and DFSM UBI scenarios



Note(s): Projections assume DFSM issuance does not create a liability and that the cost of interest payments on any additional debt is met with further debt issuances.
Source(s): Cambridge Econometrics, E3ME model.

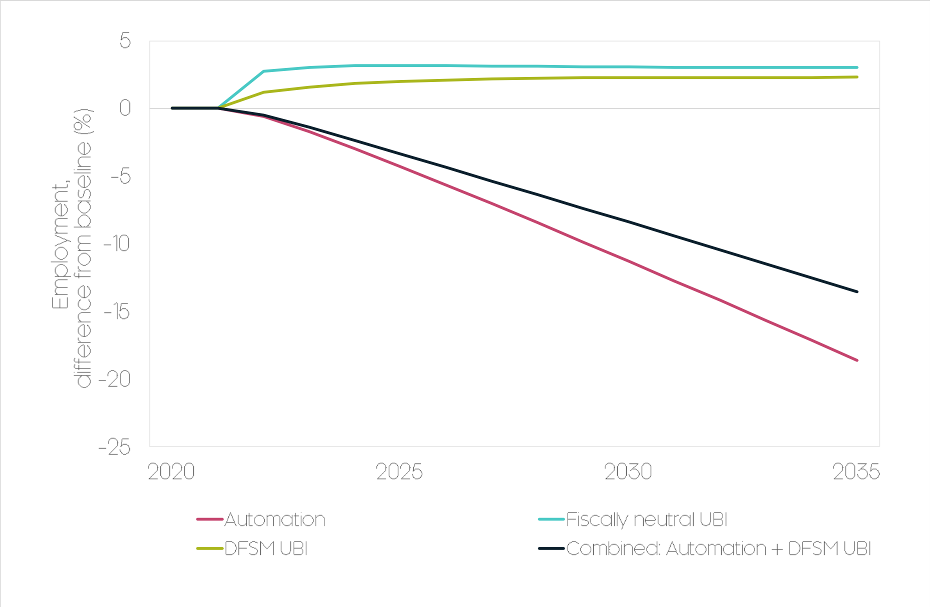
[8] Based on CE analysis of the IMF Government Finance Statistics and the ONS Gross Domestic Product: Chained volume measures, Seasonally adjusted data.

Figure 4.7: GDP impacts, difference from baseline (%)



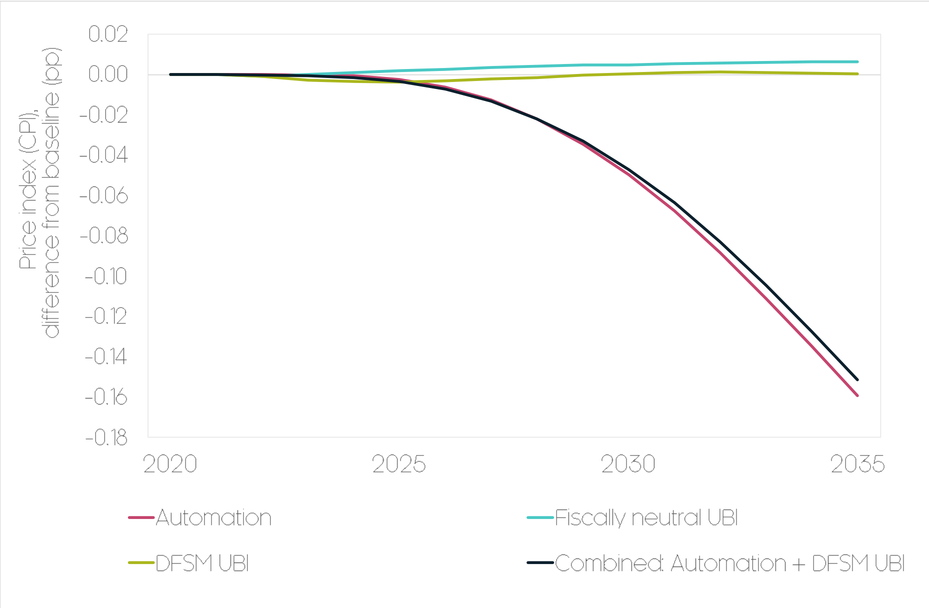
Source(s): Cambridge Econometrics, E3ME model.

Figure 4.8: Employment impacts, difference from baseline (%)



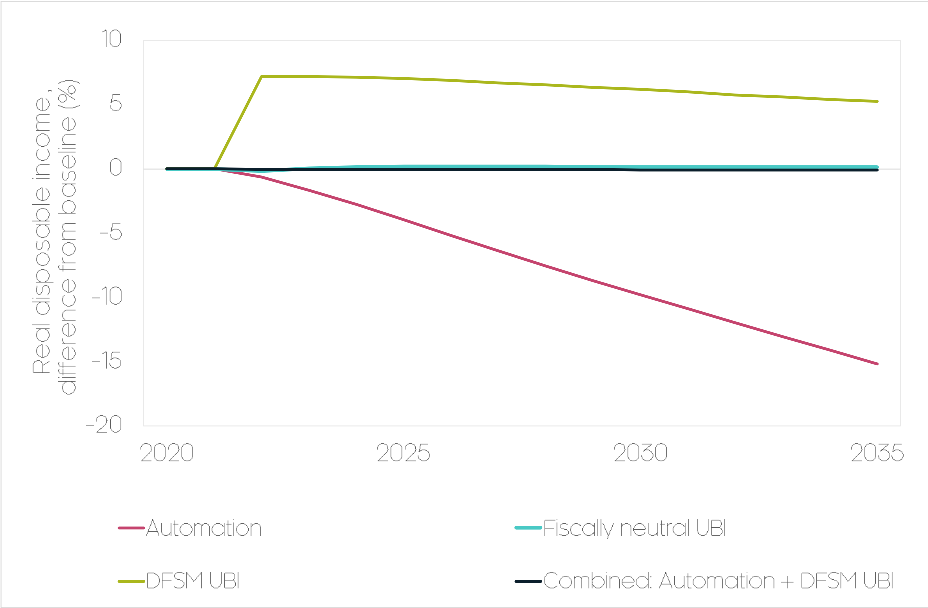
Source(s): Cambridge Econometrics, E3ME model.

Figure 4.9: Impacts on price level, difference from baseline (pp)



Source(s): Cambridge Econometrics, E3ME model

Figure 4.10: Impacts on real disposable income, difference from baseline (%)



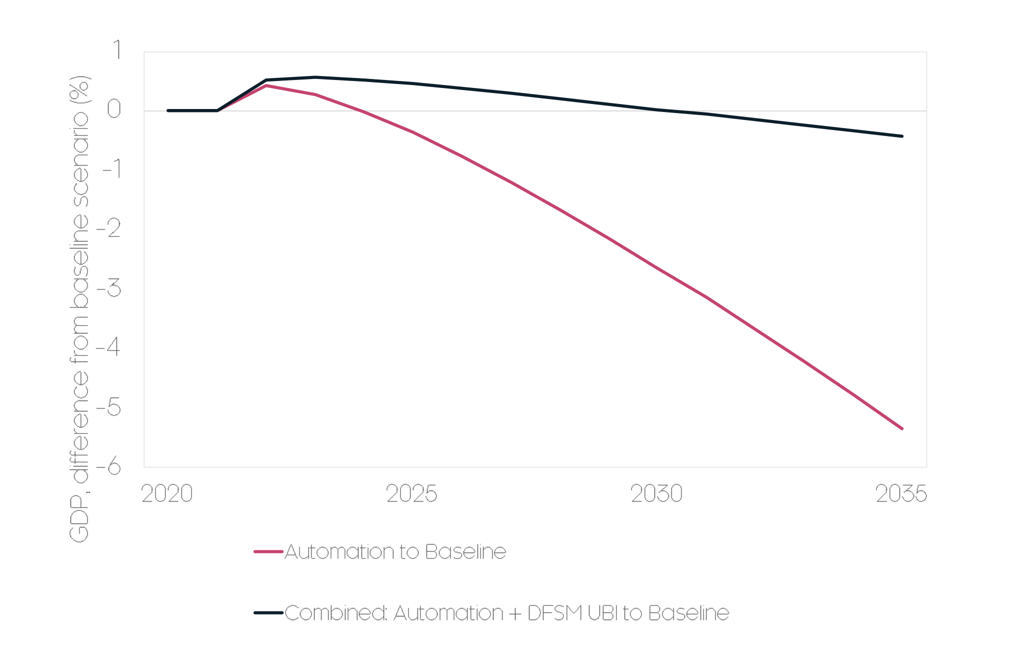
Source(s): Cambridge Econometrics, E3ME model.

Automation, basic income and debt-free sovereign money

This section shows the second set of results, examining the economic impacts of large-scale automation and how DFSM UBI might compensate for the technology-induced income losses. As explained previously, the automation scenario is intended as an illustrative scenario of future household income losses from job losses. This is then a vehicle for a further examination of the potential role of UBI. Bearing this in mind, Figure 4.11 shows the impacts of such a scenario, with the large-scale automation modelled (the red line) reducing GDP by 5.4% compared to baseline by 2035.

On top of this automation scenario, we then applied a DFSM-funded UBI with the aim of maintaining real income at baseline levels i.e.to simulate UBI as a replacement for the income lost through automation. A basic income scheme that supports real household incomes in this way also maintains GDP at near baseline levels. By 2035, GDP is just 0.4% below the baseline: while real incomes have been maintained, the composition of economic activity is slightly different, hence the (small) difference. The basic income supports a 5¼% increase in GDP from the automation run, representing a gap of just 0.4% below baseline.

Figure 4.11: GDP impacts from automation with and without a compensatory DFSM basic income scheme, difference from baseline (%)



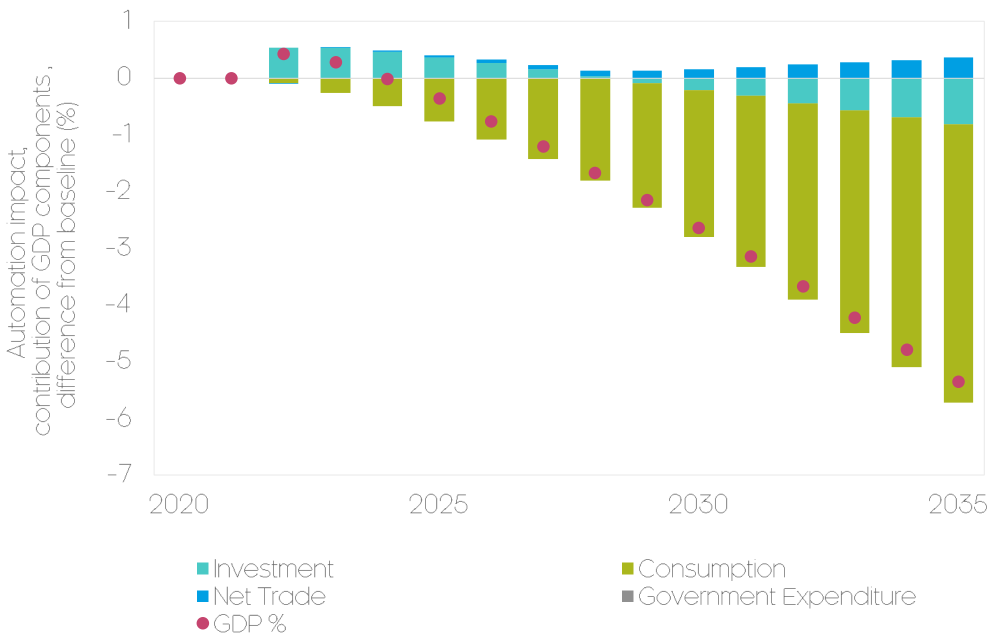
Source(s): Cambridge Econometrics, E3ME **model.**

Automation leads to large negative GDP impacts

Compared to the baseline, the ***automation scenario*** leads to strong negative GDP impacts, -5.4% by 2035 compared to baseline. This overall negative result from automation (in a scenario defined in terms of job losses) is as expected in a (post-Keynesian) economic model in which there is no presumption that the economy tends to return to operating at full capacity. While the productive capacity of the economy is greatly augmented by the new technologies, there is no need to fully utilise that capacity in the absence of (effective) demand. Were there some way to support higher demand, production in the economy (GDP) could increase.

In the long run, the impact is determined by the loss of household incomes which is caused by the high assumed job losses leading to more than 18% lower than baseline employment by 2035 (see Figure 4.8). In the short term, GDP rises somewhat from the initial investment in AI, robotics and other automation technologies. While this investment acts as short-run stimulus, in the medium and long runs, household income falls substantially, reducing consumption. These large reductions in demand lead to GDP falling below baseline from 2025 onwards alongside investment slowing once the new (automated) productive capacity is in place. The impacts are thus ultimately driven by falling consumer spending as shown in Figure 4.12:, leading to reductions in GDP.

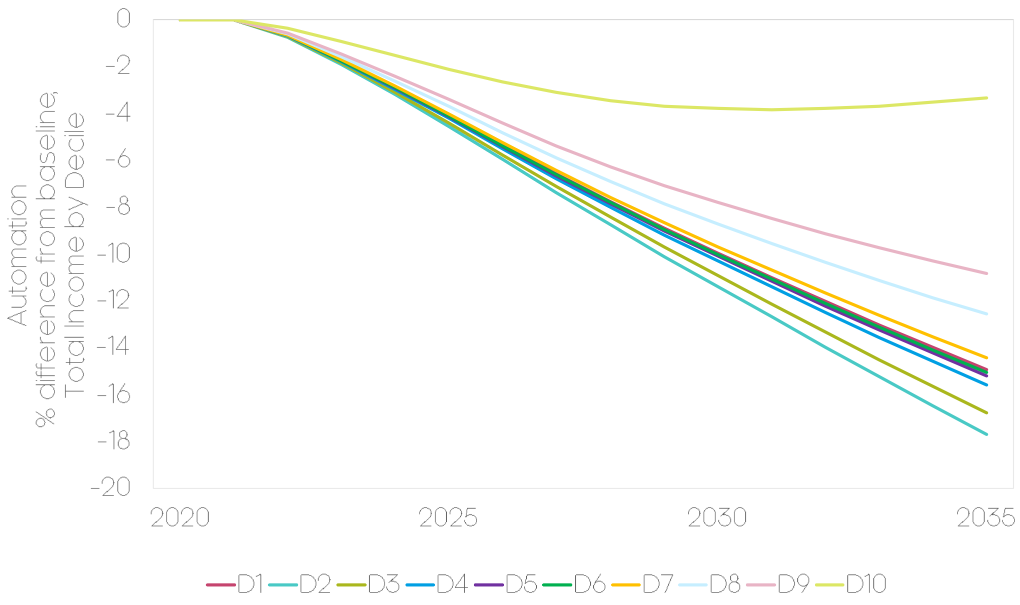
Figure 4.12: Decomposing the GDP effect in the automation scenario, difference from baseline (%)



Source(s): Cambridge Econometrics, E3ME model.

In terms of distributional effects, Figure 4.13 highlights how automation and technology-related unemployment affects low-income households the most, arguably emphasising the need for income support. While the highest-income group sees a 7% reduction in income compared to baseline, the lowest-income deciles have incomes that are 20% lower in the scenario than in the baseline. This reflects the pattern of job losses which occur more in low-skilled than high-skilled jobs. Interestingly, income losses are not the most severe for the lowest-income decile, due to the high share of inactive and unemployed population in this income group. At the other end, high-skilled jobs are (currently) both difficult to automate and are more likely to be complements to high-technology production. Wages and salaries (i.e. labour income) also account for a lower share of total incomes for the richest households. Even if wages are eroded, overall incomes do not decrease as strongly (and could even grow if capital’s share of income increases, leading to higher dividend payments).

Figure 4.13: Changes in decile incomes in the automation scenario, difference from baseline (%)



Source(s): Cambridge Econometrics, E3ME model.

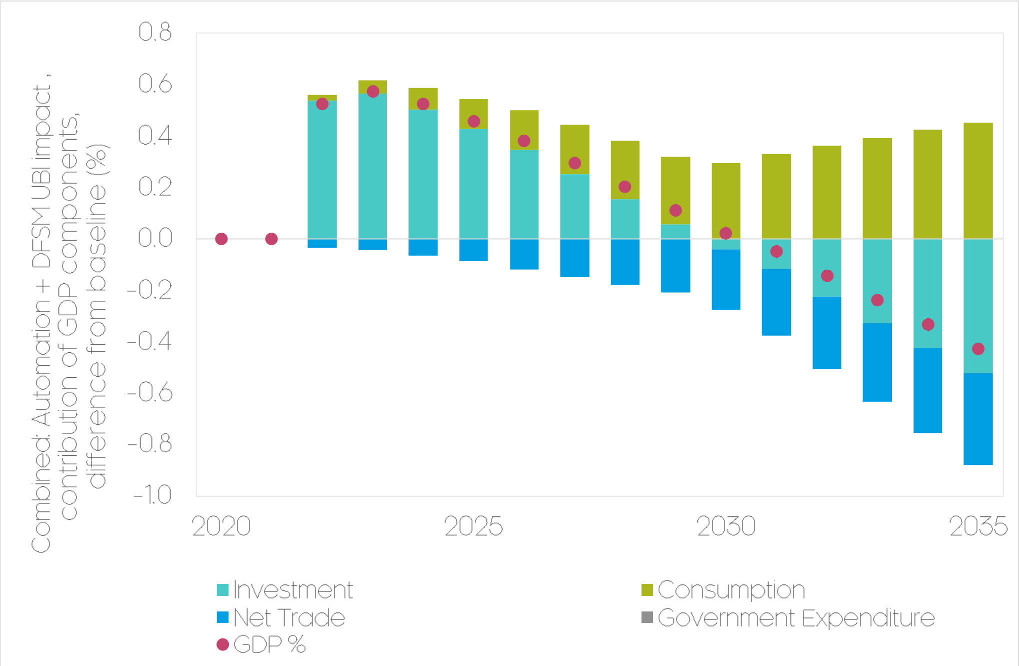
A DFSM UBI can be used to compensate lost incomes and consumptions due to automation

In the **combined scenario**, we take the automation scenario (as above) and introduce a compensatory DFSM basic income scheme to return household incomes (in real terms) to the levels in the baseline. This is how we define the income replacement. The level of this compensation is calculated in E3ME, and its value is distributed equally across deciles in monetary terms.

In doing so, the basic income shields households from the adverse effects of automation. The scenario still leads to substantial job losses, with employment 14% lower than in the baseline. However, while the automation-only scenario saw substantial GDP losses from lower income leading to lower consumption; in the combined scenario, basic income breaks this link. Fewer jobs lead to lower income from employment, but basic income fills the gap, maintaining incomes and sustaining consumption (see Figure 4.14:). Relative to baseline, the scenario shows only small losses of output by 2035 of 0.4% (as explained below).

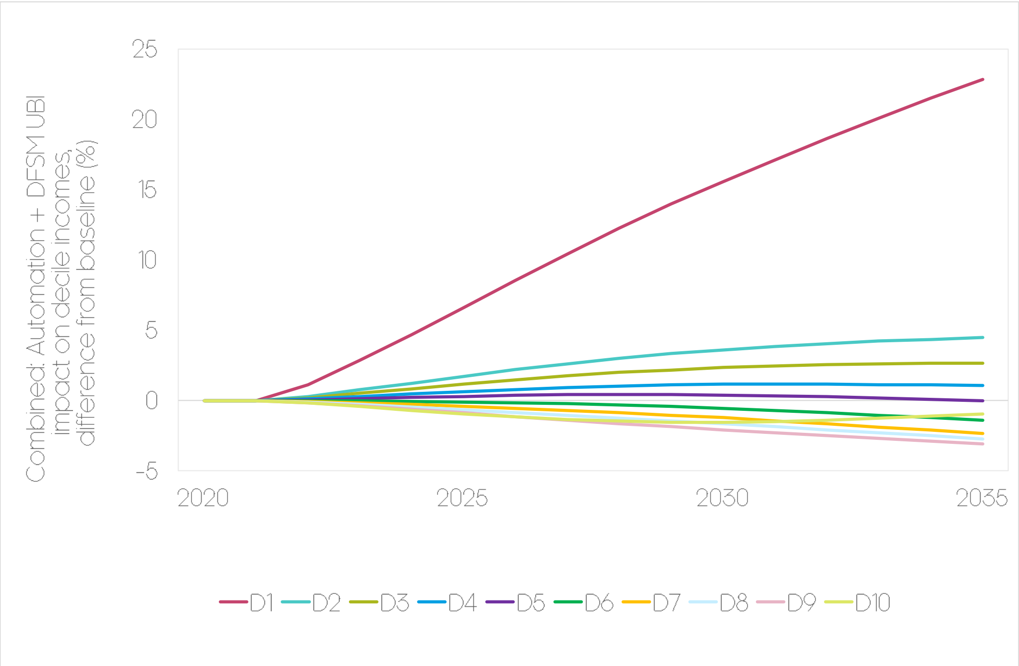
The UBI payments needed to sustain real household incomes grow steadily over the period, as more jobs (and, in turn, income) are lost to automation. In 2035, the cost of UBI reaches £178bn (in 2021 prices): about 2.2 times the cost of the UBI in the small-scale DFSM UBI scenario (see the previous section). By compensating for the automation-related income losses, consumption and GDP end up very close to baseline. Although the income compensation is the same across deciles, as a percentage of their incomes, the lowest-income decile benefits most, substantially raising their incomes above baseline (see Figure 4.15:).

Figure 4.14: Decomposing the GDP effect in the combined scenario, difference from baseline (%)



Source(s): Cambridge Econometrics, E3ME model.

Figure 4.15: Changes in decile incomes in the combined scenario, difference from baseline (%)



Source(s): Cambridge Econometrics, E3ME model.

Key conclusions are robust to the assumed scale of automation

To check the robustness of the conclusions from the combined scenario, a further test run was produced with levels of automation set to be twice as high as in the core scenario. The compensating levels of basic income were increased accordingly to sustain household real incomes at levels comparable to those in the original baseline. The test run brought the same conclusions as the core combined scenario for all the indicators reported here. The basic income supports consumption without markedly raising inflation (and this effect remains small when compared to the downward inflationary effects of automation). These runs confirm that the economic conclusions are not dependent on the chosen (and quite high) levels of automation we model.

Impacts on inflation

The strongest effect on inflation in this second set of scenarios is the automation itself, which lowers inflation relative to baseline. The effect of the DFSM UBI, to increase inflation, is negligible in comparison. Figure 4.9 shows that the price index is around 0.15 pp point lower than in the baseline by 2035, which translates to a 1.0-1.2 pp lower annual inflation rate. The addition of DFSM UBI does little to alter this profile. Prices are little different between the automation and the combined scenarios such that it is the automation effect that dominates i.e. the effect of cost-push, rather than demand-pull, effects.

E3ME captures cost-push inflation through unit costs of production driving up prices. The rate at which this occurs depends on industry-specific cost-price passthrough rates embedded in the model's econometric equations. Automation reduces unit costs (relative to the baseline) by increasing productivity and reducing labour costs (as labour input declines). This shows through in lower prices (and inflation) relative to the baseline.

As explained in the previous section, demand-pull inflation effects are relatively weaker in E3ME. Inflation impacts are thus largely driven by the cost-push channel, ands are similar in the automation and in the combined scenarios.

Impact on public finances

The combined scenario assumes that DFSM UBI is used to meet the cost of UBI. DFSM does not create liabilities for the government and, as such, does not add to the public deficit and debt stock. As discussed in detail in the previous section on the impacts of fiscally neutral and small-DFSM UBI schemes, the calculations of the impacts on public finances assume that the remaining differences in primary balances are met by changes in public borrowing, in turn affecting debt accumulation.[9]

Our analysis (Figure 4.16) shows that stronger economic performance in the combined automation + UBI scenario compared to the automation-only scenario results in lower primary deficits. Initially the primary deficit difference is estimated to be modest. However, by 2035 the public deficit-to-GDP ratio is projected to be 5 pp lower than in the automation scenario. As a result of lower debt accumulation under the combined scenario, the debt-to-GDP ratio is estimated at 40 pp less than in the automation scenario without DFSM-funded UBI.

Under the assumption that the interest rates on government debt will remain at similar levels to currently (about 2.8%), public debt interest payments in 2035

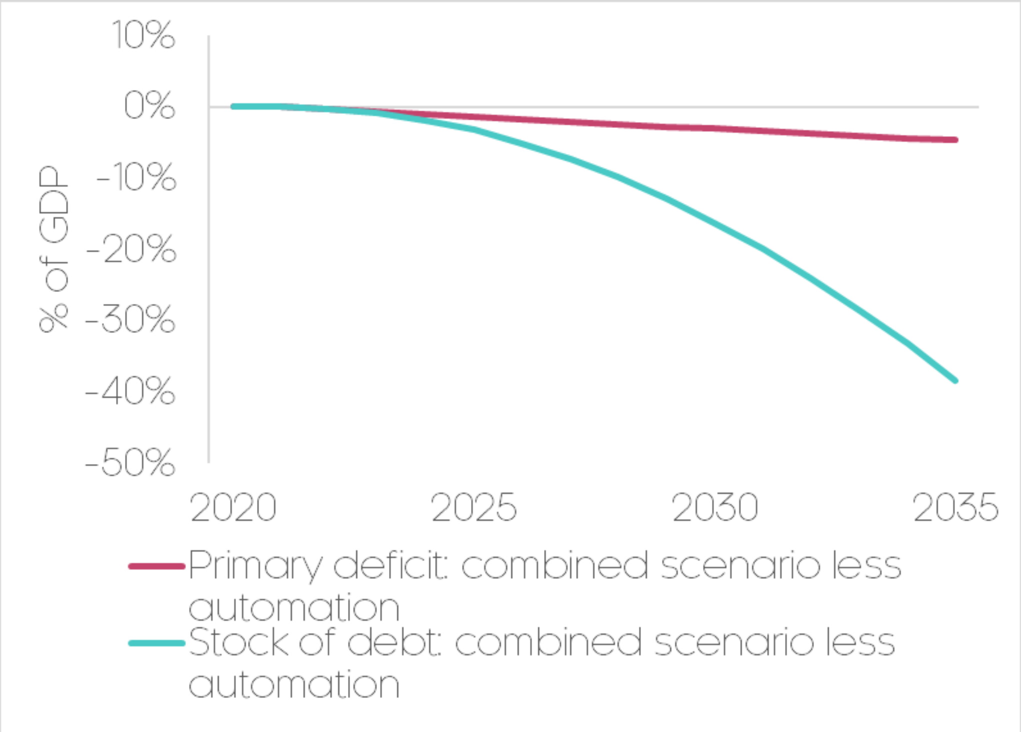
[9] The primary balance in this context is the difference between government revenues and government expenditures excluding DFSM.

could be lower by £34bn, or 1% of the modelled 2035 GDP. For comparison, over the past decade the average UK public debt interest payments stood at about 2.4% of GDP (or £40bn in 2020).[10]

These results show that a DFSM UBI scheme that substantially drives up economic performance can have a positive impact on public finances. In case of an economy performing well below capacity constraints for a protracted period, as in the automation scenario, a stimulus effect of a UBI scheme could result in a marked improvement. According to the model mechanisms, public expenditure is relatively inelastic. However, tax revenues are higher in the combined scenario than in the automation only scenario, as they closely follow the improved performance of the economy.

Alternatively, the difference can be viewed as a shift in the economy, where automation erodes the tax base of working individuals. However, care should be taken when interpreting these results, as it is likely that faced with debt accumulation, governments could resort to other ways to cover the financing gap, rather than the assumed further debt issuances. For example, robot tax strategies have previously been proposed as a solution.

Figure 4.16: Impact on public finances – combined scenario



Note(s): Calculations assume DFSM issuance does not create a liability and that the cost of interest payments on any additional debt is met with further debt issuances.
Source(s): Cambridge Econometrics, E3ME model.

[10] Based on CE analysis of the IMF Government Finance Statistics and the ONS Gross Domestic Product: Chained volume measures, Seasonally adjusted data.

5 Conclusions

This paper analyses the following two sets of scenarios:

- small-scale basic income schemes of similar size to those currently proposed in the UK, to shed light on their likely macroeconomic implications
  - in varying the schemes (payments and funding mechanisms) we also assess the sensitivity of the results to the schemes' design
- automation (to simulate potentially adverse effects on future household incomes) and the role of larger-scale UBI funded by DFSM as one possible way to offset the income losses in the face of sustained technological unemployment

In a modelling framework in which economies can operate below capacity, basic income can raise GDP

As well as demonstrating the feasibility of representing basic income scenarios in CE's E3ME model, the results highlight the following:

- Basic income schemes could potentially raise GDP without undue inflationary effects. With no presumption that the economy is at full capacity, the additional income leads to at least some additional consumption and raises capacity utilisation (observed labour productivity).
- Beyond the amount of the UBI *payment*, the magnitude of the effects can vary with the choice of funding mechanism. A fiscally neutral UBI scheme can put more income into the pockets of lower-income households who have higher propensities to consume. This can generate further expenditure and raise GDP. At least in the fiscally neutral scheme considered, the results show how this redistribution can increase consumption and raise employment to offset the initial reductions in labour supply.
  - The scheme considered is typical of current UK basic income proposals and, in this sense, points to the potential for such schemes to yield modest macroeconomic benefits on top of their intended individual-level benefits.
  - Further testing of a variant of the above scheme, in which the basic income is funded jointly through income taxes and employers' social security contributions, shows that some inflationary pressures can occur if they directly raise costs and thus prices. This highlights the importance of the design of the basic income *scheme*, rather than simply the level of the payment.

The stimulus effect depends on the method of financing

- The stimulus effect can be even stronger for a DFSM-funded UBI because this scenario adds income to households (rather than simply redistributing it). The DFSM-funded UBI injects new money into consumer income, leading to higher expenditure. This, propagated through the economic feedback loops, also results in modest increases in GDP and employment. This effect also appears to come without undue inflationary effects for a small-scale DFSM-funded UBI. At a small scale, there remains productive capacity in the short run to meet the extra demand. In the long run, productive capacity increases somewhat.

- – The difference in distributional effects between the DFSM and fiscally neutral cases further highlights the importance of wider scheme design. Interaction with tax and benefits changes, and the choice of those changes (as in the fiscally neutral case), can lead to greater distortions across the income distribution than a flatter overall schedule of payments (as was modelled in the DFSM case).

Despite enhanced productive capacity, automation may lead to lower GDP in the face of demand shortfalls

- In a scenario in which rapid automation leads to large-scale technological unemployment and a substantial decline in household incomes, the economy could be severely affected. While automation may well maintain (if not increase) productive capacity, the shift from labour to capital can substantially reduce employment, eroding household wage income. The economy still produces to meet demand but more of that income accrues as profit and this, in turn, lowers household consumption, with negative consequences for GDP (although not as negative as the impacts on households specifically).
- Considering a DFSM-UBI scheme as a policy response to such an adverse automation scenario, the modelling shows that DFSM UBI can re-stimulate the economy and, at least partially, moderate the negative economic effects. In a high automation case, undue inflation again appears to be avoided.
  - – This result continues to hold for even stronger automation and an accordingly larger DFSM UBI. Economic activity and consumption are stabilised with inflation remaining modest.

These results are consistent with a modelling framework in which economies can operate below full capacity. The analysis highlights how basic income schemes can potentially balance high technological unemployment without creating extreme inflation. The crucial feature of such a result is the presence of spare productive capacity in the economy in the short run and how, in the longer term, higher demand can spur investment in new productive capacity. Other classes of macroeconomic model do not necessarily share this feature: the assumption of an economy at capacity would very likely show the potential for stronger inflation and possibly less positive / more negative results. The analysis also shows that the design of the basic income scheme matters because this also has macroeconomic implications.

A caveat and uncertainty in our results is the nature of wage bargaining under both rapid and extensive automation and a basic income. In the case of automation, our results are arguably less sensitive to this uncertainty, to the extent that the scale of the job losses dominates in these scenarios, as the driver of depleted household incomes. Nevertheless, in both cases, there is little evidence to go on to inform this part of the modelling and, in our central runs, we adopt the assumption that falling unemployment does not necessarily drive up wages in the way E3ME's historical econometric parameters normally suggest. We make this assumption on the basis that the kind of labour withdrawal implied in the scenarios represents a departure from historical experience. Specifically, we assume that more workers opting (accepting) to supply less labour input on average in return for a basic income is not likely to lead to the same wage effects as have been observed in the past. As we note in the results, though, adopting the historical responses appears to raise incomes in a way that could in fact further stimulate the economy. At least, at these levels.

Directions for future research

Future research into macroeconomic impacts of UBI schemes should seek to address the limitations and uncertainties described below.

The research here demonstrates the ability to construct assumptions about the design of a basic income scheme and feed them into a macroeconomic model. While the level of detail is ultimately constrained by the level of detail in the macroeconomic model itself, there is no reason why more refined assumptions could not be derived from more detailed micro-level analysis. Further modelling exercises should aim to develop further the precision of the assumptions for different UBI schemes. For example, this could be achieved using microsimulation models (such as UKMOD or EUROMOD) which could be used to develop an initial set of assumptions on the static changes to incomes. These results could then be entered as assumptions to a macroeconomic model to estimate the wider impacts. Further, with feedback effects accounted for in a macroeconomic model, the results (incorporating macroeconomic dynamics) could be fed back into a microsimulation model to infer the individual-level impacts.

As explained throughout, our analysis highlights how spare capacity in the economy is a crucial factor in the results seen here. Future work (especially, at the time of writing, during a period of higher inflation) might wish to examine more carefully the conditions under which basic income might either generate inflation and/or need to function differently in a high(er)-inflation regime.

The analysis presented in this paper has not directly addressed the question of how DFSM might affect exchange rates. This is not a mechanism that is well-developed in E3ME and thus remains a point of uncertainty in our results. How the model might be extended to capture these mechanisms more comprehensively would be a fruitful area of future work. More generally, there may need to be further assessment of how public finances might operate in the presence of large-scale DFSM, especially if it does start to displace government debt in a large manner (noting, for example, that UK government debt is often a large feature of private financial portfolios).

Differentiating between initial and long-term responses to UBI could also be an interesting area to explore further. Initial responses especially on labour supply could be very different from longer-term behaviour. In the long run, choices between work and education for instance could be more important (as has been highlighted in studies of past basic income-like schemes). How this might affect future human capital accumulation is relevant at both macroeconomic (growth) and a microeconomic (jobs and income) levels.

Concluding remarks

This research has shed light on the macroeconomics of basic income at both small and large scales using a fully articulated macroeconometric model. As well as showing how basic income policies can be assessed in such a model, our results show that basic income can serve a stimulus function in an economy operating below full capacity. Below full capacity, there is little evidence of strong inflation although the extent of that inflation is sensitive to scheme design. At scale, basic income may serve an important purpose in a possible high automation future with similarly limited inflationary effects; at least, for the (DFSM) scheme considered. As we note, there are various ways in which this research programme could be fruitfully extended in the future.

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Appendices

Appendix A: E3ME

E3ME is a computer-based model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe and beyond for policy assessment and for research purposes. A technical model manual of E3ME and more information on the model is available online at www.e3me.com.

E3ME is often used to assess the impacts of climate mitigation policy on the economy and the labour market. The basic model structure links the economy to the energy system to ensure consistency across each area.

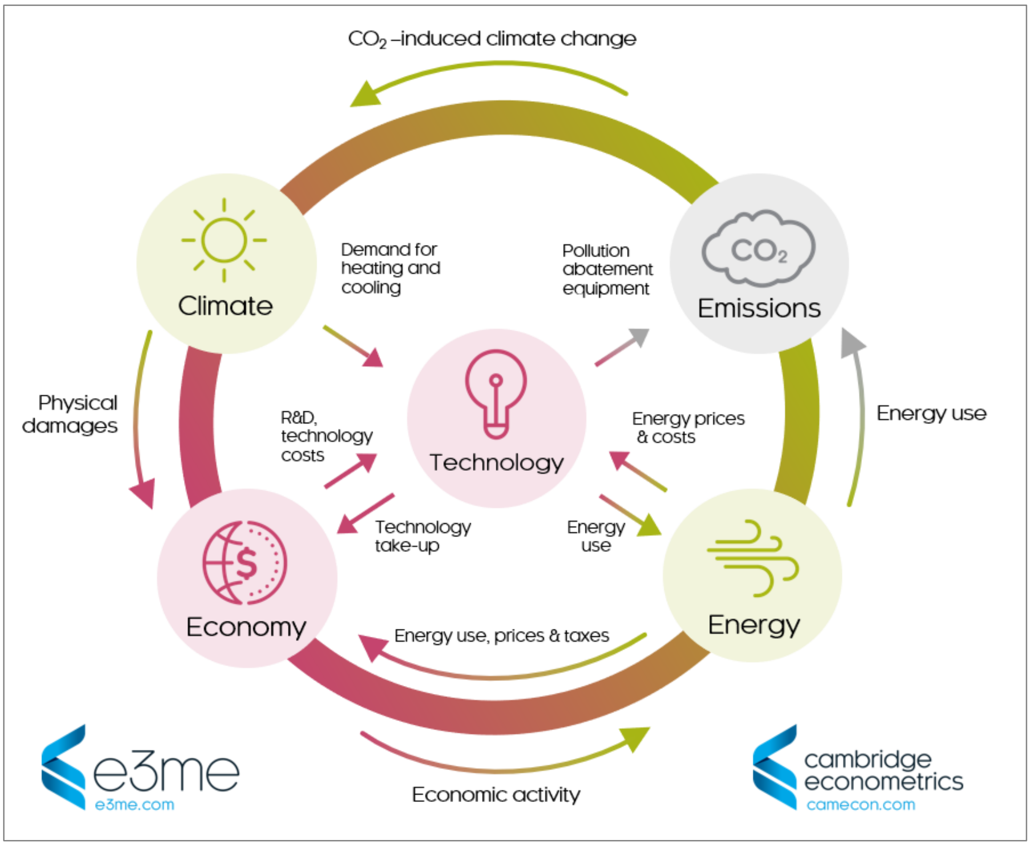
As a global E3 (energy, environment, economy) model, E3ME can provide comprehensive analysis of policies:

- direct impacts, for example reduction in energy demand and emissions, fuel switching and renewable energy
- secondary effects, for example on fuel suppliers, energy prices and competitiveness impacts
- rebound effects of energy and materials consumption from lower prices, spending on energy or higher economic activities
- overall macroeconomic impacts; on jobs and the economy including income distribution at macro and sectoral level

Theoretical underpinnings

Economic activity undertaken by persons, households, firms and other groups in society has effects on other groups after a time lag, and the effects persist into future generations, although many of the effects soon become so small as to be negligible. But there are many actors and the effects, both beneficial and damaging, accumulate in economic and physical stocks. The effects are transmitted through the environment (with externalities such as greenhouse gas emissions contributing to global warming), through the economy and the price and money system (via the markets for labour and commodities), and through the global transport and information networks. The markets transmit effects in three main ways: through the level of activity creating demand for inputs of materials, fuels and labour; through wages and prices affecting incomes; and through incomes leading in turn to further demands for goods and services. These interdependencies shown in Figure A.1 suggest that an E3 model should be comprehensive and include many linkages between different parts of the economic and energy systems.

Figure A.1 Overview of the E3ME model



Source(s): Cambridge Econometrics.

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 typical CGE framework, optimal 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 framework, and it is possible to have spare capacity. The model is more demand-driven and 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. This capacity is not fixed in the long run. Changes in demand lead to changes in required output which may signal that firms need to invest in new productive capacity. This process is governed by E3ME's normal output and investment equations, parameterised on historical data. This is described in more detail in the model manual.

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.

Structure and data used

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, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the period 1970-2018 and the model projects forward annually to 2060. The main data sources for European countries are 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 statistics. Gaps in the data are estimated using customised software algorithms.

The main dimensions of E3ME are:

- 70 countries – all G20 countries, the EU27 and candidate countries plus other countries' economies grouped
- 70 industry sectors, based on standard international classifications
- 43 categories of household expenditure
- 10 income deciles
- 22 different users of 12 different fuel types
- 14 types of air-borne emission (where data are available) including the 6 GHG's monitored under the Kyoto Protocol

Appendix B: Modelling assumptions

The high-level assumptions for the UBI scenarios presented in Table 3.1 have been translated into E3ME model inputs using various intermediate calculations and data. These steps are described in detail below.

It is important to note the trade-off in a macroeconomic modelling exercise such as this. In exchange for a more complete, dynamic analysis of the effects of basic income on the macroeconomy, we sacrifice the household-level detail that characterises (static) microsimulation exercises. In general, the discussion of 'households' that follows refers to households as the institutional sector, in macroeconomic / national accounts terms. While distributional impacts can be (and are) estimated, the level of detail possible is appreciably lower than might be gleaned from a microsimulation model of individual households. We comment to the extent possible on household-level implications but acknowledge a (future) need to explore this in greater depth, perhaps through linkages with a microsimulation model. The potential advantages of a combined approach lie in the ability to examine more nuanced schemes prior to aggregation and macroeconomic analysis; and, further, to insert macroeconomic outcomes back into the microsimulation model, to infer the distributional impacts of the macroeconomic feedbacks. Two-way linkages of this type would be at the frontier of existing micro-macro analysis.

UBI payments

2. Fiscally neutral UBI

The assumed levels of annual UBI payment by age of recipient are presented in Table B.1. The amounts of UBI in the fiscally neutral UBI scenario are based on a typical UBI scenario proposed for the UK. The amounts vary across age groups, with children receiving lower amounts than adults. Those aged 65+ receive the highest amount, at £180 per week (in 2018 terms), to be broadly similar to the existing state pension.

3. DFSM UBI

The payments in the DFSM UBI scenario are much lower. Under the assumptions of the scenario, all existing benefit payments and state pensions remain in place, with no differentiation in UBI payment by age. The amounts of UBI are identical across all age groups, at £23 per week (around £1,200 per year). This level of payment was set based on the Office for Budget Responsibility's (2021) assessment of government support for households, consisting of:

- the Coronavirus Job Retention Scheme (CJRS) (furlough)[11]
- the Self-Employment Income Support Scheme
- increased generosity of benefits, most substantively, the increase of £20 per week in Universal Credit to eligible families

[11] As Keep and Brien (2021) point out, this classification differs from that of the National Audit Office, which considers the CJRS as support to businesses. Both interpretations have merit but, for the purposes of this exercise, we consider the principal effect of the CJRS to support workers' salaries i.e. to sustain their incomes.

We opt for this categorisation as giving the amount that the UK government expressly earmarked to support incomes in response to the pandemic. This figure excludes, for example, non-household support but also additional welfare payments incurred as a result of the economic downturn (i.e. as regular automatic stabilisers).

In both scenarios, these amounts are kept constant in real terms over the duration of the modelled period. In other words, the UBI payments are assumed to track inflation in a way similar to many other current social transfers in the UK. In the absence of a microsimulation model to perform the detailed calculations, these UBI amounts are assumed to be non-taxable, which simplifies the calculation of changes to disposable income (allowing for further income taxation in the scenarios as needed).[12] In the context of an aggregate (macroeconomic) model, this should not materially affect the final results.

Table B.1 UBI amounts per person (£2018)

Age group	Fiscally neutral UBI		DFSM-funded UBI	
	Weekly	Annual	Weekly	Annual
0-15	50	2,609	23	1,224
15-64	80	4,174	23	1,224
65+	180	9,392	23	1,224

Note(s): The UBI income amounts are not taxable.
Source(s): Cambridge Econometrics analysis.

UBI cost and financing

Fiscally neutral UBI

Table B.2 presents the estimated cost of the proposed UBI schemes. The total cost of the UBI payments in the fiscally neutral UBI scheme is estimated to be £321bn in 2018. The cost is estimated by multiplying the estimated population in different age groups by the proposed UBI rates.[13] As this scheme must be fiscally neutral, the cost must be covered through cuts to government expenditure (here, £154bn in savings from reduced benefits) or new revenue

[12] The complexities of the impact of income thresholds and progressive income tax rates on additional UBI income cannot be fully modelled within E3ME, hence a non-taxable UBI was selected for simplicity. A taxable UBI scheme could lead to more redistributive outcomes, since a progressive portion of UBI income would be taxed from high earners.

[13] Population by age group data are based on the ONS data.

raised (£84bn in higher income taxes and £84bn in higher employee social security contributions).

Table B.2 Cost and sources of financing of the UBI schemes (£2018bn)

	Fiscally neutral UBI	DFSM UBI
Cost of UBI payments	-321	-81
Covered by:		
Withdrawal of the existing benefits	154	0
Income tax revenue increase	84	0
Employers' social security contributions	84	0
Debt-free sovereign money	0	81

Note(s): The estimates are approximate, based on the analysis of average income and tax payments in different quintiles and other simplifying assumptions.
DFSM UBI payments are calculated from 2020/21 reported COVID-19 expenditure rescaled to 2020 population (for input to E3ME).
Source(s): Cambridge Econometrics analysis of ONS data, UKMOD.

Further details on the measures to achieve fiscal neutrality in a static setting (before allowing for macroeconomic feedbacks to affect these values) are as follows:

- Cuts to expenditure as a result of withdrawal of certain existing benefits.[14] The total saving as a result of withdrawal of these benefits is estimated at £154bn, based on CE calculations using the ONS data.
- An increase in income tax revenue to make up a further £84bn. Removal of the personal income tax allowance could bring an additional £104bn of government revenues, based on a simulated UKMOD Explore (CeMPA, n.d.) microsimulation scenario run by CE.[15] As this additional revenue would exceed the remaining gap of £84bn by £21bn (after rounding and accounting for social security adjustments, as below), the income tax rates could be uniformly reduced by approximately 1.8 pp. It is estimated that overall these changes to income tax rates would amount to a 6 pp increase in average effective income tax rates.
- Increased employers' social security contributions to raise the remaining £84bn. In revenue terms, this would be equivalent to imposing a flat 12.5% rate on employees' National Insurance Contributions but, in earlier test runs, splitting the cost between firms and households proved more stable.

Further knock-on impacts on government finances as a result of economic responses to UBI are modelled endogenously by E3ME.

DFSM UBI

The estimated cost of the small-scale DFSM UBI is £81bn (in 2018 prices). As UBI payments in this scenario are fully funded using debt-free sovereign money, no changes are required to the existing benefit payments, or tax and social security rates.

As van Lerven *et al* (2021) observed, government borrowing in 2020/21 was of a similar amount to net purchases of government bonds by the Bank of England. Consequently, van Lerven *et al.* (2021) assert that public sector

[14] Benefits to be replaced are listed later in this appendix.

[15] Based on a scenario run by CE using UKMOD Explore, removal of the personal income tax allowance would have increased government revenues by £107bn in 2021. This figure was scaled proportionally using population figures to estimate the approximate saving in 2018, and estimated at £104bn.

borrowing that year was indirectly financed by newly created money; thus resembling DFSM. Insofar as the UK government proved able and willing to fund such a package of measures in this way, and that the household support represented just one part of that policy package, we model a corresponding scenario that re-interprets such a situation as sustained DFSM-funded UBI.

It should be noted that due to a simplified treatment of taxes and benefits in E3ME, some of these assumptions were simplified in order to enter them as scenario assumptions into E3ME, as explained in more detail in Table B. These differences also lead to small discrepancies in the estimated costs and sources of financing for the UBI schemes.

The direct static effect on disposable income

Fiscally neutral UBI

This section presents the (initial) changes in income as a result of the policies proposed for the two UBI schemes. These calculations are based on a static analysis of changes in income, meaning that they do not, by themselves, account for households' responses in terms of labour participation or hours worked that arise as a result of changes in income and tax rates.

It should be noted that these changes are approximate *average* changes to income across quintiles. In practice, the results from microsimulation modelling show that even within a quintile, such policies can have differential impacts on individual or household income based on their unique circumstances.

Table B.3 presents the changes in income per person as a result of transfers proposed in the fiscally neutral UBI scenario. The estimated changes to benefit and state pension payments are calculated using ONS (2021) data on the average payments received by quintile and OBR data (n.d.) on the average benefits received by age. The scenario assumes withdrawal of the following benefits:

- Tax credits
- State pension and pension credit
- Child benefit
- Other benefits, including Universal Credit, Jobseekers Allowance and Employment and Support Allowance

As the largest recipients of these benefits, quintiles 1 and 2 would see their incomes decline the most as a result of their withdrawal. The average annual income lost as a result of withdrawal of these benefits is estimated at over £3,000 per person in these two quintiles.

In contrast, the burden of the increasing effective income tax rates is borne by the upper quintiles. The average changes in income as a result of removal of the personal income tax allowance have been adapted from a custom UKMOD scenario run (CeMPA n.d.).[16] Difference in per-person employee income as a result of increased employer social security is £0, effectively

[16] The scenario was run by CE using an online version of UKMOD (CeMPA n.d.). The total assumed increase in income tax payments of £93bn was allocated according to the quintile share in the change in mean equivalised household income (before housing costs) under a scenario which assumes a reduction of the personal income tax allowance to £0. UK. Changes in income by decile were converted to changes in income by quintile using simple averaging.

assuming that the cost of increased employers' social security contributions is fully borne by the employers in the static setting.[17] Across all quintiles, the average per-person UBI payments differ due to a different age composition of the quintiles. For example, quintiles 1 and 2 have a higher share of pensioners who are assumed to receive higher UBI to replace state pensions. The age composition of quintiles is estimated based on the ONS data (ONS 2019).

The overall changes in per-person income across quintiles are moderate: The bottom quintile is estimated to see average incomes increase by £2,357 per person. The top quintile would see average income per person increase by £1,069 per annum. It should be noted that these calculations assume that the increase in the employers' social security contributions is not passed onto the employees in the form of lower employee earnings.

It should be noted that these changes are approximate *average* changes to income across quintiles. In practice, the results from microsimulation modelling (Torry 2019) show that even within a quintile, such policies can have differential impacts on individual or household income based on their unique circumstances.

Table B.3 Static changes to income in the fiscally neutral UBI scenario (£2018 per person per year)

	Benefit and state pension payments	Income tax	Employer social security contributions *	UBI payments	Total change in income
Q1	-3,205	-508	0	6,038	2,357
Q2	-3,407	-862	0	5,404	1,199
Q3	-2,364	-1,429	0	4,558	867
Q4	-1,477	-1,938	0	4,148	885
Q5	-1,093	-2,329	0	4,148	1,069

Note(s): The estimates are approximate, based on the analysis of average income and tax payments in different quintiles and other simplifying assumptions.
* Increases in employer social security contributions are assumed to not impact employee earnings in the static analysis.
Source(s): Cambridge Econometrics analysis of ONS data and UKMOD scenario.

In principle, the above approach to articulating the distributional effects for insertion into a macroeconomic model could be derived from existing studies, including those that apply microsimulation models. This may be a fruitful area of exploration in the future.

DFSM UBI

The static changes to the average income per person under the DFSM UBI scenario are solely driven by the additional UBI payments (Table B.4). The scenario assumes no changes in existing tax or benefit policies and identical small UBI payments regardless of age. Therefore, incomes are increased evenly across quintiles to the full amount of the proposed UBI, at £1,224 per person per annum.

[17] Employer NI contribution increases have been calculated using ONS data (ONS 2021). The change in income was calculated as the difference between that implied by a flat 12.5% employer NI rate on all earned income and the current payments.

Table B.4 Static changes to income in the DFSM UBI scenario (£ per person per year, 2018 prices)

	Benefit payments	Income tax	Social security contributions	UBI payments	**Total change in income**
Q1	-	-	-	1,224	1,224
Q2	-	-	-	1,224	1,224
Q3	-	-	-	1,224	1,224
Q4	-	-	-	1,224	1,224
Q5	-	-	-	1,224	1,224

Note(s): The estimates are approximate, based on the analysis of average income and tax payments in different quintiles and other simplifying assumptions.
Source(s): Cambridge Econometrics analysis of ONS population data.

The combined redistributive effect of these transfers (including the additional income from UBI, additional tax and social security payments and removed benefits) is presented in Figure B for both UBI scenarios. The total static change in income in different quintiles is expressed as a percentage of the total disposable income per household.

Fiscally neutral UBI

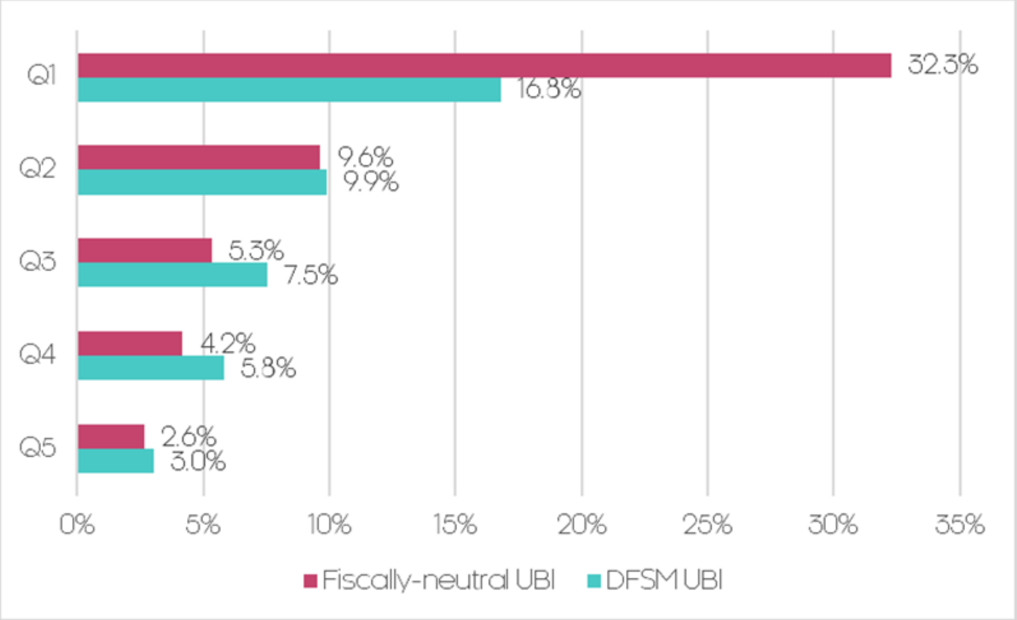
Under the assumptions of a fiscally neutral scenario UBI, the bottom 20% of households would see their incomes rise by 32% on average. Quintiles 2 and 3 would see their total disposable income increase by 10% and 5%, respectively. The top quintile would see their disposable incomes increase only slightly by 2.6%. It should be noted that while all quintiles see their incomes increase, the UBI scheme is still fiscally neutral in static conditions because the increase in incomes is offset by the increased employers' social security contributions. Employers' social security contributions are excluded from the calculation of income.

DFSM UBI

Under the DFSM UBI scenario assumptions, households across all quintiles receive equal amounts of additional income (at £1,224 annually). Expressed as a share of total pre-UBI disposable income, these payments boost the disposable income of the bottom quintile by about 17% (since the average annual disposable income per person across these two deciles is approximately £7,300). However, the same monetary amount of additional UBI represents a much smaller percentage increase in disposable income to the top quintile. Since the average disposable income in that quintile is approximately £40,000, the additional UBI payments increase the disposable income by just 3%.

Figure B underscores the importance of thinking of UBI in terms of scheme design rather than simply the level of the payment. UBI payments (the unconditional income paid to individuals) augment the incomes of lower-income groups by a larger amount in percentage terms than those of higher-income groups (absent any other interactions with the tax/benefits system). However, depending on how the UBI is funded (the scheme), the net impacts on the distribution can be quite different. While the second-lowest income quintile does still benefit slightly from a basic income in the fiscally neutral case, those gains are smaller in percentage terms than for those higher up, in the third and fourth quintiles.

Figure B.1 Redistributive effect of the proposed UBI schemes (static change in disposable income by quintile as percentage of pre-scheme total disposable income)



Note(s): The estimates are approximate, based on the analysis of average income and tax payments in different quintiles and other simplifying assumptions.
Source(s): Cambridge Econometrics analysis of ONS data and UKMOD results.

Dynamic effects on labour supply

As a result of these initial ('static') changes to income, households will dynamically adjust the amount of time spent at work by altering the hours worked (at the intensive margin) or deciding whether to enter or leave the workforce altogether (the extensive margin).

These changes (for both hours worked and participation) can be decomposed into two distinct effects:

- The substitution effect, arising as a result of changes in the marginal effective tax rates on labour. In the fiscally neutral UBI scenario, as a result of increasing effective marginal tax rates, the financial incentive to work becomes lower, and therefore, individuals choose to work less.
- The income effect, which arises as a result of changes in total disposable income. Individuals or households tend to choose to work less as their income increases due to the decreasing marginal utility of consumption. Therefore, a static increase in income as a result of UBI payments could lower the amount of labour supplied.

In general, there is limited evidence specific to the impact of UBI on labour supply decisions, owing to few examples around the world of such policies being introduced. Therefore, the calculations of the impacts on labour supply decisions under different UBI scheme assumptions are based on a more general approach proposed by Adam and Phillips (2013).

The hours worked (intensive margin) response occurs in response to financial incentives, as measured by the changes to marginal effective tax rates (METRs) on earned income. The labour force participation rate (extensive margin) response occurs in response to financial incentives in- and out-of-work, as measured by the changes in the participation tax rate (PTR). In both calculations, the estimates are obtained for each quintile based on the average changes in income and taxes.

The magnitudes of the parameters (elasticities) measuring the strength of the response to changing incentives come from the same source (Adam and Phillips 2013), and are aligned to the central parameters used in the recent UBI study for Scotland (Fraser of Allander Institute, Manchester Metropolitan University and IPPR Scotland 2020).

As mentioned below, E3ME's equations embed a labour supply effect in response to changes in benefits. Given the specific evidence we use on basic income, we bypass this (initial/direct) channel by:

- modelling basic income as exogenous increases in household income, rather than via conventional benefits: this avoids any standard E3ME labour supply effect in response to basic income
- alongside the above changes in income, modelling a separate labour supply response (as detailed below), in line with our derived assumptions

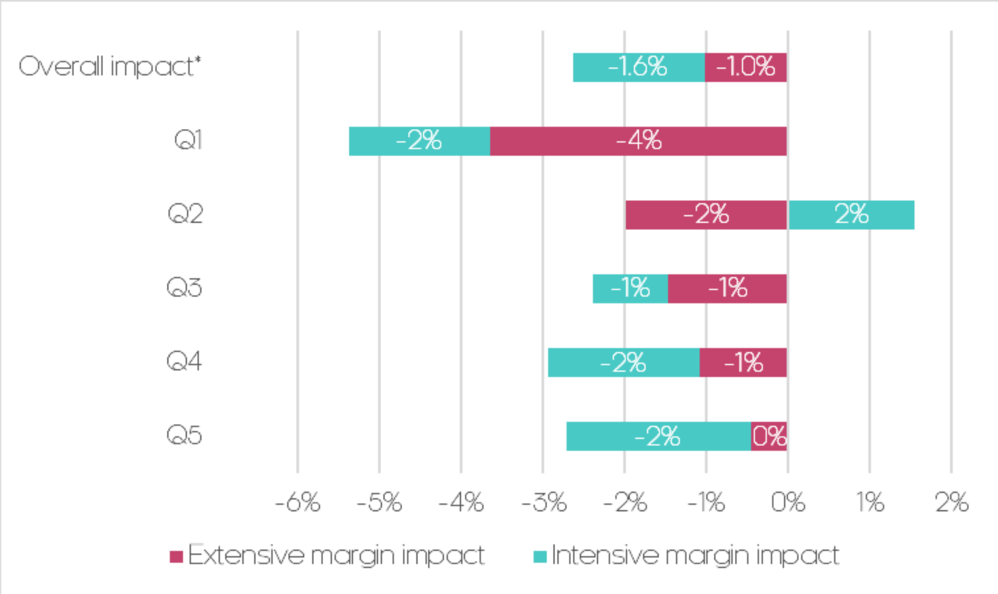
This better reflects the available evidence on basic income while avoiding a double-counted effect were basic income to enter the model as a conventional benefit. Wider effects then follow as normal in the model.

Fiscally neutral UBI

The estimated labour supply effects under the fiscally neutral UBI scenario are presented in Figure B. The intensive margin impact suggests that static changes in income could result in a 1.6% reduction in hours worked. The estimates of the extensive margin impacts suggest that the labour participation rate would decline by a smaller 1.0%. The combined effect on both labour participation and hours worked suggests that the total labour supply would decline by 2.6%.

Also, noteworthy is the positive intensive margin impact on labour supply of the second quintile. This is due to an estimated decrease in the marginal effective tax rate (METR) of this group as a result of withdrawal of means tested benefits. The same effect is not observed for the first quintile, as their marginal effective tax rate is calculated to be nearly unchanged: while the withdrawal of the existing benefits reduces its METR, the removal of the personal tax income allowance increases the METR.

Figure B.2: Extensive and intensive margin labour supply impacts under the fiscally neutral UBI scenario



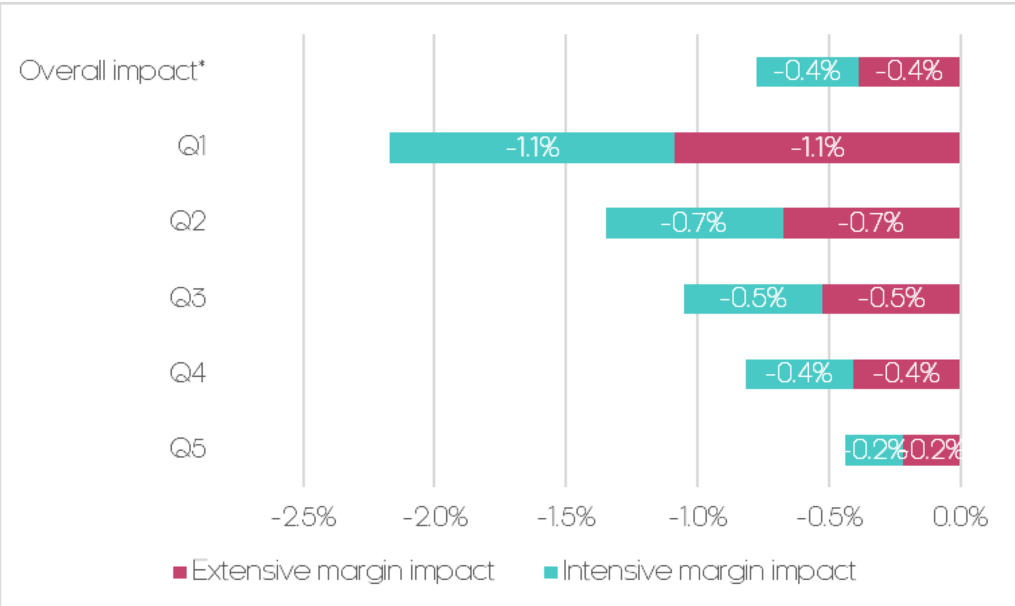
Note(s): The overall impact on labour supply is calculated using weighted impacts across quintiles. The weight for each quintile is based on the quintile share of total earned income based on ONS data.

Source(s): Cambridge Econometrics analysis of ONS data.

DFSM UBI

The estimated labour supply effects under the DFSM UBI scenario are presented in Figure B. As this scenario assumes no changes to the income tax rates or the social security rates, the sole driver of the labour supply decisions is the income effect as a result of additional UBI payments. Accordingly, the impacts on labour supply are much lower. It is estimated that the total labour supply would decline by approximately 0.8%. The effect is composed of a 0.4% decline in the labour participation rate (extensive margin) and a 0.4% decline in hours worked (intensive margin). The estimated reduction in labour supply is stronger among the poorer quintiles, in which the additional UBI transfers provide a more significant boost to incomes (as a share of total disposable income).

Figure B.3 Extensive and intensive margin labour supply impacts under the DFSM UBI scenario



Note(s): The overall impact on labour supply is calculated using weighted impacts across quintiles. The weight for each quintile is based on the quintile share of the total earned income based on ONS data.
Source(s): Cambridge Econometrics analysis of ONS data.

These scenario assumptions (the changes in hours worked and labour force participation) are entered into E3ME as exogenous shocks. In further estimation steps, which are performed within E3ME, labour force participation and hours worked are modelled using econometrically-estimated equations (Cambridge Econometrics 2019). The specifications of these equations are such that they capture dynamic relationships between these two employment indicators and other macroeconomic factors. For example, the average hours worked are estimated individually for each industry based on the stock of capital and output. The labour force participation rate is modelled separately by sex and age group based on a theoretical model proposed by Wilson and Briscoe (1992), and is determined by factors including output, real retained wages, the benefit or pension rate, and the unemployment rate.

Basic income scenario assumptions as direct modelling inputs

The scenario assumptions described above, calculated based on the literature and ONS data have been translated to modelling inputs to E3ME. Table B.5 provides a summary of how the scenario assumptions were translated into model assumptions. E3ME uses a decile-level treatment and requires dynamic assumptions specified for the complete projection period.

Table B.5 UBI scenario technical direct modelling inputs

<table>
<tr><th>Modelling inputs</th><th>Fiscally neutral UBI</th><th>DFSM UBI</th></tr>
<tr><td rowspan="3">Net value of the transfers under the UBI scheme</td><td>The net transfer includes universal basic income received and benefits removed.</td><td>The transfer is the universal basic income received.</td></tr>
<tr><td>The amount received varies by decile (-8-25% of total disposable income), with the lowest deciles receiving the highest amounts relative to their income and highest income deciles losing income.</td><td>The amount received ranges from 3% to 17% of total disposable income, with the lowest deciles receiving the highest amounts relative to their income.</td></tr>
<tr><td colspan="2">The transfers’ value is entered into the model as a percentage of total income by decile. The transfer is fixed in real terms over the projection period.
This enters the model as an exogenous increase in household income, so as to be able to model the labour supply response (as below) without double-counting the effects.</td></tr>
<tr><td>Funding of the UBI</td><td>The funding for the basic income is covered from an increase in income taxes and employee's social security contributions in equal parts.

The average tax increase associated with the basic income is estimated based on various sources of data and is entered to E3ME as a modelling input.</td><td>The universal basic income is funded using DFSM. The introduction of the basic income does not have any accompanying changes elsewhere in the existing tax and benefit system.</td></tr>
<tr><td>Reduction in labour force participation and hours worked</td><td colspan="2">As a response to the benefits received, all deciles are assumed to reduce their labour supply. This reduction is entered as uniform across deciles and over the modelled timeframe in percentage terms.
These changes are based on the evidence cited and enter alongside the basic income as an exogenous increase in household income (rather than as a conventional benefit, as above). This avoids any double-counted response from the model’s standard treatment of benefits and labour supply.</td></tr>
</table>

<table>
<tr><th>Modelling inputs</th><th>Fiscally neutral UBI</th><th>DFSM UBI</th></tr>
<tr><td></td><td>The assumed participation rate reduction is 1.0% and the hours worked reduction is 2.0% compared to baseline.</td><td>The assumed participation rate reduction is 0.4% and the hours worked reduction is 0.4% compared to baseline.</td></tr>
<tr><td rowspan="2">Increase in employment</td><td colspan="2">In the scenarios, we assume that the reduction in hours worked is offset by firms hiring more employees to provide the same amount of total labour input.</td></tr>
<tr><td>This enters into the scenario as a compensating 2.0% exogenous increase in employment for all sectors over the modelled timeframe.</td><td>This enters into the scenario as a compensating 0.4% exogenous increase in employment for all sectors, over the modelled timeframe.</td></tr>
</table>

Source(s): Cambridge Econometrics assumptions.

Automation scenario, as the problem definition for further policy analysis

The major concern that drives this research project is the prospect of large-scale automation, to an extent and at a pace that leads to sustained technological unemployment. Without jobs, income from labour will be severely eroded, with the risk of adverse consequences for households and the macroeconomy should effective demand collapse. This is the problem that this research ultimately seeks to examine, with UBI as a possible solution to replace the income lost from a lack of jobs.[18] In the first stage of the project, the automation scenario is separately examined against a “no automation” baseline (scenario 1), to shed light on the potentially deleterious effects.

This section presents a summary of the assumptions underpinning the automation scenario, considering:

- jobs at risk of automation, rendering at least some jobs obsolete, reducing real incomes and thus consumption and output (further reducing employment);
- the investment costs of new automation technologies, which adds to aggregate demand; and
- efficiencies (productivity improvements) arising from the new automation technologies, altering production processes and prices.

Jobs at risk and job losses

Our modelling of automation relies principally on PwC (2017) to inform estimates of jobs vulnerable to automation. As PwC (2017) notes, this analysis still depends on some assessment of what automation (AI/robotics) technologies might be capable of in the future. This analysis suggests that some 30% of UK jobs are at potential high risk of automation by the mid-2030s.

The original PwC analysis suggests that automation will occur in three waves:

- The Algorithm wave, with 2% of jobs at risk by 2022
- The Augmentation wave, with 20% of jobs at risk by 2030
- The Autonomy wave, with 30% of jobs at risk by 2035

[18] While the current concern about automation technologies is a prime motivation for this current research, links can be drawn to longstanding concerns about: technological change; the inequality that might arise from those who benefit from such change (and those who do not); and the potential ramifications of such inequality for macroeconomic stability. In that light, it is not implausible to think that such forces might have contributed to underlying factors leading to, for example, the Great Recession.

The shares of jobs at risk in particular sectors of the economy are informed by PwC (2017) with further detail for selected sectors then provided by PwC (2018).

The jobs at risk were translated into job losses by assuming that half of those jobs at risk would ultimately be lost (and this still generates a strong impact on household incomes, in line with the purpose of this scenario. The estimated job losses by 2035 (expressed as a percentage of those in the baseline)) are presented in Table B.6 estimates of job losses in individual years between 2020 and 2035 were obtained by linear interpolation.

Table B.6: Sectoral job loss assumptions in the automation scenario (percentage difference from baseline) 2035

Sector	Estimated job losses by 2035
Agriculture, forestry & fishing	-9.4%
Mining & manufactured fuels	-14.3%
Basic manufacturing	-22.5%
Engineering & transport equipment	-22.5%
Electricity supply	-15.9%
Other utilities	-26.2%
Construction	-11.5%
Distribution & retail	-21.0%
Transport	-28.2%
Communications, publishing, accommodation	-28.2%
Business services	-15.5%
Public & personal services	-8.2%

Source(s): Cambridge Econometrics analysis of PwC (2017) and PwC (2018).

Investment cost of automation technologies

The automation technologies come at a cost that must be borne by the sectors in which the automation occurs. This additional investment contributes to aggregate demand while the deployment of automation technologies is underway. Thereafter, annual maintenance costs are incurred. It is this investment that ultimately leads to the job losses and other macroeconomic effects in the scenario.

While there is substantial heterogeneity in technologies, and thus investment costs, our assumptions regarding the purchase costs are based on International Federation of Robots (IFR 2020) and Robotiq (2021) data:

- services automation: £50,689 per unit (in 2019 prices), derived by dividing the sales value by the number of units sold, as reported by the IFR (2020)
- industrial automation: £101,378 per unit (in 2019 prices), derived by applying a cost differential of two to the above cost of services automation, based on analysis by Robotiq (2021)

The scenario assumes that these costs will fall over time due to production efficiencies at a rate of 5% pa over the entire forecast period. This is in line with short-term forecasts by the IFR (2020), although it is a more conservative estimate than the 10% pa fall in costs estimated by Statista (2021). The annual maintenance costs are assumed at 10% of the initial purchase cost. Based on Acemoglu and Restrepo (2020), the scenario assumes a replacement rate of 3.3 jobs per new robot.

We do not make any specific assumptions about the production source of the robots (i.e. domestic versus imported). Instead, the import content follows that implied by the model/data for other sector-level investments. A more refined automation scenario is always possible but, in the context of research looking at basic income as an income replacement policy, detailed adjustment would have little bearing on the conclusions. Were robots more likely to be imported, GDP in the short term (during the replacement phase) might be slightly lower than otherwise but, in the long term, the outcomes would not differ materially.

Productivity improvements

Automation will confer additional productivity on those who remain in the workforce. This will potentially increase the overall productive capacity of the economy (all else equal). It is to be distinguished from the real productivity of a unit of labour-replacing technology compared to a worker.

Here, we assume that the automation-supported workforce is 50% more productive. We consider this to be a conservative assumption given the replacement rate of 3.3 jobs per new robot from Acemoglu and Restrepo (2020) and the fact that technologies do not have the same physical limits as humans.

Removing competitiveness gains related to automation

Note that in scenarios featuring large-scale automation, the automation assumptions are only explicitly included for the UK, the focus country of this analysis. However, one-sided automation would upward bias the modelling results due to competitiveness gains. Were the UK to be the only country which automates, its production costs and product prices would fall compared to the rest of the world. This reduction in prices and improving competitiveness would result in better trade balance for the UK through higher export and lower import volumes. To avoid this impact from influencing the results, as this would not occur if the pace of automation is similar across developed countries, we removed competitiveness gains related to automation from imports and exports in the modelling. The remaining small impacts on imports and exports are related to the general size of incomes and growth in the economy but are unrelated to competitiveness gains.

A brief technical summary of the automation scenario assumptions entering E3ME is provided in Table B.7.

Table B.7 Automation scenario technical assumptions and direct modelling inputs

	Exogenous modelling inputs and assumptions
Job losses	• Large-scale job losses in all sectors based on PwC (2017, 2018). • Sectoral job loss assumptions are taken to be half the number of jobs at high risk as in PwC (2017, 2018). Linear interpolation is used to obtain yearly data. • The above implies economy-wide job losses of 20% by 2035 compared to baseline. • Risk of job losses vary by sector (reductions of 9-30% by 2035 compared to baseline) based on automation potential assessed by PwC (2017, 2018), with linear interpolation in between time points.
Investment in robots and AI systems	• Total investment in robots and AI systems depends on purchase and maintenance costs and numbers of robots to replace jobs. Import content of that investment follows other investments i.e. as implied by the model/data. • Assumed jobs:robots replacement ratio of 3.3:1. • Current purchase cost of robots of £101,378 per industrial robot and £50,689 per service/collaborative robot based on Ford (2015) and IFR (2018). • Purchase cost of robots falls by 5% pa, in line with the projected change over 2020-23 by the IFR (2018). • Annual maintenance costs are assumed to represent 10% of the original total purchase costs. • The lifetime of the robots assumed to be longer than the projection period i.e. not requiring replacement investment over the period. • Investment in robots is made (funded) by the same sector in which the job losses occur.
Productivity increase from using AI systems and robots	• Automated systems are more productive because they can operate for 24 hours each day. • Automation raises the labour productivity of the remaining workforce by 50%.

Source(s): Cambridge Econometrics assumptions.

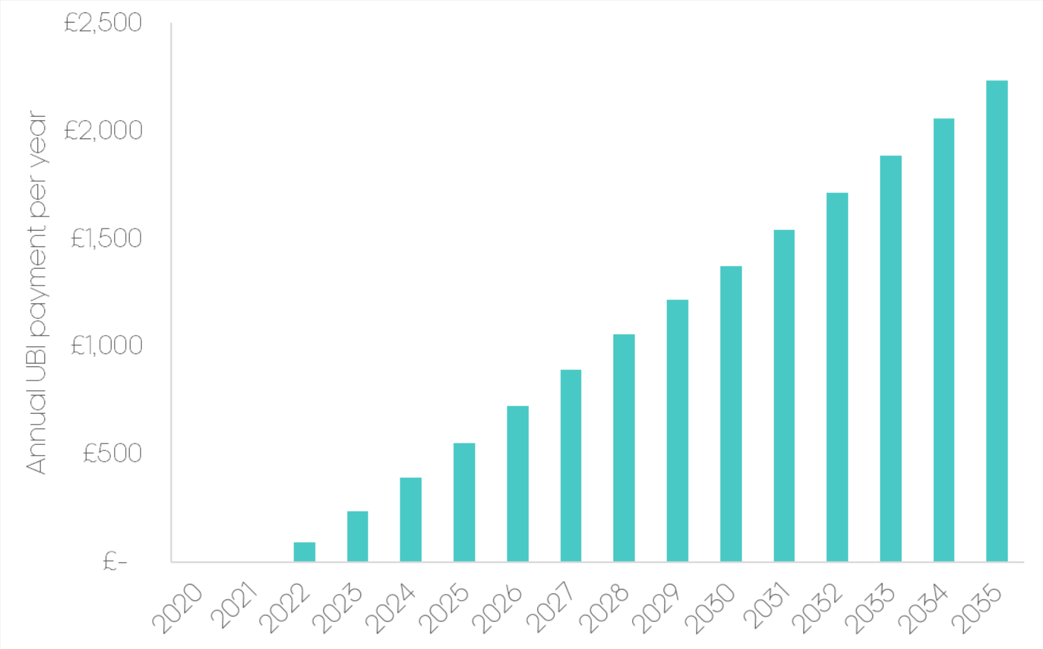
Combined scenario

The combined scenario is designed to evaluate the impacts of a DFSM-funded UBI scheme under conditions of high-automation job losses. Therefore, the combined scenario has the same automation-related scenario assumptions as the main automation scenario.

The UBI scheme in the combined scenario is designed to top-up incomes in such a way that the household incomes are compensated for the income lost as a result of job losses brought by automation. As automation gradually results in job losses, the UBI payments need to increase in line with the income lost.

We assume a simple UBI scheme design with uniform rates across all age groups. As shown in Figure B, the payments required to compensate for the lost income need to significantly increase over the modelled period. By year 2030, when we assume about 10% of jobs could be lost due to automation, the compensating UBI income payments are assumed at £1,371 per person. In year 2035, when 15% of jobs are assumed to be lost, UBI payments needed to compensate for income lost are set at £2,231 per person per annum.

Figure B.0.4 Combined scenario annual UBI payments, per person



Source(s): Cambridge Econometrics analysis.

The total cost of these UBI payments grows in line with these rates, as well as the projected growth in population.[19] We estimate that the annual cost of the UBI scheme proposed for the combined scenario would amount to £95bn in 2030 and would increase to £158bn in 2035. The scenario assumes that this cost can be met with issuance of DFSM, and therefore, the scheme does not assume any fiscal changes or changes to the existing social security payments.

Effectively, a DFSM-funded UBI scheme serves as a stimulus to incomes and consumer expenditures. Further impacts of such stimulus on output, employment, and prices are dynamically modelled using E3ME.

Note that as in the Scenario 2 and 3 we assume reduction in labour supply as a response to the level of UBI. The labour supply response is calculated within E3ME, based on the same rule as in the previous scenarios. The model finds a 0.71% reduction in the participation rate and in hours worked by 2035, which translates to a 0.41% is the yearly average reduction between 2022-2035.

General modelling assumptions in the scenarios

The scenarios feature large-scale and unprecedented changes to the labour market. Such effects likely lie outside of the model's historical experience (with respect to the data on which the econometric parameters were estimated). Some simplifying assumptions were thus applied when modelling the scenarios in E3ME, which are summarised in Table B.8.

[19] E3ME population projections are based on the ONS Population Projections.

Table B.8 General modelling assumptions

Modelling assumptions	
Sectoral wages follow sectoral prices in all scenarios	The behaviour of households and firms is typically modelled in E3ME using an econometric approach. A cointegrating econometric specification is used to capture the responsiveness of sectoral wages to changes in key drivers such as the unemployment rate and productivity. When modelling forward-looking policy scenarios, these parameters determine the economic results. However, due to the large structural changes to the labour market that are implied in these scenarios, the econometrically-estimated relationships could break down, which draws into question the suitability of the econometrically-estimated equations for this analysis. In particular, in the high automation scenario, there is a large increase in unemployment, coupled with a large boost to productivity, which would each have opposing effects on wage rates. In the basic income scenarios, the cointegrating equations would tend to suggest that the low unemployment (the product of more people working but at fewer average weekly hours, as well as reduction in labour participation) would lead to a strong wage response, actually driving up real incomes overall. Given the uncertainty regarding workers' wage-bargaining power, muting this response weakens this positive GDP effect, erring towards the lower end of the range of possible results. To deal with this issue, while still allowing wages to respond endogenously to developments in the scenario, we impose a simple assumption for sectoral wages to follow industry prices. Other labour market responses (notably the reduction in employment in the automation scenario and the change in participation rates in the UBI scenario) are applied by assumption.
Unemployment in the baseline	The input assumptions in the basic income scenarios feature strong labour supply responses, especially in the fiscally neutral scenario (UBI1). The combination of reducing the labour force participation rate and increasing employment reduce the unemployment rate quite substantially. For convenience (stability of model solution), we have raised the level of unemployment in the baseline. Given the absence of an unemployment-wage effect (see above), we do not believe that this unduly affects the results.
Marginal propensity to consume across deciles does not change over time	In the decile level treatment of E3ME, the marginal propensity to consume (MPC) for the income groups remains the same over time whereas, as real income generally increases, these MPCs might gradually fall. Table B shows the value of those marginal propensities but relaxing this assumption would not likely change the broad scale or message of these results.
Financial indicators	It could be argued that an increase in DFSM could push up interest rates on government bonds (and thereby affect exchange rates). These effects are not captured in the current set of results. Prices are modelled using a series of econometric equations, which respond to demand for goods/services and costs of production. A Taylor rule is used to mimic central bank behaviour in setting interest rates, and from that, a commercial rate of interest is derived.

Source(s): Cambridge Econometrics assumptions.

The evidence on whether reducing working hours raises worker productivity (during the working hours that remain) is unclear. In the scenarios, we assume that a similar level of labour input (total hours) is required for production before and after the provision of a basic income. As part of a sensitivity analysis, we then consider alternative cases in which lower hours are compensated for by higher productivity. (In that sensitivity, we examine the case in which a given level of output can be sustained by the same number of workers as before (and who are, on average, working fewer hours each).

Table B.9 Marginal propensities to consume by decile

	MPC
D1	1.00
D2	1.00
D3	0.94
D4	0.94
D5	0.86
D6	0.86
D7	0.76
D8	0.76
D9	0.62
D10	0.62

Source(s): Cambridge Econometrics, E3ME.