MODELLING THE IMPACT OF COVID-19 ON THE UK ECONOMY: AN APPLICATION OF A DISAGGREGATED NEW-KEYNESIAN MODEL

Cyrille Lenoël

NIESR

Garry Young

NIESR

NIESR Discussion Paper No. 531

12 August 2021

About the National Institute of Economic and Social Research

The National Institute of Economic and Social Research is Britain's longest established independent research institute, founded in 1938. The vision of our founders was to carry out research to improve understanding of the economic and social forces that affect people's lives, and the ways in which policy can bring about change. Over eighty years later, this remains central to NIESR's ethos. We continue to apply our expertise in both quantitative and qualitative methods and our understanding of economic and social issues to current debates and to influence policy. The Institute is independent of all party political interests.

National Institute of Economic and Social Research
2 Dean Trench St
London SW1P 3HE
T: +44 (0)20 7222 7665
E: enquiries@niesr.ac.uk
www.niesr.ac.uk
Registered charity no. 306083

This paper was first published in August 2021

Modelling the impact of Covid-19 on the UK economy: an application of a disaggregated New-Keynesian model

Cyrille Lenoël and Garry Young

Abstract

We set out a framework that can be used to evaluate policies intended to mitigate the economic effects of Covid-19. In our framework shocks that affect only certain sectors can spill over to other sectors because of input-output linkages and limited income insurance. We show that policies such as the furlough scheme can prevent the sharp rises in unemployment that might arise in the absence of the scheme, and illustrate how such policies can be evaluated using the framework.

Keywords: Covid-19, recession, sectoral model, input-output
JEL Classifications: E00, E12, E20, E23, E24, E30, E52, E60, E62

Acknowledgements

We are grateful to the Economic and Social Research Council under grant number ES/V003844/1 for funding this project as part of its Covid 19 Rapid Response programme. We are also grateful to Jagjit Chadha, Peter Dolton, Corrado Macchiarelli, Barry Naisbitt and Craig Thamotheram for comments and suggestions, and to Ian Hurst for help integrating the sectoral model into NiGEM.

Contact details

Cyrille Lenoël: c.lenoel@niesr.ac.uk
National Institute of Economic and Social Research, 2 Dean Trench Street, Smith Square, London SW1P 3HE.
Garry Young: g.young@niesr.ac.uk

Introduction

The Covid-19 pandemic has had a significant and uneven impact on the UK economy. The need to reduce personal interaction to limit the spread of the virus resulted in restrictions in economic activity that were mitigated by a range of policy support measures. Most prominent among the restrictions were three national lockdowns and the closure of venues in the contact-intensive hospitality, leisure and entertainment sectors. Most prominent among the mitigation measures were the government furlough scheme (the Coronavirus Job Retention Scheme, CJRS) that paid businesses to support the incomes of furloughed workers, and various government-underwritten loan schemes that helped businesses to survive.

GDP fell by 25 per cent between February and April 2020 in the most severe phase of the crisis, but then recovered as the first lockdown ended and the economy adapted to the continuing restrictions. By April 2021, GDP had recovered to only 4 per cent below its January 2020 peak. Unemployment had risen to 4.8 per cent of the labour force in February-April 2021, up 0.8 percentage points from a year earlier, but this was a much smaller increase that many had expected partly reflecting the impact of the furlough scheme, with around 14 per cent of the workforce estimated to be on furlough in March 2021.

Providing support to the economy at a time of economic contraction has had a severe impact on the public finances. According to the latest estimates, public sector net borrowing (PSNB ex) in the financial year ending March 2021 was £297.7 billion, 14.2 per cent of GDP, the highest such ratio since the end of World War Two, when it was 15.2% in March 1946. Public sector net debt (excluding public sector banks, PSND ex) was £2195.5 billion at the end of May 2021, 99.1 per cent of GDP, the highest ratio since the 99.5 per cent of GDP recorded in March 1962.

Comparing these outcomes for the public finances with forecasts made before the pandemic suggests that the government borrowed around £250 billion more than expected in 2020-21 alone, with further larger deficits expected at least until the pandemic is over. While the mitigating policy measures appear to have been successful in supporting the economy through the pandemic, there will in time need to be an evaluation of the policy measures to assess whether they provided value for money and a consideration of what alternative policies might have been implemented instead.

Such an evaluation would require an economic modelling framework that could quantify what might have happened in the absence of the policy measures.

The purpose of this paper is to set out a framework that could be used for this purpose. A key element of the framework we propose is a mechanism that explains how narrow shocks that affect only certain parts of the economy can spill over to the rest of the economy with severe consequences if they are not mitigated by countervailing policy measures. In our framework this amplification of shocks comes about because of input-output linkages between different economic sectors and limited income insurance that causes narrow shocks to be transmitted widely, particularly when monetary policy is constrained by the zero lower bound. The framework has many features in common with that set out by Guerrieri, Lorenzoni, Straub and Werning (2020) who argue that stay-at-home measures in contact-intensive industries[1] can become a 'Keynesian supply shock'. Textbook descriptions of the nature of the shock are provided by Blanchard and Illing (2021) and Jones (2021).

There are several possible channels by which the Covid-19 shock could affect the economy. These include:

- *Lower productivity and hours of work of those in employment*. This supply-side effect comes about as people reduce their working hours as they become ill, self-isolate or care for their children who are unable to attend school. Lower productivity would be a consequence of workers with key skills being absent.

- *Lower economic activity due to establishments being locked down*. This applies particularly to pubs, restaurants, non-essential retail, sports facilities, tourist attractions and theatres that are not allowed to trade. It applies to some extent to schools, universities and places of worship, for example, where buildings are closed but some activity is continuing offsite. It also applies to other areas, such as construction and manufacturing establishments sites where it is not possible to practise social distancing. This is both a shock to supply and effective demand that could have repercussions throughout supply chains and through reduced income flows.

- *Lower desired consumer spending and investment*. This demand-side effect comes about because of heightened uncertainty as households aim to build precautionary saving balances and businesses defer investment until there is greater clarity about the course of the virus and its effects.

- *Lower demand and supply from other countries fighting Covid-19*. As well as lower export demand, this effect would also include disturbances to supply chains and limited availability of components produced in other countries. It also includes the effects of lower tourism into the UK.

- *Lower demand for risky assets due to lower confidence and less risk appetite*. This affects the cost of capital to businesses through lower asset prices and higher corporate bond spreads. It also reduces the willingness of banks to lend without loan guarantee schemes.

[1] In the rest of the paper, we use the terms industries and sectors interchangeably.

To some extent mitigating policy measures have prevented some of these possible channels of the shock from being evident in practice. For example, promises to do ‘whatever it takes’ have given households and businesses the confidence not to defer spending in a way that might otherwise have been an important constraint on demand. And monetary policy decisions to increase asset purchases are likely to have underpinned asset prices and limited increases in credit spreads.

For the most part the most significant manifestation of the Covid-19 shock appears to have been reduced spending on social consumption either due to establishments being locked down or because of voluntary restraint. So, we use this aspect of the shock to illustrate the model.

The structure of the paper is as follows. Section 2 sets out the details of the economic modelling framework. Section 3 explores the effect of a social consumption shock. It shows how the effect is magnified compared with a general consumption shock and illustrates how using a furlough scheme to reduce the response of employment to the consumption shock is able to mitigate its effects. Section 4 concludes and outlines how the model may be used to evaluate policy measures in more detail.

2. Model details

This section describes how a macroeconomic model of the UK economy has been constructed to analyse the effects of shocks like Covid-19 and Brexit that have heterogeneous effects across sectors. The approach taken has been to build a sectoral dimension into an already well-established model, namely the UK version of the National Institute Global Econometric Model (NiGEM).

NiGEM is the leading global macroeconomic model, used by both policymakers and the private sector across the globe for economic forecasting, scenario building and stress testing. It is described in detail in Hantzsche, Lopresto and Young (2018). It consists of individual country models for the major economies that are linked through trade in goods and services and integrated capital markets. The individual country models have a New Keynesian structure where output is tied down in the long run by factor inputs and technical progress but reflects demand side influences in the short run due to nominal rigidities.

Whereas the UK country model in NiGEM is a one sector model, the extended UK version (NiSEM) includes nine distinct industrial sectors based around the national accounts supply and use tables. The sectors are mining and quarrying (1.1% of GDP in 2018, mainly oil and gas extraction), manufacturing (10.1% of GDP), construction (6.4% of GDP), private non-traded services (21.1% of GDP), private traded services (23.6% of GDP), finance (6.8% of GDP), imputed rent (9.5% of GDP), public sector (18.1% of GDP), and an energy-producing sector comprising agriculture and utilities (3.3% of GDP).[2] Output in the major sectors is produced using labour, capital and intermediate goods supplied from other industries underpinned by calibrated production functions. Productivity growth is driven by increases in capital per worker (capital deepening) and (labour augmenting) technological change that varies by industry. The demand for each industry's gross output is given by domestic final and intermediate demand plus, where relevant, exports less imports, where exports are related to world demand and relative export prices.

The sectoral composition of the model has been chosen to balance the trade-off between model size and tractability. It is sufficiently detailed to distinguish between the main industry groupings that perform different roles in the UK economy without being too large as to be costly to maintain within a regularly used and updated model. Importantly the large services sector is not treated as a homogeneous group within the model but is broken down into private and public services, and private services are broken down further into finance, imputed rent, non-traded private services, such as the retail sector, accommodation and food activities, and private traded services, such as consultancy.

Taking account of sectoral heterogeneity is particularly important when the economy is affected by shocks, such as Brexit and Covid-19, that affect some sectors more than others.

[2] A full definition of the sectors is provided in Appendix A.

The main types of heterogeneity present in the model come from different sectoral interdependencies, differences in factors shares in the various sectors, and different demand dependencies.

Modelling framework and the national accounts

One of the key aspects of NiSEM is that it takes account of the interdependence between industrial sectors that arises through input-output linkages. As a matter of accounting, the total *gross* output of any domestic industrial sector is made up of the value-added output (at basic prices) produced in that sector plus the value of intermediate goods and services (at purchasers' prices) purchased from other sectors to produce gross output. That is, for sector *i*:

$$Y_i^g = Y_i^v + \sum_j Z_{ij} \qquad (1)$$

Where Y_i^g is the gross output of sector i, Y_i^v is value-added output of sector i, Z_{ij} is intermediates of sector *j* used by sector i and $\sum_j Z_{ij}$ is all domestically-produced intermediates used by sector *i*.

Table 1 shows how in the UK 2018 national accounts the total domestic output of each NiSEM sector at basic prices breaks down into its value-added output plus its use of intermediates produced by other domestic sectors. For agriculture and utilities (sector A) for example, gross output of £199 billion is composed of £64 billion of value-added output and £135 billion of intermediate goods and services, an intermediate share of 68 per cent. This is a relatively high intermediate share, though in this sector a high proportion of intermediates comes from other firms within the sector rather than other sectors. Looking instead at intermediate consumption of output produced by other sectors as a share of value-added output reveals that the finance sector is the largest user of intermediates at 89 per cent of value added, with intermediates produced by the private traded sector accounting for 67 per cent of finance sector value added. Across the economy as a whole the average share of intermediates in gross output is 47 per cent, a high degree of interdependence.

Table 1: 2018 Use Table at Purchasers' Prices – total domestic and value-added output (£million)

		Intermediate consumption by industry:									
PRODUCTS		A	B	C	F	G	I	K	L	P	TOTAL
Agriculture, electricity, water	A	80541	432	28311	2000	9668	12950	1674	1316	6318	143210
Mining and quarrying	B	10435	5578	26811	3075	27	187	9	0	236	46358
Manufacturing	C	19517	6451	224554	55157	67534	74169	7285	203	61568	516438
Construction	F	4922	415	2262	105195	7234	16791	4997	7928	3970	153714
Public	G	212	13	1684	1308	34753	7089	2746	8	10158	57971
Private non-traded services	I	1230	50	2898	611	20361	35043	11625	139	26744	98701
Finance	K	4635	2047	15610	5362	11036	21793	39741	14410	19184	133818
Imputed rent	L	0	0	0	0	0	0	0	0	0	0
Private traded services	P	13694	4254	44166	19723	59944	107615	86512	2307	249794	588009
Total intermediate consumption at purchasers' prices		135186	19240	346296	192431	210557	275637	154589	26311	377972	1738219
Taxes less subsidies on production		776	131	1246	1235	1080	14683	3345	0	4548	27044
Compensation of employees		20774	4712	121069	54151	264562	224773	71152	0	287051	1048244
Gross operating surplus and mixed income		42050	16583	69835	67813	80479	163411	54770	181313	158705	834959
Gross valued added at basic prices		63600	21426	192150	123199	346121	402867	129267	181313	450304	1910247
(share of value added, per cent)		3.3	1.1	10.1	6.4	18.1	21.1	6.8	9.5	23.6	100.0
Total output at basic prices		198786	40666	538446	315630	556678	678504	283856	207624	828276	3648466
Memo: domestic output of products		189285	36829	512031	316690	537515	742323	260754	207624	845415	3648466

Source: ONS Supply and use tables (2020) Letters correspond to the NiSEM sector groupings (see Annex A for the definition)

Table 1 also shows how value-added output at basic prices in each sector breaks down into compensation for employees and profits, known in the national accounts as gross operating surplus and mixed income for business owners and the self-employed, plus taxes less subsidies on production. That is,

$$Y_i^v = wN_i + \Pi_i + TAXPROD_i \qquad (2)$$

Where wN_i is total compensation made up of the average wage *w* times the number employed, N_i, Π_i is profits, and $TAXPROD_i$ is taxes less subsidies on production (not to be confused with taxes less subsidies on *products*). It is worth noting here that self-employment income is included within profits. Also note that the value-added output of the imputed rent sector (L) that is imputed to homeowners is matched by a corresponding imputed income that is accounted for in profits.

The share of value-added going to employees varies significantly across sectors, reflecting different production and business models. In the whole economy the share of value-added going to employees is 55 per cent when self-employment income is included within profits.

Table 1 also shows the relative size of the different sectors in terms of the value-added output they produce at basic prices. The private traded (23.6 per cent) and non-traded services sectors (21.1 per cent) are the largest producers of value-added output in the UK economy. Manufacturing accounts for 10.1 per cent of the economy in value-added terms, but this understates the importance of manufacturing to the economy as its gross output incorporates a high proportion of intermediate goods and services produced in other sectors that are sold in manufactured form but do not count as manufacturing value added.

The total supply of products (goods and services) available to the economy at purchasers' prices comes from domestic output at basic prices (comprising value-added and intermediate production), an adjustment from basic prices to purchasers' prices, and imports:

$$Y_j = Y_j^V + \sum_i Z_{ij} + M_j + BPA_j \qquad (3)$$

Where *M* is imports and *BPA* is an adjustment from basic prices to purchasers' prices made up of a reallocation of distributors' trading margins (to ensure that products are valued at purchasers' prices appropriately) and by adding on the effect of indirect taxes such as VAT (taxes less subsidies on products, not to be confused with taxes less subsidies on *production*).

Table 2 shows the national accounts data for 2018 for the products of the nine NiSEM sectors. This 'supply' table shows that the largest sectors in terms of gross output supplied at basic prices are private traded (23 per cent) and non-traded services (20 per cent). A large proportion of the supply of manufactures is imported.

Table 2: 2018 Supply Table (£million)

PRODUCTS		Domestic output of products at basic prices	Share (%)	Imports of goods	Imports of services	Distributors' trading margins	Taxes less subsidies on products	Total supply of products at purchasers' prices
Agriculture, electricity, water	A	189285	5.2	16797	1117	9051	9679	225929
Mining and quarrying	B	36829	1.0	34581	149	1529	446	73534
Manufacturing	C	512031	14.0	433964	20212	311354	114236	1391797
Construction	F	316690	8.7	0	2207	0	30360	349257
Public	G	537515	14.7	0	3307	0	3884	544706
Private non-traded services	I	742323	20.3	2512	28942	-337543	29476	465710
Finance	K	260754	7.1	0	26396	0	10741	297891
Imputed rent	L	207624	5.7	0	3812	0	0	211436
Private traded services	P	845415	23.2	2635	110457	15609	32723	1006839
Total		3648466	100	490489	196599	0	231545	4567099

Source: ONS Supply and use tables (2020) Letters correspond to the NiSEM sector groupings (see Annex A for the definition)

In aggregate, this total supply of products at purchasers' prices is used for final demand plus intermediate consumption:

$$Y = C + I + G + X + \sum_{i=1}^{9} \sum_{j=1}^{9} Z_{ij} \qquad (4)$$

Where *Y* is the total output of the economy at purchasers' prices, including output of intermediate products, *C* is household consumption, *I* is investment (including stockbuilding), *G* is government consumption, *X* is exports of goods and services, and Z_{ij} is the intermediate consumption of the output of industry i by industry j.

Table 3 shows the sources of demand in 2018 for the products of the nine NiSEM sectors. This 'use' table shows that the largest sectors in terms of gross output used are manufacturing (30 per cent) and private traded services (22 per cent). The overall gross output is mainly used for intermediate consumption (38 per cent) and household consumption (30 per cent). This varies by sector. For example, construction is mainly used for intermediate consumption (44 per cent) and gross capital formation (55 per cent), whereas public sector output is primarily used for general government consumption (68 per cent).

Table 3: 2018 Use Table at Purchasers' Prices – intermediate and final demand (£ million)

PRODUCTS		Total intermediate consumption at purchasers' prices	Households and NPISH consumption	Gross capital formation	General government consumption	Exports of goods	Exports of services	Total demand for products at purchasers' prices
Agriculture, electricity, water	A	143210	66789	233	6642	8597	458	225929
Mining and quarrying	B	46358	442	-2084	0	28328	490	73534
Manufacturing	C	516438	455970	91160	9643	304780	13806	1391797
Construction	F	153714	1833	190896	0	0	2814	349257
Public	G	57971	102180	1164	372146	0	11245	544706
Private non-traded services	I	98701	328147	8971	3957	5617	20317	465710
Finance	K	133818	76765	0	0	0	87308	297891
Imputed rent	L	0	210916	0	0	0	520	211436
Private traded services	P	588009	142649	92827	6033	3810	173511	1006839
Total		1738219	1385691	383167	398421	351132	310469	4567099

Source: ONS Supply and use tables (2020) Letters correspond to the NiSEM sector groupings (see Annex A for the definition)

Summing equation (3) and combining with (4) gives the familiar national income identity that in aggregate value-added output (at basic prices) is equal to final demand at purchasers' prices less the basic price adjustment:

$$Y^V = C + I + G + X - M - BPA \qquad (5)$$

The national income identity shows that *ex post* the overall supply of value added is equal to overall final demand. Aggregate models of the economy, based around the quarterly national accounts, tend to ignore intermediate production and consumption because it nets out at the aggregate level.

Demand and supply in the sectoral model

The sectoral model is incorporated into the UK country model in NiGEM (described in Hantzsche, Lopresto and Young, 2018). NiGEM is a New-Keynesian model in that in the long run output depends on factor supplies and productivity, but in the short run reflects both demand and supply influences. The key agents in NiGEM are households, firms, government and monetary authorities.

The main amendments that are made to NiGEM to incorporate the sectoral model are changes to the supply side of the model. This involves replacing an aggregate production function with sectoral production functions for the individual sectors linked by input-output relations. This has consequences for some of the main components of the model: employment, investment, output, exports and imports are all broken down into their sectoral components. But other parts of the model are unchanged. In particular, household consumption, government behaviour and monetary policy assumptions are unchanged.

We also experiment with changes to the way in which prices and wages are determined in the model. The price and wage equations together determine equilibrium unemployment and how the model returns to equilibrium following shocks. In general, a negative demand shock in NiGEM results in temporary unemployment and spare capacity that put downward pressure on prices. While equations for most demand components are specified in real terms and so independent of the level of prices, aggregate demand in NiGEM is sensitive to price changes through the effects of lower prices in boosting export and import competitiveness and in prompting monetary policy relaxation to below-target inflation. We continue to use the existing NiGEM wage and aggregate price equations, but allow sectoral price differences to emerge that affect the path of adjustment.

Demand

One of the key model variables is the total or gross output of each sector at basic prices, as shown in equation (1) and the penultimate row of Table 1. This is related to demand by the identity:

$$Y_i^g = Y_i^c + X_i - M_i - R_i \qquad (6)$$

That is, gross output of sector i (at basic prices) is equal to domestic final and intermediate demand for the output of i (Y_i^c) plus exports (X_i) net of imports (M_i) less a residual term (R_i) that in aggregate is equal to taxes less subsidies on products. For the different sectors the residual also includes the reallocation of distributors' trading margins, that sums to zero, and the difference between the gross output of sectors and products, that also sums to zero. As shown in Table 2, the residual is strongly positive in manufacturing and strongly negative in private non-traded services reflecting the reallocation of distributors' trading margins. Further details on how the residual terms on the gross output equations in the model are determined is provided in Appendix B.

While equation (6) holds as an identity, in all sectors of the model except one it is also a behavioural relationship in that output is assumed to be responsive to demand shifts. The exception is in mining and quarrying where gross output is determined exogenously and imports adjust to ensure that the identity holds.

The main component of demand in each sector is domestic final and intermediate demand.

Domestic final and intermediate demand

A key simplifying assumption in the model is that the domestic final and intermediate demand for the output of i (Y_i^c) is determined in fixed proportions to the aggregate components of final demand and the total intermediate demand of each industry. Specifically,

$$Y_i^c = a_{c,i}C + a_{I,i}I + a_{G,i}G + \sum_{j=1}^{9} a_{i,j}Z_j \qquad (7)$$

Table 4 shows the proportions in which the different components of intermediate and final demand were allocated to each product in 2018.

Table 4: 2018 Domestic final and intermediate demand shares

		Intermediate consumption by industry											
PRODUCTS		A	B	C	F	G	I	K	L	P	Households and NPISH consumption	Gross capital formation	General government consumption
Agriculture, electricity, water	A	0.60	0.02	0.08	0.01	0.05	0.05	0.01	0.05	0.02	0.05	0.00	0.02
Mining and quarrying	B	0.08	0.29	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
Manufacturing	C	0.14	0.34	0.65	0.29	0.32	0.27	0.05	0.01	0.16	0.33	0.24	0.02
Construction	F	0.04	0.02	0.01	0.55	0.03	0.06	0.03	0.30	0.01	0.00	0.50	0.00
Public	G	0.00	0.00	0.00	0.01	0.17	0.03	0.02	0.00	0.03	0.07	0.00	0.93
Private non-traded services	I	0.01	0.00	0.01	0.00	0.10	0.13	0.08	0.01	0.07	0.24	0.02	0.01
Finance	K	0.03	0.11	0.05	0.03	0.05	0.08	0.26	0.55	0.05	0.06	0.00	0.00
Imputed rent	L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00
Private traded services	P	0.10	0.22	0.13	0.10	0.28	0.39	0.56	0.09	0.66	0.10	0.24	0.02
Total		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: ONS Supply and use tables (2020) Letters correspond to the NiSEM sector groupings (see Annex A for the definition)

These shares are stable over time suggesting that it is a reasonable simplifying assumption that the shares are fixed in normal times. An alternative assumption would be that the shares respond to relative output prices. This could be explored further though we would expect substitution between sectors to be very limited.

One of the consequences of the Covid-19 shock is that the shares did change sharply in 2020 as the share on household consumption spent on private non-traded services fell sharply. This is considered further in the next section (section 3).

External demand

The other key source of demand for the output produced by a sector is exports net of imports. The main trading sectors in NiSEM are manufacturing, private traded services and finance, though other sectors also trade a little. In contrast to the allocation of domestic final and intermediate demand which is assumed to be price insensitive, exports and imports are assumed to be sensitive to relative prices.

Exports of each sector are determined by a simple demand relationship:

$$\frac{X_{i,t}}{W_{i,t}} = a_X.\frac{X_{i,t-1}}{W_{i,t-1}} + (1 - a_X).\, b_X \left(\frac{P_{i,t}^X}{WP_{i,t}^X}\right)^{-c_X} \qquad (8)$$

Where $W_{i,t}$ is world demand for product i and $\frac{P_{i,t}^X}{WP_{i,t}^X}$ is the relative price of UK to world exports expressed in a common currency. This relationship allows partial adjustment of the UK share of world exports to a long-run equilibrium determined by a constant elasticity demand curve.

Imports have a similar structure in all traded sectors except mining and quarrying:

$$\frac{M_{i,t}}{Y_{i,t}^C} = a_M.\frac{M_{i,t-1}}{Y_{i,t-1}^C} + (1 - a_M).\, b_M \left(\frac{P_{i,t}^M}{P_{i,t}}\right)^{-c_M} \qquad (9)$$

Where $Y_{i,t}^C$ is domestic final and intermediate demand for the output of i and $\frac{P_{i,t}^M}{P_{i,t}}$ is the relative price of imports to domestic prices expressed in a common currency. This relationship allows partial adjustment of the import share of domestic final and intermediate demand to a long-run equilibrium determined by a constant elasticity demand curve.

The structure of imports is different in mining and quarrying where UK firms are assumed to be able to sell what they like at the world price and imports are determined by residual to meet domestic final and intermediate demand.

Supply

Supply in most sectors of the model can be thought of as being determined by the activities of a large number of profit-maximising imperfectly competitive firms.[3] Such firms set output prices as a mark-up over marginal costs and set output to supply whatever demand is forthcoming at the chosen price. To produce the desired amount of output they make use of the pre-determined quantity of capital and hire whatever amount of labour is consistent with their short-run production function. Over time they build capital according to the gap between the marginal product of capital in the sector and the user cost, subject to adjustment costs.

Lockdowns imposed during the Covid-19 crisis are implemented in the model as reductions in the amount of effective demand facing certain sectors.

---

[3] The exceptions are the public and imputed rent sectors, and mining and quarrying where there is a competitive international market for output.

As noted earlier, gross output of each sector (at basic prices) is equal to value added output (at basic prices) plus intermediate goods and services used by that sector (equation (1)). It should be noted that the trade data does not distinguish between intermediate and final imports and so the fixed proportion applies only to domestic intermediates. There is assumed to be a production function for value added output, while intermediates used are assumed to be a fixed proportion of gross output ($Z_{ij} = a_{i,j}Y_i^g$). This latter assumption is a simplification that could be relaxed in future research using the model, for example in considering the effects of policies designed to reduce energy usage.

The value-added production function

Value added output in each sector is assumed to be given by a CES production function:

$$Y_i^V = A_i\left(\beta_i K_i^{-\rho_i} + (1-\beta_i)N_i\lambda_i{}^{-\rho_i}\right)^{-1/\rho_i} \qquad (10)$$

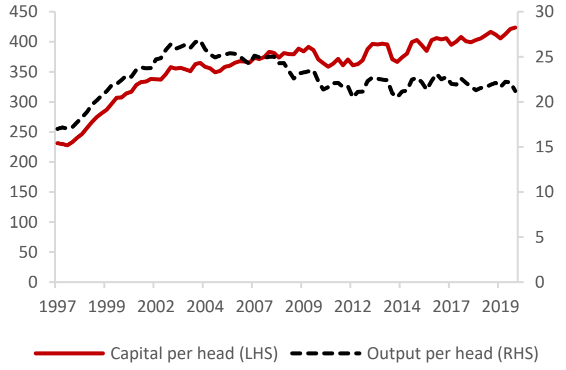
Where *K* is the net capital stock, *N* is employment in heads and λ is the estimated rate of labour augmenting technical progress. This function is used to determine a) the labour input needed as a function of capital, output and technical progress, b) potential output of each sector and c) the marginal product of capital. The elasticity of substitution between labour and capital is given by $\sigma_i = 1/(1+\rho_i)$ and is set equal to 0.5 ($\rho_i = 1$) in every sector, consistent with the NiGEM production function used in the aggregate wage and price equations.

Employment is measured in heads using the ONS productivity jobs series split by industrial sector. Using a 'heads' measure of employment means that trends in hours worked per employee are captured in estimated total factor productivity in each sector. The capital stock is measured using the ONS experimental 'productive capital stock' that is appropriate when measuring capital as an input into production.

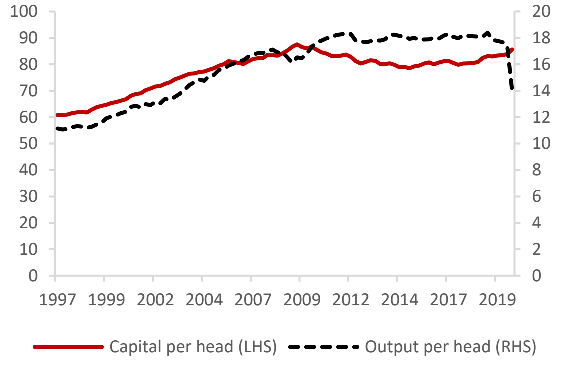
Chart 1 shows the capital-labour ratio for the six main private sector industries in the model (the imputed rent and mining and quarrying sectors are untypical).

Chart 1: Output per head and capital per worker in key sectors (£million, CVM per worker)

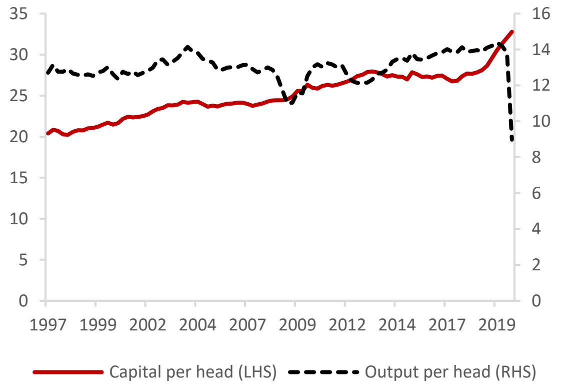
Agriculture, electricity and water



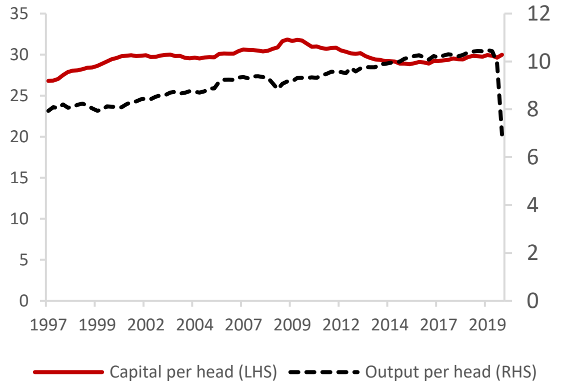
Manufacturing



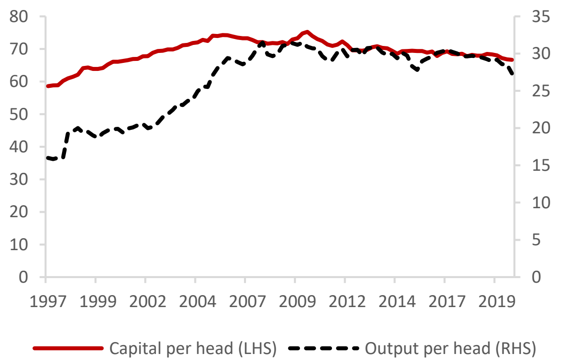
Construction



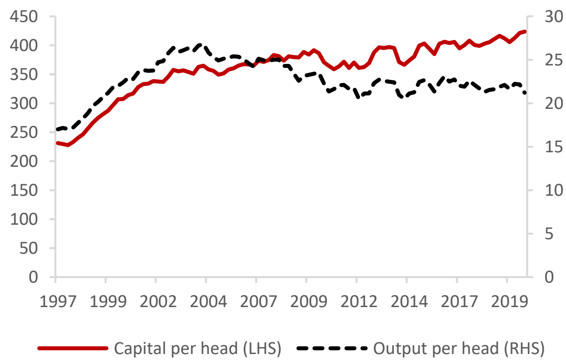
Private non-traded services



Finance and insurance



Private traded services



Source: Employment per sector from ONS productivity jobs series and capital from experimental productive capital

The figures in Chart 1 highlight a number of differences between the six industry sectors shown. First, capital intensity is highest in the combined agriculture and utility sector and lowest in the construction and private non-traded sectors. Second, capital intensity was increasing in every sector until the financial crisis that began in 2007, but largely stagnated thereafter in all sectors apart from construction and the combined agriculture and utility sector. Third, productivity (output per head) is highest in finance and the combined agriculture and utility sector and lowest in the construction and private services sectors. Fourth, productivity grew more slowly or fell in all sectors after the financial crisis, except construction. Fifth, output per head fell sharply due to Covid-19 at the end of the sample in all sectors, but less prominently in finance and the combined agriculture and utility sector.

The production function in each sector is calibrated by assuming:

i. that the production function determines potential output and that actual output is equal to potential output on average up to a constant. The constant is calibrated such that potential output is equal to actual output in 2018q4;

ii. that the capital share is revealed by the share of gross operating surplus and mixed income in gross value added at basic prices;

iii. that the rate of technical progress in each sector was different before and after the financial crisis that began in 2007q3. This is to account for the observed post-financial crisis slowdown in productivity growth.

Taking log differences of the production function (10) gives:

$$\Delta lnY_i^V = \beta_i \Delta lnK_i + (1-\beta_i)\Delta lnN_i + (1-\beta_i)\Delta ln\lambda_i \qquad (11)$$

Where an estimate of λ_i can be backed out by normalising it to 1 in 1997q1 and averaging pre- and post-financial crisis. A value of the constant A_i can then be obtained by making the arbitrary normalising assumption that potential output is equal to actual output in 2018q4.

Table 5 reports estimates of the capital share (β_i) for each sector and calibrated rates of technical progress assumed for the pre- and post-crisis periods. TFP growth is lower post-financial crisis in all sectors except construction and private non-traded services where it is higher.

Table 5: Production function parameters

	capital share (β_i)	Pre-crisis TFP (%pa)	Post-crisis TFP (%pa)
Agriculture, electricity and water	0.67	1.9	-4.7
Mining and quarrying	0.78	n/a	n/a
Manufacturing	0.37	4.7	0.6
Construction	0.56	-1.54	3.7
Public	0.24	n/a	n/a
Private non-traded services	0.44	1.7	2.8
Finance	0.45	9.3	0.2
Private traded services	0.36	4.1	2.0

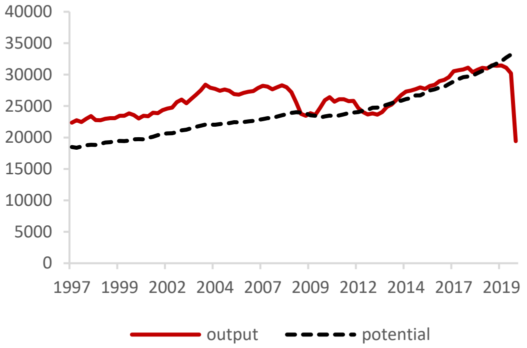
Note: Capital share = Gross operating surplus and mixed income divided by GVA at basic prices in 2008 (see Table 1). TFP normalised at 1 in 1997q1 then calibrated using equation (11): $\Delta ln\lambda_i = \frac{1}{(1-\beta_i)}\Delta lnY_i^V - \frac{\beta_i}{(1-\beta_i)}\Delta lnK_i - \Delta lnN_i$. Pre-crisis TFP set to average of $\Delta ln\lambda_i$ from 1997q2 to 2007q2 and post-crisis TFP set to average of $\Delta ln\lambda_i$ from 2007q4 to 2019q4.

Potential output

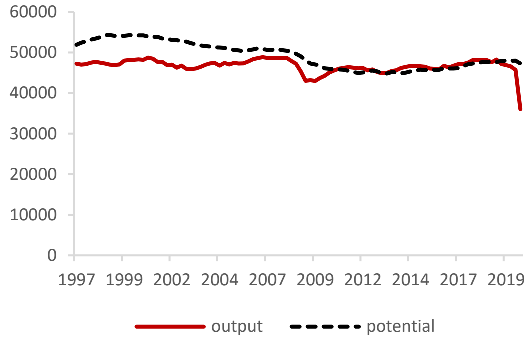
Chart 2 shows how actual value-added output compares with potential output as implied by the production function calibrated using the values shown in Table 5. The charts show that output fell relative to implied potential in the aftermath of the financial crisis and, more significantly, in 2020q2 when Covid-19 led to large parts of the economy being locked down. The furlough scheme has prevented a sharp drop in potential output similar to the drop in output because employees on furlough are considered as employed and still enter in the production function.

Chart 2: Actual and implied potential value-added output in key sectors (£million, CVM)

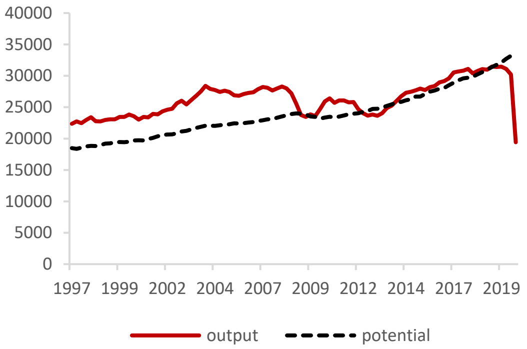
Agriculture, electricity and water



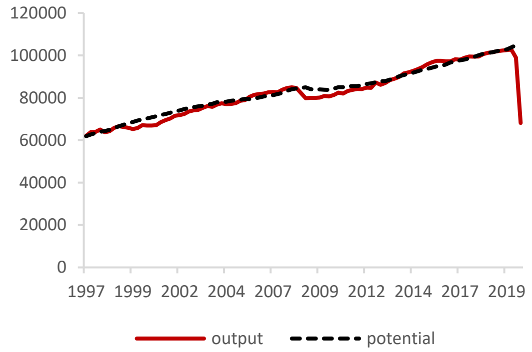
Manufacturing



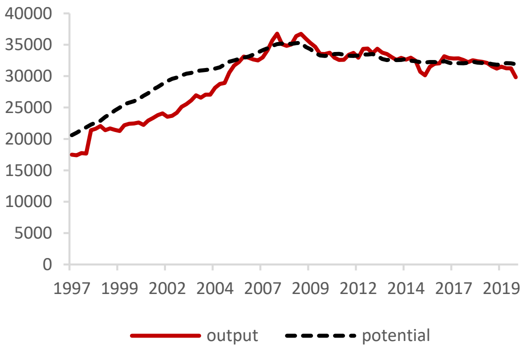
Construction



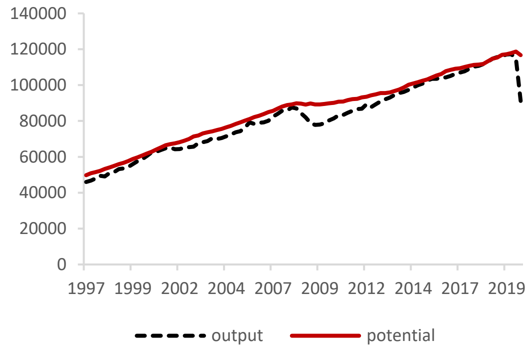
Private non-traded services



Finance



Private traded services



Note: Potential output normalised to actual output in 2018q4. Source: ONS and NiSEM

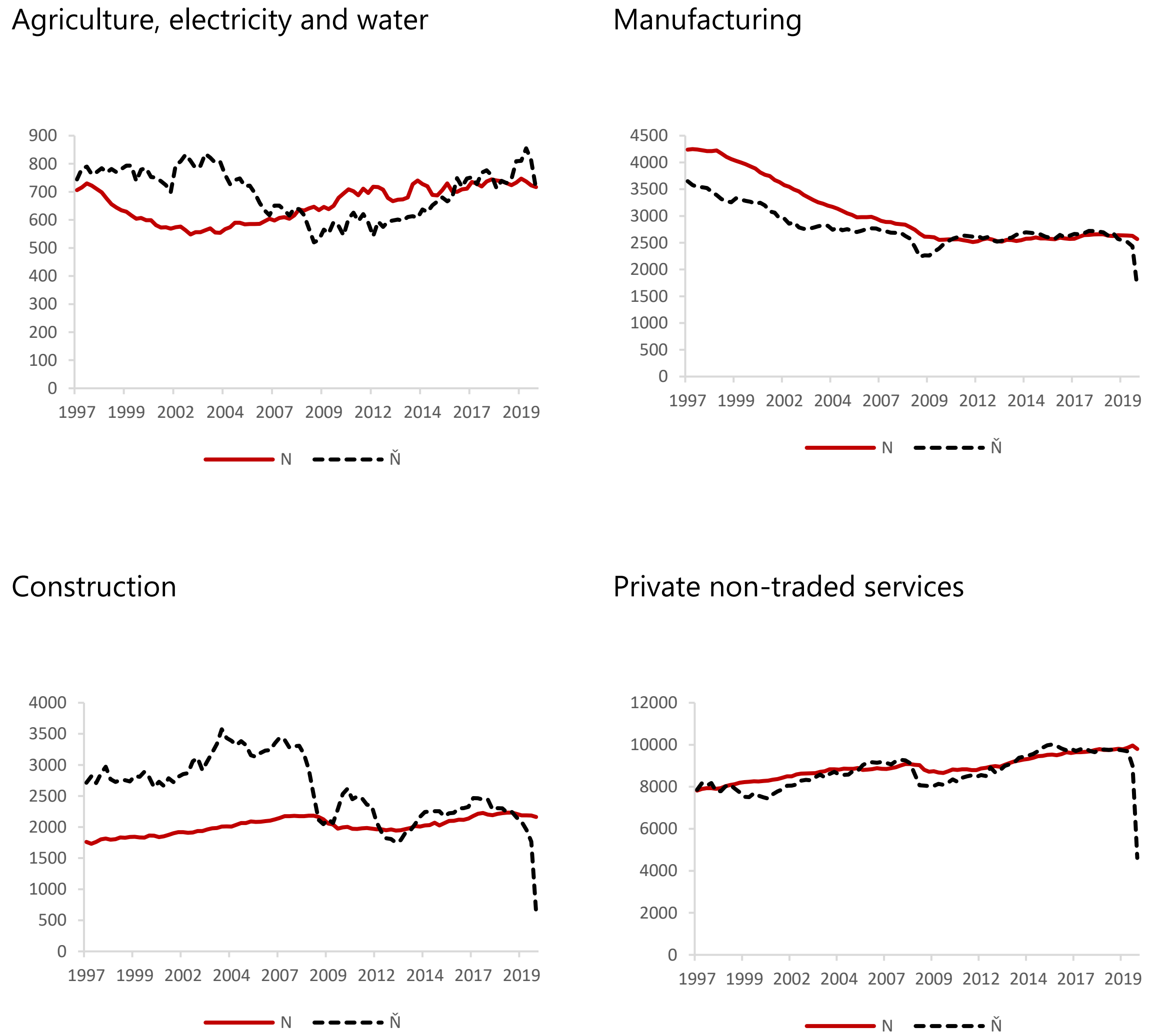
Employment

The production function also determines how much labour is required to produce a given amount of output subject to the capital stock available. This can be written as $\widehat{N}_{it}$ and is given by:

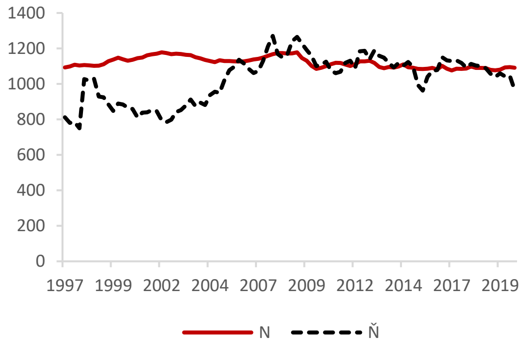
$$\widehat{N}_{it} = \frac{1}{\lambda_{it}} \frac{(1-\beta_i)Y_{it}^V}{\left(A_i - \beta_i \frac{Y_{it}^V}{K_{it}}\right)} \qquad (12)$$

Chart 3 shows how actual employment compares to the implied labour requirement generated by (12) for each sector.

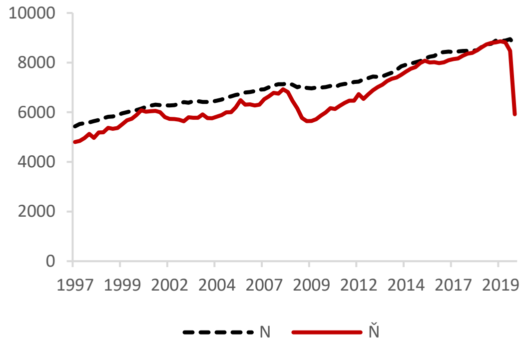
Chart 3: Employment and implied labour requirement in key sectors (thousands)



Finance and Insurance



Private traded services



Note: Implied employment $\widehat{N}$ is given by equation (12). Source: ONS and NiSEM.

The implied labour requirement drives employment in the long run in NiSEM, though the relationship is not strong in the short term. The figures shown in Chart 3 appear to be consistent with partial adjustment of actual employment to the amount of labour required as labour is hoarded in economic downturns.

A simple backward-looking error-correction mechanism is used to model the relationship between employment and implied labour requirement in the short term:

$$\Delta N_{it} = a_{0,i} + a_{1,i}\Delta \widehat{N}_{it} + a_{2,i}\left(N_{it-1} - \widehat{N}_{it-1}\right) \qquad (13)$$

Such equations can reflect optimal behaviour in a dynamic environment when firms face quadratic adjustment costs (Nickell, 1985). Table 6 shows the coefficients when (13) is estimated by OLS.

Table 6 **Fitted employment relationships**

	Energy	Manufacturing	Construction	PNTS	Finance	PTS
$a_{0,i}$	0.6 (0.4)	22.3 (4.0)	-0.88 (0.3)	27.5 (5.2)	-0.76 (0.7)	59.1 (7.6)
$a_{1,i}$	0.006 (0.1)	0.058 (2.3)	0.026 (1.9)	0.037 (3.7)	0.02 (1.2)	0.01 (7.1)
$a_{2,i}$	0.01 (0.7)	-0.063 (7.5)	-0.01 (2.3)	-0.03 (2.2)	0.008 (1.1)	-0.053 (3.8)
$\bar{R}^2$	-0.01	0.41	0.09	0.18	0.015	0.40

Note: Equation is $\Delta N_{it} = a_{0,i} + a_{1,i}\Delta\widehat{N}_{it} + a_{2,i}(N_{it-1} - \widehat{N}_{it-1})$. t-statistics shown in parentheses.

The fitted relationships are consistent with lagged adjustment of employment to the implied labour requirement for manufacturing, private traded and non-traded services, and to some extent construction, but do not explain the behaviour of employment in the combined agriculture and utilities sectors and finance. These two sectors account for a relatively small fraction of UK employment and their employment in NiSEM is modelled using (13) with imposed coefficients.

In practice, the determination of employment is likely to differ from a simple dynamic relationship like (13), particularly when there are large shocks like that due to Covid-19. In the face of such shocks, firms that usually adjust gradually may adjust more abruptly. As a consequence, we experiment with different adjustment processes.

Linking employment determination to the assumed production function appears to suggest that labour demand in the model is unaffected by factor prices, but this is not the case. Factor prices instead influence output prices and so affect labour demand by changing the amount of output that is demanded.

Simple models of optimising firm behaviour predict that the capital stock is chosen so that the marginal product of capital is equal to its user cost. The value-added production function implies that the marginal product of capital is given by:

$$\frac{\partial Y_i^V}{\partial K_i} = \left(\frac{Y_i^V}{K_i}\right)\frac{\beta_i}{\beta_i+(1-\beta_i)\frac{K_i}{N_i\lambda_i}} \quad (14)$$

In annualised percentage terms the implied marginal product of capital varies significantly across sectors, from around 15 per cent in the capital-intensive combined agriculture and utilities sector to 120 per cent in labour-intensive construction.

The user cost of capital (u_i) in a sector depends on the cost of finance (r_i), adjusted for risk and taxes, and the rate of capital depreciation (δ_i). That is,

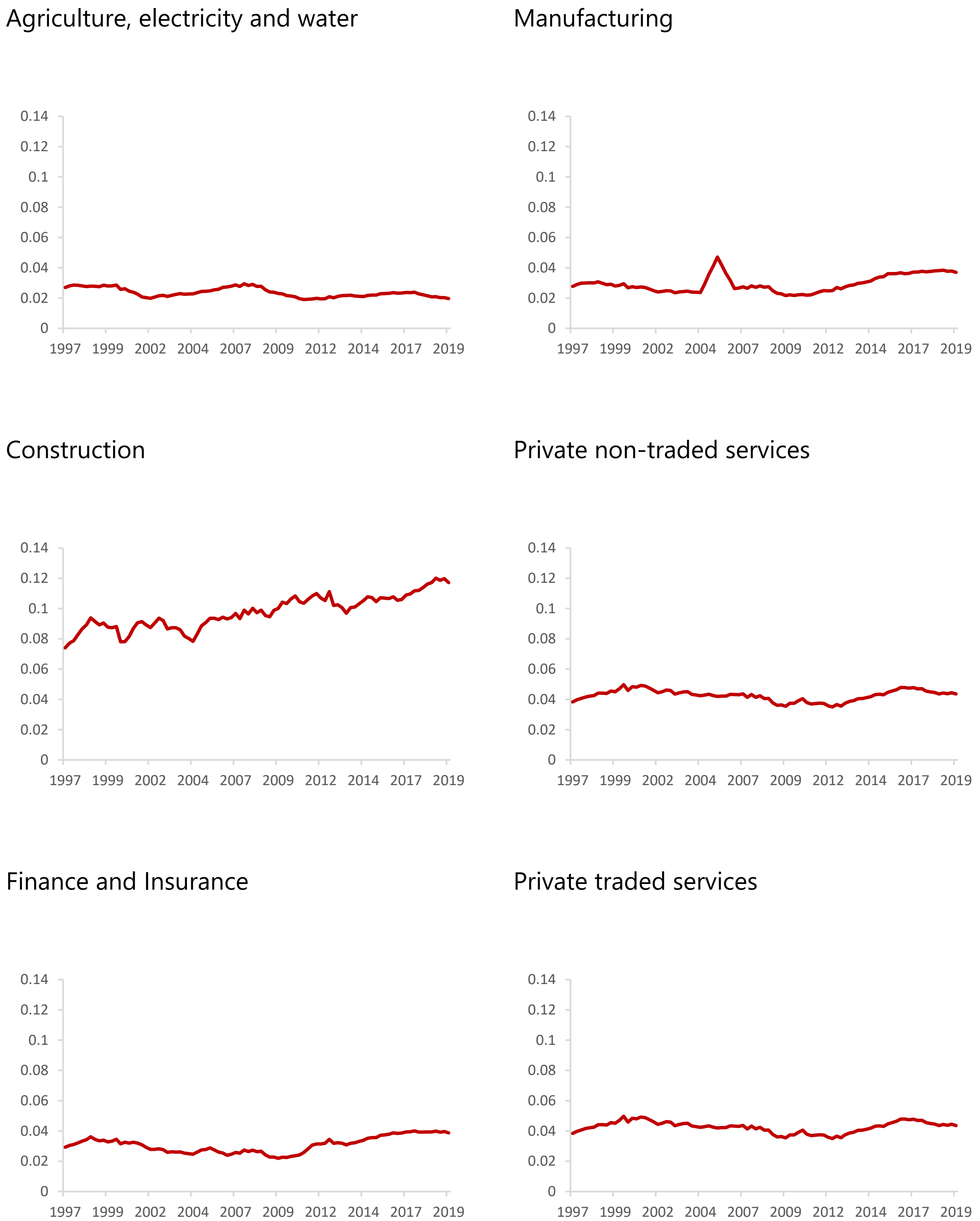
$$u_i = r_i + \delta_i \quad (15)$$

Where the rate of depreciation is implied by the capital stock relationship:

$$K_{it} = (1-\delta_i)K_{it-1} + I_{it} \quad (16)$$

The quarterly depreciation rate varies from around 1.5 per cent per quarter in the combined agriculture and utilities sector to about 10 per cent per quarter in construction.

Chart 4: Investment-capital stock ratio in key sectors (ratio)



Note: Annual gross fixed capital formation by industrial sector is interpolated to produce a quarterly series.

It is not easy to reconcile the high implied return on capital relative to its user cost and the relatively low capital intensity of production in most sectors. This is a common finding in the UK and could reflect mismeasurement issues or that there are various frictions that prevent capital investment. A Bank of England, H M Treasury and Financial Conduct Authority working group[4] has been convened to investigate the challenges and potential barriers to investment in productive finance assets in the UK. A 'super-deduction'[5] was introduced in the 2021-22 Budget to stimulate private investment in new plants and machineries.

A forward-looking investment relation can be derived on the assumption that businesses in each sector maximise their value subject to quadratic capital adjustment costs (Bond and Meghir, 1994):

$$\frac{I_{it}}{K_{it-1}} = \beta_{i0} + \beta_{i1}\left(\frac{\partial Y_i^V}{\partial K_i} - u_{it} - \psi_{it}\right) + \beta_{i2}\frac{I_{it+1}}{K_{it}} \qquad (17)$$

In theory, the coefficient β_{i1} is determined by the cost of adjusting the capital stock – the larger the adjustment cost the smaller is β_{i1} – and β_{i2} is approximately equal to 1 – δ_i, the proportion of the capital stock that survives from one period to the next. The term in brackets is the marginal product of capital less the user cost adjusted for a time-varying premium reflecting uncertainty and borrowing restrictions not already included in the user cost.

In practice we assume that the user cost in each sector is the same and given by the NiGEM model series for the user cost of capital. We also impose the same value of β_{i1} = 0.013 and β_{i2} = 0.9 in each sector. These values are based on estimation results for the manufacturing sector. The value of the constant term is then chosen so that the equation residuals average zero over the sample period.

Chart 4 plots the investment capital ratio in the key sectors. This mainly shows that the ratio is relatively smooth as is consistent with significant capital adjustment costs.

Prices

Under imperfect competition, firms charge a mark-up over marginal cost. We continue to use the NiGEM price equation for aggregate unit total costs based on marginal costs in an aggregate CES production function (see Hantzsche *et al*, 2018). Prices in each industry are assumed to be proportional to aggregate unit total costs.

---

[4] Her Majesty's Treasury, Bank of England and Financial Conduct Authority convene working group to facilitate investment in productive finance | Bank of England

[5] The 'super-deduction' is composed of a 130% capital allowance on qualifying plant and machinery investments and a 50% first-year allowance for qualifying special rate assets. The 'super-deduction' will expire at the end of fiscal year 2022-23.

3. Modelling the economic effect of Covid-19 and policies to mitigate it

The effects of a social consumption shock

While the first wave of the pandemic from March to June 2020 led to severe disruptions in nearly every sector, the second wave from October 2020 to March 2021 mainly affected activities related to social life: eating at a restaurant, going to a movie or staying at a hotel. We illustrate the impact of a forced reduction of social consumption by assuming a reduction in demand in private non-traded services (PNTS) equivalent to 1 per cent of GDP. We compare the result of this simulation with a consumption shock that would be evenly spread across all sectors. We later on discuss the mitigating impact of the establishment of a furlough scheme to protect jobs.

Description of the shocks

Lenoël and Young (2020) describe the effect of the first lockdown on sectoral GDP by distinguishing between the sectors that were directed impacted like PNTS and sectors that were indirectly impacted like finance and utilities. They estimate that a lockdown that directly reduces GDP by 15 per cent could reduce GDP by around 25 per cent once spillovers are taken into account.

In this paper, we run two simulations:

- Simulation 1: An endogenous shock to household consumption, equivalent to 1 per cent of GDP
- Simulation 2: An endogenous shock to final and intermediate demand in the private non-traded services sector equivalent to 1 per cent of GDP

The shocks are assumed to occur in the first quarter, and then to decay at a rate of 50 per cent every quarter, to model social contact restrictions being imposed suddenly but lifted more gradually during the pandemic.

Table 7 shows the macro results of the simulations for GDP, household consumption and inflation. As one would expect, the consumption shock works through the same channels in both simulations. The forced reduction in consumption leads to an initial increase in the household savings ratio of 1.3 percentage points. The decline in production associated to lower consumption reduces the demand for labour, which leads to higher unemployment and lower household income. Households try to smooth their consumption, which leads to a drop in the savings rate to below the baseline after the 2nd quarter (see Chart 5 for the household savings ratio). The endogenous monetary policy reaction function counteracts a drop in inflation by reducing the policy rate from 0.1% to 0% and keeping it below the baseline for several years.

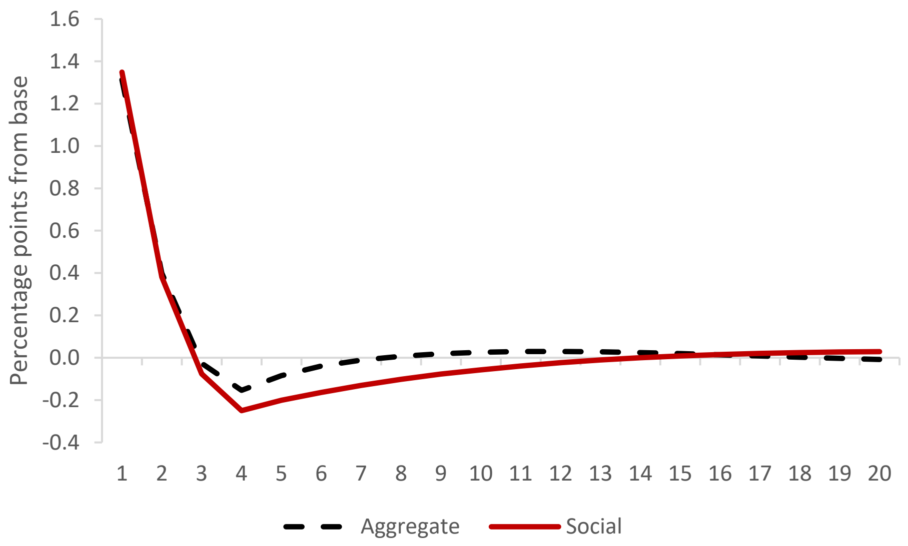
While the two simulations are calibrated to a similar size shock of 1 per cent of GDP, the shock concentrated in PNTS leads to a slightly stronger reduction of GDP because of the spillovers from PNTS to other sectors. Spillover effects happen as soon as the first quarter because the relationship between inputs and outputs across sectors is instantaneous: a decline in output in sector A directly translates into a reduction in inputs for sector B which uses A as an input and therefore the output of B is also instantaneously reduced.

Table 7: Aggregate versus social consumption contraction shock of -1% of GDP

	GDP		Consumption		Inflation	
Quarters	Aggregate	Social	Aggregate	Social	Aggregate	Social
1	-0.64	-0.73	-1.63	-1.62	0.02	0.03
2	-0.29	-0.34	-0.71	-0.72	0.02	0.05
3	-0.09	-0.11	-0.24	-0.26	-0.00	0.05
4	0.02	0.01	0.02	-0.03	-0.04	0.04
5	0.05	0.01	0.05	-0.01	-0.09	0.00
6	0.06	0.01	0.07	-0.00	-0.12	-0.02
7	0.07	0.02	0.08	0.01	-0.12	-0.03
8	0.07	0.02	0.09	0.01	-0.10	-0.03
9	0.07	0.02	0.09	0.02	-0.07	-0.03
10	0.07	0.02	0.09	0.02	-0.04	-0.03

Source: NiSEM simulation. Expressed as percentage points from base. ‘aggregate’ refers to a standard consumption shock of -1% of GDP and ‘social’ refers to a shock to final and intermediate demand in the private non-traded services sector equivalent to -1% of GDP.

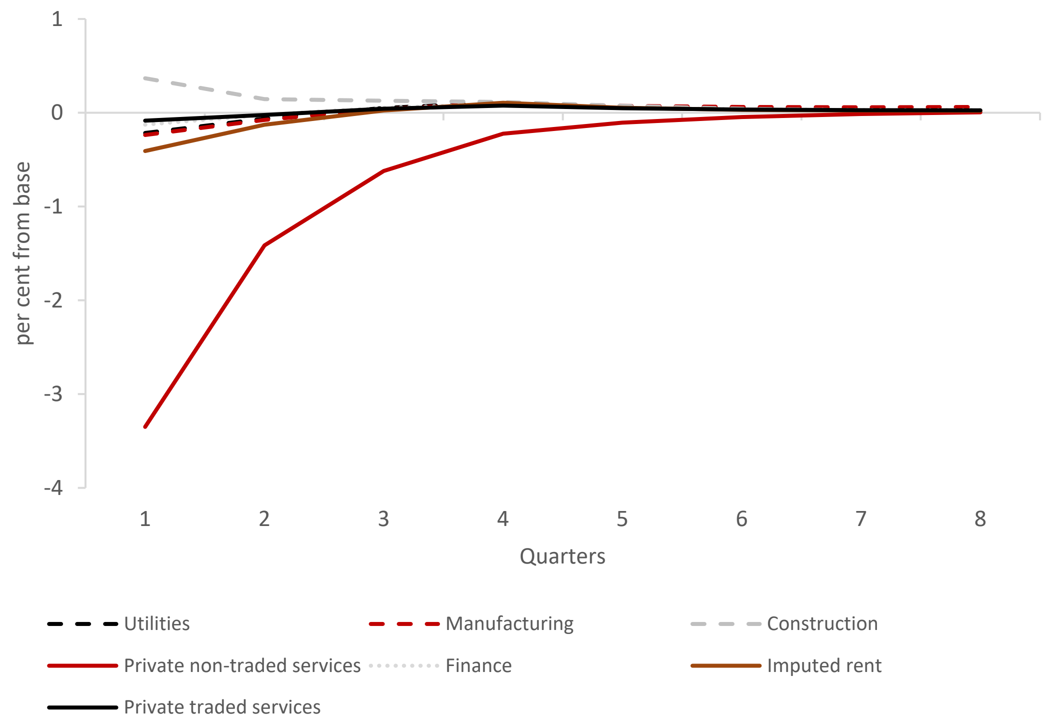
Chart 5: Household savings ratio changes to a consumption shock of -1% of GDP



Source: NiSEM simulation. 'aggregate' refers to a standard consumption shock of -1% of GDP and 'social' refers to a shock to final and intermediate demand in the private non-traded services sector equivalent to -1% of GDP.

A key relationship in the model is the supply and use table summarised in Table 4. The table shows how the demand for intermediate and final and goods and services (shown by the columns) flows across different products (shown by the rows). According to this relationship, the direct spillover effects from a reduction in PNTS products were expected to be most acute in private traded services (share of 37 per cent), manufacturing (share of 29 per cent) and construction (share of 12 per cent). But our second simulation suggests that when the indirect effects of all sectors feeding into each other are included, the sectors most affected by a 1 per cent of GDP social consumption shock were imputed rent (decline in GVA of 0.4 percent), manufacturing (-0.24 percent), agriculture and utilities (-0.22 percent), finance (-0.13 percent) and private traded services (-0.08 percent). Chart 6 shows GVA for selected sectors in the social consumption simulation.

Chart 6: GVA spillovers from a social consumption shock



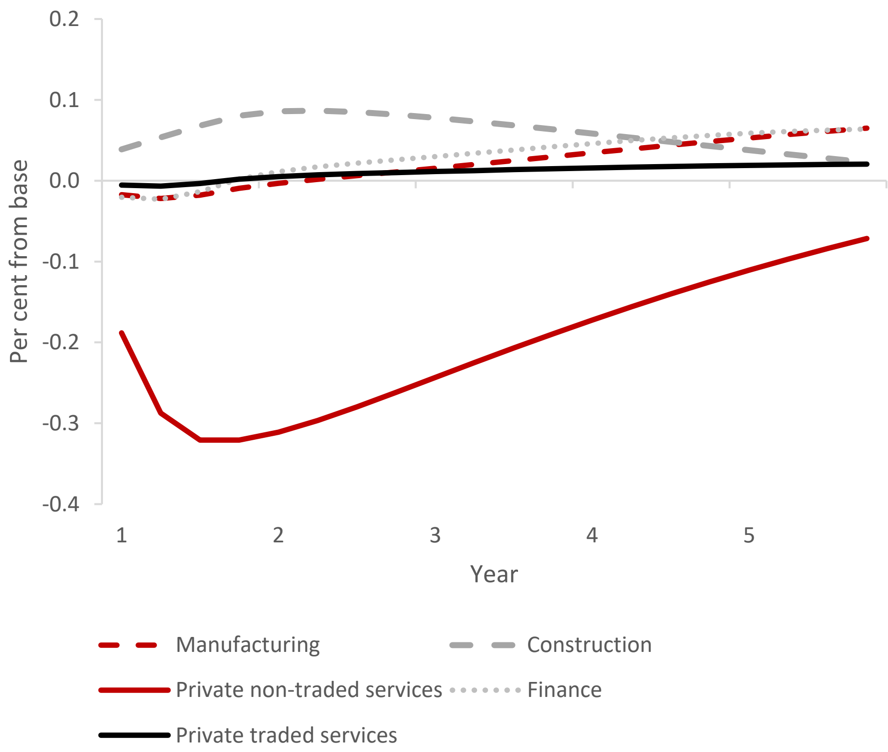
Source: NiSEM simulation of a -1% of GDP shock to final and intermediate demand in the private non-traded services sector

It is not only the initial shock that is amplified; the social consumption shock is also more persistent than the aggregate consumption shock. Employment stays persistently lower in simulation 2, which leads to lower household income. The consumption smoothing is more pronounced and the savings rate stays lower for longer (see Chart 5).

The negative demand shock leads to a reduction in wages and unit total costs because of the opening of an output gap compared to the baseline. Supportive monetary policy leads to a reduction in real interest rates that supports investment in all private sectors except in PNTS. Construction is particularly sensitive to higher investment, and this explains why the construction sector then benefits from an increase in GVA compared to baseline. GVA in sectors other than PNTS is at or close to the baseline as soon as the 4th quarter (see Chart 6).

The social consumption simulation shows interesting employment dynamics across sectors. Private non-traded services are one the biggest UK sectors by employment, accounting for 28 per cent of jobs. The negative shock to this sector in the social consumption shock scenario reduces employment by up to a third of a percent in that sector (see Chart 7), around 31,000 jobs. After initially declining, employment increases in the other sectors that benefit from a reallocation of labour, leaving total employment unchanged after 5 years. The only exception is mining and quarrying where both employment and output are by construction unaffected by the social consumption shock. The aggregate consumption shock also leads to a reallocation of labour away from PNTS, but of a smaller magnitude: employment is lower by 12,000 in PNTS in the social consumption shock after 4 years, compared to 5,000 in the aggregate consumption shock.

Chart 7: Employment spillovers from a social consumption shock



Source: NiSEM simulation of a -1% of GDP shock to final and intermediate demand in the private non-traded services sector

These simulations show how a social consumption shock induced by lockdown restrictions can spill over to the rest of the economy, and lead to a persistent reallocation of labour.

The impact of the furlough scheme on unemployment

Governments around the world set up some mitigating policies to support households and businesses during the pandemic. One of the most important policy measures in Europe – though not in the US – was a furlough scheme by which workers temporarily out of work (ie ‘on furlough’) receive income financed by the state while retaining their formal employment links with their employers. In the UK furlough scheme, the state paid up to 80 per cent of the wage of a furloughed worker, up to £2,500 per month.

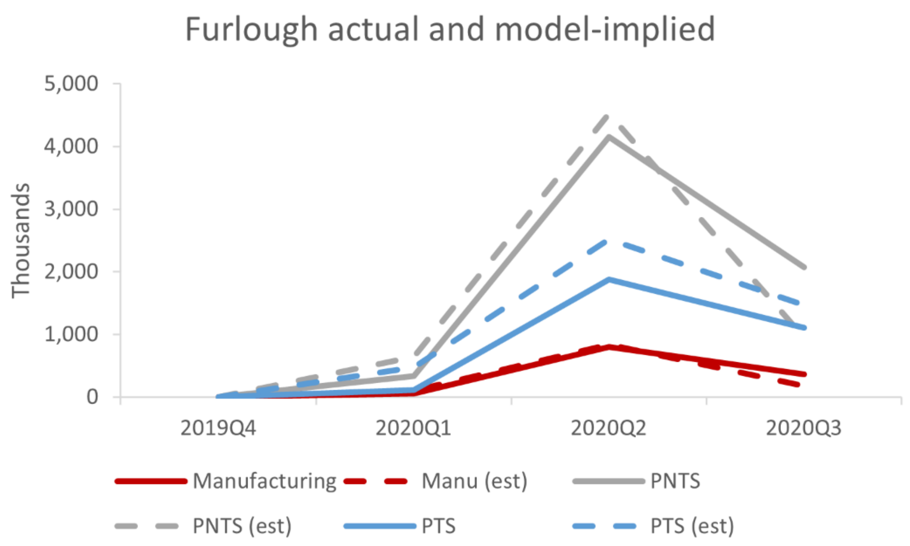
The furlough scheme limited the rise of unemployment that would have been expected from a reduction in demand during the pandemic (see for example Bennedsen et al, 2020). The UK unemployment rate reached a pandemic-peak of 5.1 per cent in the three months to December 2020, much lower than the peak of 14.8 per cent in the US in April 2020. In both countries, unemployment was below 4 per cent before the pandemic.

The furlough policy delays the adjustment of the labour market. It acts as an incentive for businesses to retain staff that they may need later on when demand recovers, thus avoiding the costs associated to sacking, hiring and training. When this policy is not in place, firms would be likely to adjust their labour force much quicker, as was experienced in the US at the beginning of the pandemic.

Because the recent experience of the furlough scheme is unique and as the UK has not experienced such large shocks in recent history we do not know how employment would have been adjusted in the absence of the scheme. As a stylised assumption to show how the model could be used to evaluate the policy, we model this policy by assuming that when the furlough scheme is in place, only 5 per cent of employment adjusts every quarter, whereas when it is not in place, 50 per cent of employment adjusts every quarter. That is, we assume that coefficient $a_{2,i}$ in equation (13) is 0.05 when the furlough scheme is in operation, roughly consistent with estimated smooth adjustment observed in large sectors such as private traded services and manufacturing as reported in Table 13. But we assume coefficient $a_{2,i}$ would be 0.5 without the furlough scheme as businesses would be forced to adjust employment quickly without support.

In each case, the level of employment required to produce observed output is derived from the production function. If this is correct we would expect the observed number of employees on furlough to be given by the difference between the actual and model-implied required level of employment during the pandemic. Chart 8 shows that our model works well for industries that made large use of the furlough scheme like PNTS, PTS and manufacturing.

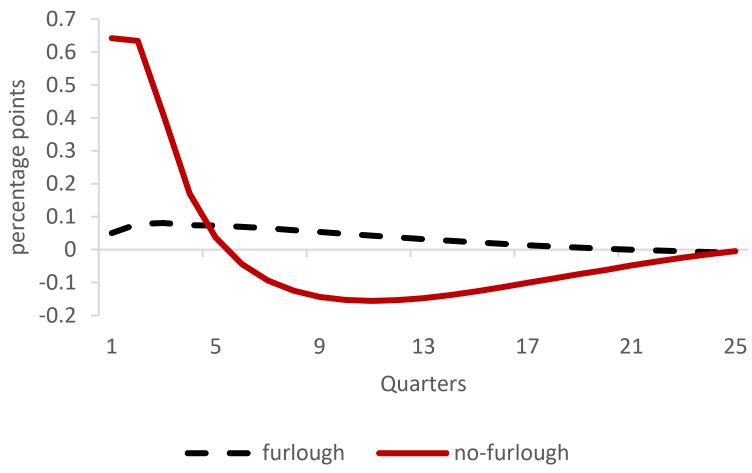
Chart 8: Actual and model-implied furloughed by sector



Social consumption shock with and without furlough

We run the social simulation described above with and without the furlough scheme. Without furlough, unemployment increases by 0.6 percentage point compared to only 0.1 with furlough (see Chart 9). In the private non-traded services sector where GVA decreases by about 3 per cent, employment decreases by 2.2 per cent (or 200k) without furlough, compared to only 0.3 per cent (or 32k) with furlough. Unemployment returns to baseline sooner in the non-furlough case because employment adjusts faster to the recovery in demand after the initial shock due to more wage adjustment. This affects relative prices and so stimulates product demand and hence employment.

Chart 9: Unemployment rise following a social consumption shock



Source: NiSEM simulation of a -1% of GDP shock to final and intermediate demand in the private non-traded services sector

But there are still some long-term costs related to a surge in unemployment in the non-furlough case. Higher unemployment puts downward pressure on wages, which leads to lower inflation. Investment is lower in every sector because of higher long real rates. The Bank of England is limited in its ability to reduce Bank rates because we don't allow for a negative Bank Rate.

The furlough scheme was clearly effective in cushioning the worst effects of the pandemic, but this came at a high cost to the Treasury. The furlough scheme cost £61.3 billion in the fiscal year 2020-21, or about 2.9 per cent of GDP. Dividing by the average number of employees covered by the furlough scheme, we estimate that the furlough scheme cost £2,783 per employee per quarter. We use this estimate to establish a cost associated to the furlough scheme in the social consumption simulation.

Because the social consumption shock is concentrated in the PNTS sector – and other sectors are only impacted by spillover effects – nearly all of the furloughed jobs are in this sector. Table 8 gives the estimates from the NiSEM simulation of the number of furloughed workers and the associated cost to the Treasury. In the first quarter, around 370 thousand employees are put on furlough, of which 338 thousand come from the PNTS sector (3.5 per cent of the employees in the sector). The ratio of furloughed workers is of the same magnitude as the percentage fall in gross value added in PNTS (-3.4 per cent). As the social consumption shock dissipates and the economy adjusts, the number furloughed declines to zero in the fourth quarter. The total cost of the furlough scheme in this simulation is estimated to be £1.7 billion. This is much lower than the £61.3 billion cost for fiscal year 2020-21 because the size of the shock in the simulation (1% of GDP) is much smaller than the pandemic shock (around 25% of GDP in April-May 2020).

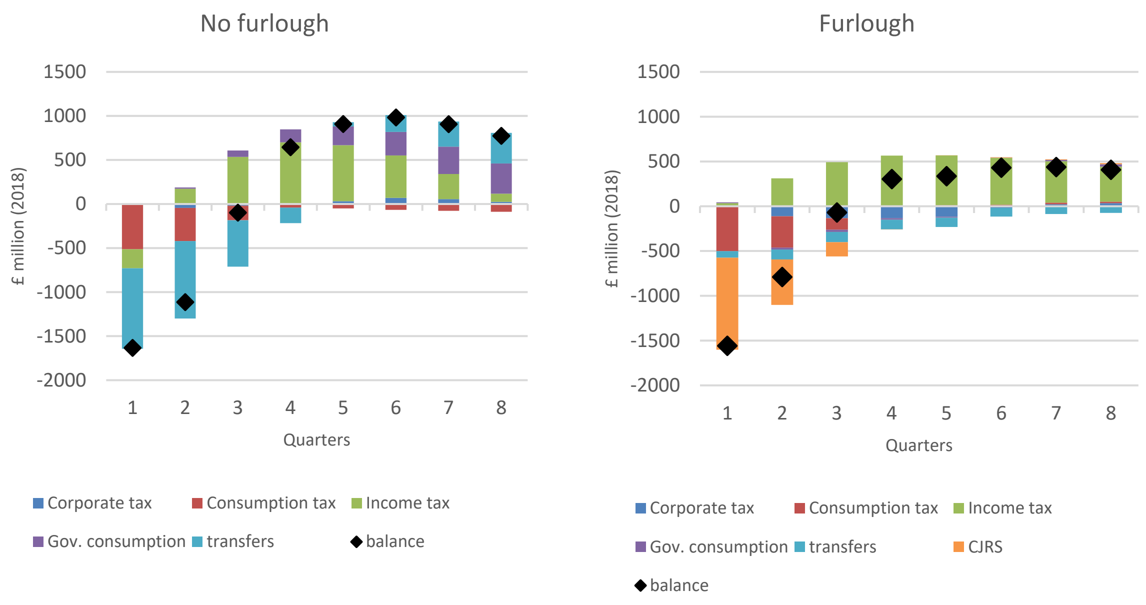
Table 8: The cost of furlough to a social consumption shock of 1% of GDP

Quarter	Number furloughed (thousands)	Cumulative cost (£ million)
1	369.9	1,030
2	180.4	1,532
3	55.8	1,687
4	0.0	1,687

Source: NiSEM simulation

One could ask whether this is money well-spent or whether similar policy objectives could have been achieved by other means. For this purpose, we compare the net cost of the furlough policy to the Treasury, considering indirect costs like the impact on tax revenues and unemployment benefits. Chart 10 decomposes the change in the general government budget balance into its main components for the social consumption shock with and without furlough. The simulations show that the increase in the budget deficit in the furlough case is not larger than in the non-furlough case: £1.6 billion in the first quarter, declining to close to 0 in the third quarter for both simulations. In the non-furlough case, social transfers are higher and income tax receipts are lower because of the rise in unemployment. In the furlough case, the furlough scheme (called CJRS in Chart 10) is the main contributor of the increase in the deficit. These simulations show that under the assumptions made the furlough scheme manages to keep the link between employers and employees at no additional cost to the Treasury when the indirect costs of the avoiding a rise in unemployment are factored in.

Chart 10: Decomposition of the change in budget balance to a 1% of GDP social consumption shock, with or without furlough policy.



Source: NiSEM. CJRS is the direct cost of the furlough scheme. The model induces an endogenous increase in income tax to reduce the budget deficit towards its target

There are several considerations that would need to be added to a full evaluation. One is that the take-up of the furlough scheme may be higher than implied by our model because firms may abuse the scheme.[6] Chart 8 shows that the take-up of the CJRS seems to have been higher in the second quarter of 2021 than implied by our model). Abuse of the furlough scheme increases the cost to the Treasury, without intended economic benefits.

Another consideration is the distribution of income of the people who are forced into inactivity (either via furlough or unemployment) because of the social consumption shock. Jobs in the private non-traded sector like hospitality and retail where the shock is concentrated tend to be lower paid. For such workers, becoming unemployed and claiming Universal Credit and other welfare transfers would not reduce their income as much as for higher paid workers. So if the economic shock affects also sectors with higher wages, then the cost of the furlough scheme would be much higher than the alternative policy because the cap on furlough payments (£2,500 per employee per month) is much higher than the caps of social transfers (Job Seeker Allowance is capped at £323.7 per month for people aged 25 and over).

[6] See reports of fraud and abuse https://www.ftadviser.com/companies/2021/07/13/how-hmrc-is-stepping-up-its-furlough-fraud-investigations/

4. Conclusion

This paper sets out a modelling framework to assess how the UK economy has been affected by Covid-19 and policies to mitigate its economic effects.

A key element of the framework we propose is a mechanism that explains how narrow shocks that affect only certain parts of the economy can spill over to the rest of the economy with severe consequences if they are not mitigated by countervailing policy measures. In our framework this amplification of shocks comes about because of input-output linkages between different economic sectors and limited income insurance that ensure that narrow shocks are transmitted widely, particularly when monetary policy is constrained by zero lower bound.

By way of a simulation exercise we show how the economy reacts to a social consumption shock and compare the response when a furlough scheme is in operation and when it is not. On the basis of some particular stylised assumptions we show that the furlough scheme manages to keep the link between employers and employees at no additional cost to the Treasury when the indirect costs of the avoiding a rise in unemployment are factored in.

In due course it will be important to evaluate the economic policies brought in by the government over the course of the pandemic. We believe that the model can be used for this purpose. The model can also be an important tool for evaluating long-term growth policies, especially those that are focused on particular sectors.

REFERENCES

Bennedsen, M. Larsen, B. Schmutte, I. Scur, D. (2020), ‘Preserving job matches during the COVID-19 pandemic: firm-level evidence on the role of government aid’.

Blanchard, O. and Illing, G. (2021), ’The Covid-19 Pandemic’, section 9.6 of *Macroeconoomics*, January 2021.

Bond, S. and Meghir, C. (1994), ‘Dynamic Investment Models and the Firm's Financial Policy’, *Review of Economic Studies*, 1994, vol. 61, issue 2, 197-222

Guerrieri, V., Lorenzoni, G., Straub, L. and Werning, I. (2020), ‘Macroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages?’ National Bureau of Economic Research. (No. w26918).

Hantzsche, A., Lopresto, M. and Young, G. (2018), ‘Using NiGEM in uncertain times: introduction and overview of NiGEM’, *National Institute Economic Review* No. 244 May 2018.

Jones, C. (2021), ‘COVID-19 and the Macroeconomy’, Supplement to Macroeconomics, 5th edition, 27 February 2021.

Lenoël C. and Young G. (2020), ‘Prospects for the UK Economy’, *National Institute Economic Review* No. 252 May 2020.

Nickell, S. (1985), ‘Error correction, partial adjustment and all that: an expository note’, *Oxford Bulletin of Economics and Statistics*, 47(2), 119-129.

APPENDIX A: SECTORAL OUTPUT DEFINITIONS

Components of output GVA chained volume index (reference year = 2018)

NiSEM sector	ONS components	Weight per 1000 (2018)	SIC2007 code	NiSEM code
Mining and quarrying	Mining and quarrying	11.2	B	B
Manufacturing	Manufacturing	100.6	C	C
Construction	Construction	64.5	F	F
Private non-traded services	Wholesale and retail trade; repair of motor vehicles and motorcycles	104.5	G	I
	Accommodation and food service activities	29.4	I	
	Real estate activities excluding imputed rent	40.1	L - 68.2IMP	
	Other services	36.9	R, S and T	
Private traded services	Transportation and storage	40.4	H	P
	Information and communication	65.7	J	
	Professional and support	129.6	M and N	
Financial services	Finance and insurance	67.7	K	K
Imputed rent	Imputed rent	94.9	68.2IMP	L
Public sector	Total government, health and education	181.2	O, P and Q	G
Rest of Industry	Agriculture, forestry and fishing	6.4	A	A

	Electricity, gas, steam and air conditioning supply	14.2	D	
	Water supply; sewerage, waste management and remediation activities	12.7	E	
Total GVA		1000		

APPENDIX B: MODELLING RESIDUAL CATEGORIES.

In practice, a number of short cuts are taken to simplify the model. In particular, exports and imports for each sector are simplified by either replacing the trade of each sector with quarterly series for trade in similar products or by ignoring the imports and exports of that sector altogether. Residual trade categories are then needed to ensure adding up.

For example, exports and imports of the mining and quarrying sector are measured by exports and imports of crude oil. This means that for each sector the residual category captures the effects of taxes less subsidies on products, reallocation of distributors' trading margins and the difference between gross output of sectors and products that sum to zero, plus the difference between the actual and modelled trade surplus of the sector.

This means that for all national accounts identities to be satisfied in the model, the sum of all residual categories should be equal to taxes less subsidies on products + RXG + RXS – RMG – RMS. Where RXG and RMG are the residual categories in exports and imports of goods respectively, and RXS and RMS are the residual categories in exports and imports of services respectively.

This is achieved by using the following equations for the R_i variables in the model:

$$R_A = 0.02 \quad Y_A^C - 0.04\, RXG - 0.02\, RMG$$

$$R_B = 0.0 \quad Y_B^C - 0.44\, RXG + 0.04\, RMG$$

$$R_C = 0.37 \; Y_C^C - 1.24\, RXG + 0.30\, RXS - 0.95\, RMG - 0.35\, RMS$$

$$R_F = 0.125\, Y_F^C + 0.09\, RXS - 0.05\, RMS$$

$$R_G = -0.015 Y_G^C + 0.15\, RXS - 0.05\, RMS$$

$$R_I = 0.12 \quad Y_I^C - 0.29\, Y_C^C + 0.12\, RXG + 0.46\, RXS - 0.05\, RMG + 0.47\, RMS$$

$$R_K = -0.065\, Y_K^C$$

$$R_L = 0.0 \qquad Y_L^C - 0.06\, RMS$$

$$R_P = 0.108 \quad Y_P^C + 0.12\, RXG - 0.04\, RMG$$

Summing over these equations shows that

$$\sum_i R_i = 0.02\ Y_A^C + 0.08\ \ Y_C^C + 0.125\ \ Y_F^C - \ 0.015\, Y_G^C + 0.12\ \ Y_I^C - 0.065\ \ Y_K^C + 0.108\ \ Y_P^C + RXG + RXS - RMG - RMS$$

The first terms in Y_i^C implicitly provide an equation for aggregate taxes less subsidies on products. The coefficients on the residual trade categories in the individual R_i equations are chosen so that they add up correctly to the total residual trade categories.