Europe Economics

Measuring Whole Industry Total Factor Productivity (TFP) of the Railway in Great Britain

Final report

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Contents

Executive Summary

This study has been commissioned by the Office of Rail and Road (ORR) to develop a set of total factor productivity (TFP) measures for the rail industry in Great Britain. The study focuses on developing a robust analytical framework for measuring, interpreting, and reporting on TFP trends across the whole industry.

The study measures TFP for the rail industry as a whole.[1] It also develops TFP measures for three segments of the rail industry:

- Network Rail;
- train operating companies (TOCs); and
- freight operating companies (FOCs).

TFP growth captures the change in output that is not explained by changes in inputs. Two output concepts can be used for TFP estimation. **Gross Output (GO)** treats intermediates as explicit inputs and therefore requires measures of labour, capital and intermediates for TFP estimation. **Gross Value Added (GVA)** nets out intermediates in the definition of output, such that only labour and capital appear as inputs in TFP calculations. This study develops both GO and GVA TFP measures for the rail industry and the three segments.

Methodology and data

The study adopts a typical growth-accounting TFP framework, comparing the growth of output with the cost-weighted growth of inputs. This requires measuring outputs and inputs, and the study draws on several data sources, including operators' statutory accounts, Network Rail regulatory reporting, ONS data, Department for Transport accounts, and ORR usage and finance statistics.

For GO-based TFP, output is measured using physical volumes, such as passenger-km, freight-tonne km and train km. We construct quality-adjusted measures of GO that incorporate changes in punctuality and, in the case of passenger services, rolling stock quality.

For GVA-based TFP, output is measured in financial terms. For TOCs and FOCs, GVA is derived from ONS Annual Business Survey (ABS) data and National Accounts data. For Network Rail, GVA is constructed directly from company data as the sum of staff costs and depreciation.

Inputs consist of labour, capital and intermediate consumption (for GO-based TFP), and labour and capital only (for GVA-based TFP).

- Labour inputs are based on full-time-equivalent (FTE) data.
- Intermediate inputs are derived from operating costs net of staff costs and capital depreciation.
- Capital inputs are constructed as flows of capital services using the Perpetual Inventory Method and a user-cost approach. For TOCs and FOCs, some capital services (in particular, rolling stock) are proxied using lease payments.

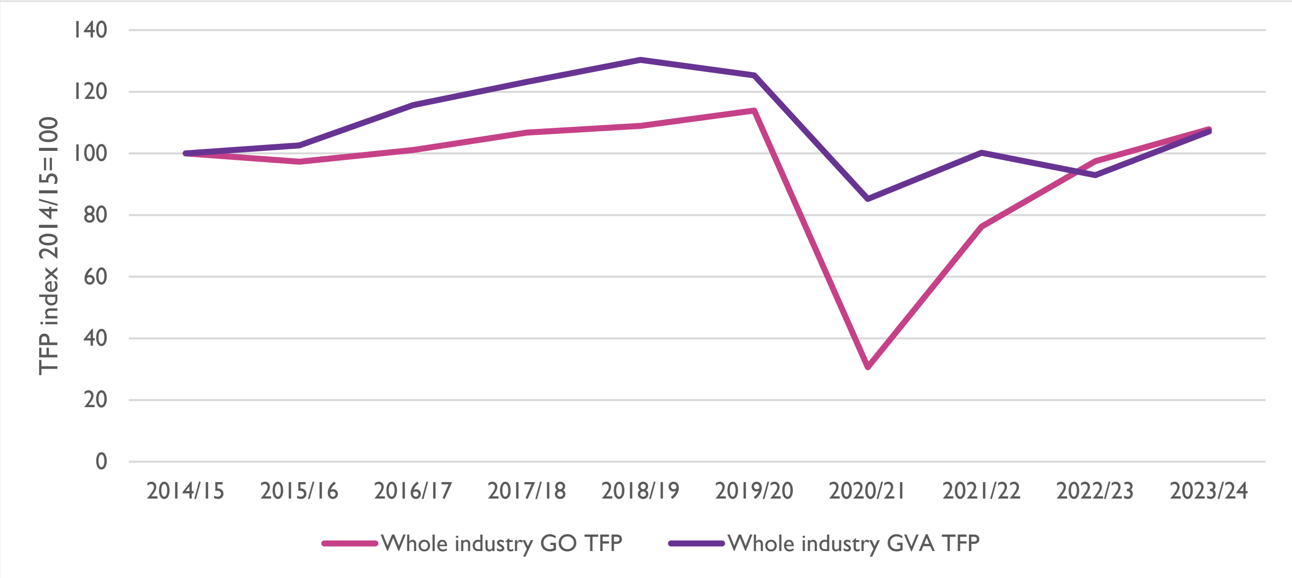
For each year from 2014/15 to 2023/24 we construct consistent series for output and for the main inputs for Network Rail, TOCs and FOCs. Monetary values are converted into "volumes" using appropriate price indices, and we calculate the share of total cost accounted for by each input. TFP growth in a given year is calculated as the residual change in output not explained by a change in inputs.

[1] Excluding HS1 and rolling stock companies

Results

Our results find that whole industry TFP increases from 2014/15 to 2023/24. It rises steadily from 2014/15 to 2019/20, as can be seen in Figure 0.1, below. During the first year of the Covid-19 pandemic, there was sharp drop in rail sector output (measured as the weighted combination of passenger km and freight tonne km) that result in a sharp drop in measured GO TFP for the industry. Since then, TFP growth has rebounded and in 2023/24 whole industry TFP is above its 2014/15 level, though it is slightly below its pre-pandemic peak in our preferred quality-adjusted specification.

Figure 0.1: Whole industry quality-adjusted GO TFP index, 2014/15=100

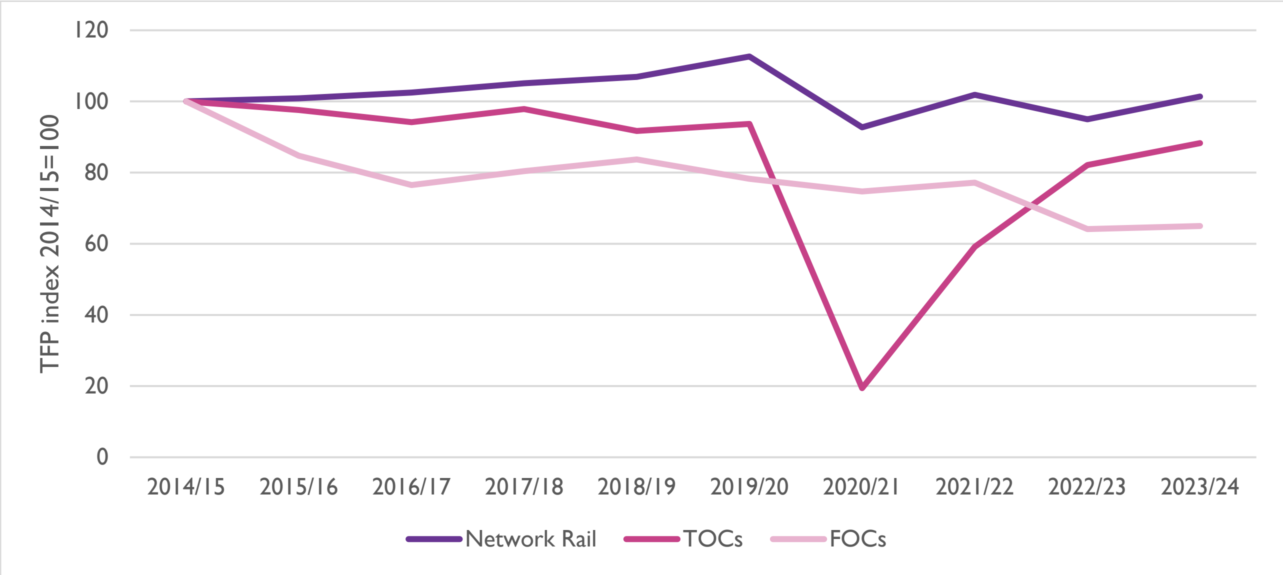


Source: Europe Economics calculations

On a GVA basis, whole-industry TFP also rises strongly before the pandemic, experiences a sizeable but less dramatic fall in 2020/21 than under the GO measure, and then partially recovers. Similar to the GO measure, by 2023/24 the whole-industry GVA TFP index is above its 2014/15 level but remains slightly below its pre-pandemic peak. The differences between the two indices reflects the fact that GVA is derived from financial data (revenues and costs) and is influenced by pricing and accounting effects as well as by physical volumes.

Figure 0.2 compares the quality-adjusted GO TFP indices for Network Rail, TOCs and FOCs. It highlights a divergence between infrastructure and operators. Network Rail's TFP rises steadily through the pre-pandemic years then experiences a setback in 2020/21 and a smaller dip in 2022/23, ending the period with the TFP index about 1.5 points above its 2014/15 level. By contrast, the TOC and FOC indices show that operator productivity has fallen over the period. TOC TFP drifts down before the pandemic, then falls extremely sharply in 2020/21 as passenger-km collapse while inputs adjust only slowly, and despite a strong rebound remains below its 2014/15 level by 2023/24. FOC TFP is less volatile but follows a declining path over most of the period, with only a modest Covid-related dip and limited subsequent recovery.

Figure 0.2: Quality-adjusted GO TFP index by segment, 2014/15=100

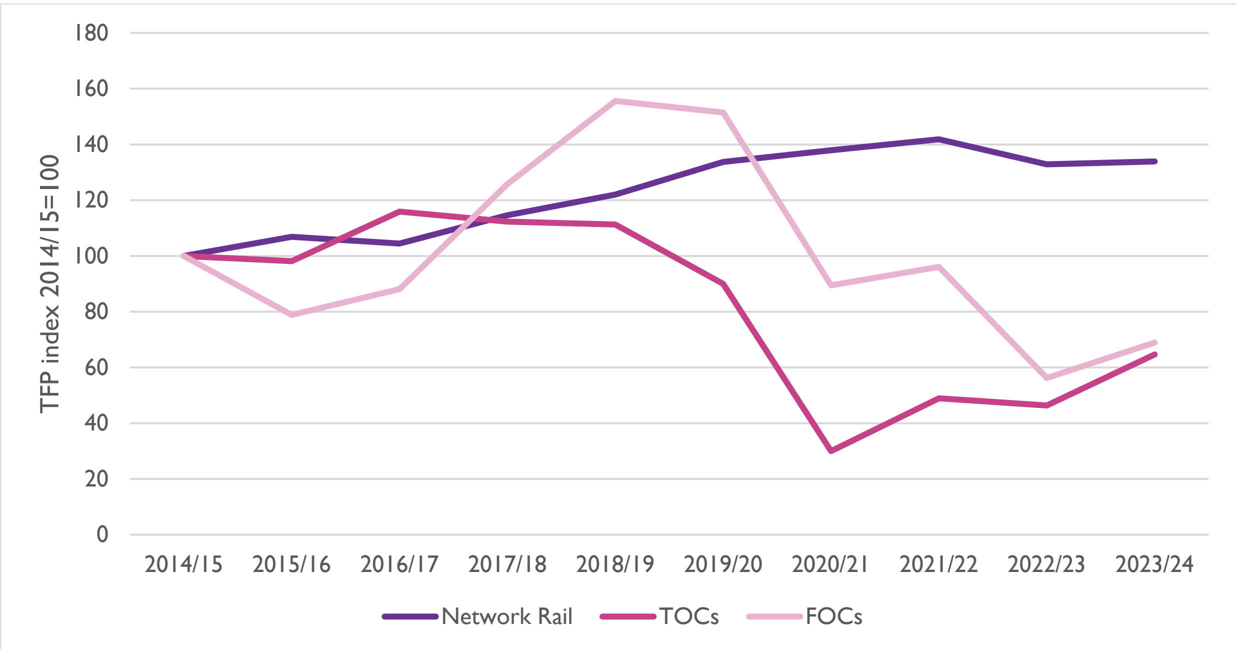


Source: Europe Economics calculations

Taken together, the three series indicate that the overall increase in whole-industry TFP is driven largely by developments on the infrastructure side, while productivity in passenger and freight operations has, on balance, deteriorated.

On a GVA basis, Network Rail's TFP rises more strongly and smoothly, including during the pandemic. GVA-based TFP for TOCs and FOCs is substantially more volatile than the corresponding GO measures. For TOCs there are periods of rapid GVA-TFP growth and subsequent decline; for FOCs, GVA-TFP rises very sharply in some pre-pandemic years and then falls back by a similar amount in 2020/21 and 2022/23. Overall, the message is similar to the GO TFP results – Network Rail's measured productivity has increased over the period, while operator productivity has fallen.

Figure 0.3 GVA TFP index by segment, 2014/15=100



Source: Europe Economics calculations

We have carried out numerous sensitivity tests on our TFP estimates, including testing different output measures, different price indices, different depreciation assumptions and different quality adjustments. The sensitivity tests show that two modelling choices have particularly significant impacts on the level and slope of the TFP indices:

- The valuation of the railway network used to anchor Network Rail capital inputs. Our preferred approach uses DfT's valuation of the railway network, which is based on the depreciated replacement cost (DRC) of the network. If the regulatory asset base (RAB) valuation is used instead, which is multiple times smaller, Network Rail's capital stock yields substantially faster growth in capital services and, consequently, a gradual decline in GO TFP over the period, in contrast to the positive trend in our core results. We consider the DRC valuations, which are designed to capture the replacement cost of the physical assets, as the more appropriate economic measure of capital input. Specifically, our preferred approach uses the 2015/16 valuation DfT reported, excluding the land element of the network. More recent DfT valuations are available but require far more modelled back-casting to get to an initial stock estimate for 2014/15.
- The definition of GO for passenger operators impacts the size of the drop in TFP in the pandemic. Defining output in terms of train-km produces higher TFP levels and shallower Covid swings than passenger-km, because train capacity was maintained even when passenger demand fell.

Discussion

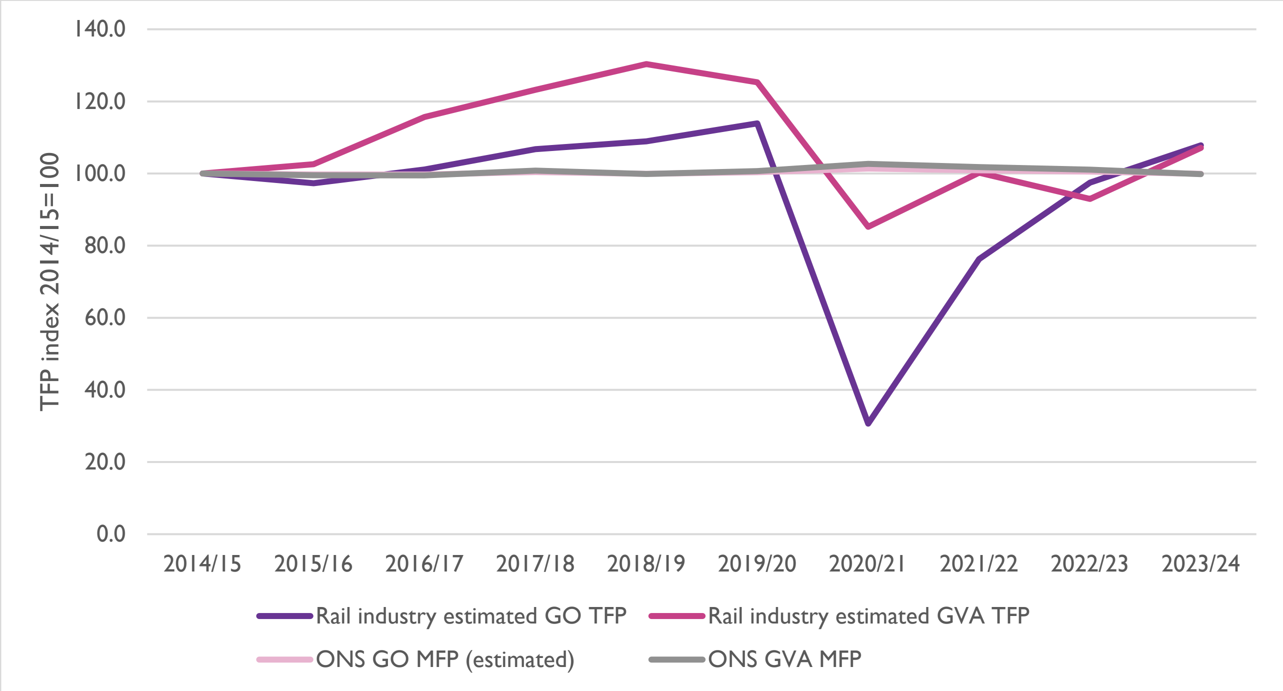
The results suggest two main messages about productivity developments in the rail industry over 2014/15–2023/24.

First, on the infrastructure side, Network Rail's positive GO-based TFP trend prior to 2020/21 appears to be driven largely by a gradual reduction in measured capital services, while train-km are broadly maintained or increased. In other words, the value of rail infrastructure assets is falling (in real terms) while output is being maintained, implying Network Rail is doing more with less (i.e. being more productive). It is unclear whether such gains can be sustained in the long run without potential implications for asset condition, reliability and the required scale of renewals expenditure.

Second, on the operator side, productivity performance has been more challenging. TOC GO-based TFP shows a slight downward trend before the pandemic, followed by extreme swings during the Covid-19 shock and recovery (reflecting changes in capacity utilisation as trains ran empty), and remains below its 2014/15 level at the end of the period. FOC TFP is less volatile but exhibits a gradual decline over time. These patterns indicate that, while the system has restored much of its pre-pandemic output, operators have not, on balance, achieved sustained improvements in the efficiency with which labour, capital and intermediate inputs are used to deliver services.

The estimated productivity growth series for the rail industry are far more volatile than equivalent measures for the UK economy produced by ONS. The figure below shows that ONS estimates of UK economy MFP growth have been flat over the past decade, either in GVA-terms or when we convert the published figures to GO-based MFP. Contrastingly, rail productivity growth has experienced substantial increases and reductions over the period, rising quicker than the wider economy prior to Covid-19, then dropping sharply and partially rebounding. We advise caution in comparing our estimates for the rail sector with wider estimates for the overall economy given measurement and conceptual differences, but the high-level message is that measured rail productivity was more cyclical and more heavily affected by the Covid shock (particularly in the case of the GO-based measure), consistent with the sector having limited short-run flexibility in relation to labour and capital inputs.

Figure 0.4: Comparison of rail industry TFP indices with ONS MFP for the UK economy



Source: Europe Economics calculations

Looking ahead, we consider that there is value in maintaining and periodically updating these TFP series, improving the underlying data where possible (for example, on GVA for Network Rail and on the split between rolling-stock leases and maintenance), and interpreting TFP evidence alongside other quantitative and qualitative information on costs, outputs, asset condition and service performance. Used in this way, TFP can contribute to a richer understanding of how the rail industry's productivity is evolving and where future regulatory attention may be most usefully focused.

1 Introduction

1.1 Scope of our work

This study has been commissioned by the Office of Rail and Road (ORR) to develop a set of total factor productivity (TFP) measures for the rail industry in Great Britain. The study focuses on developing a robust analytical framework for measuring, interpreting, and reporting on TFP trends across the whole industry.

The study covers three segments of the rail industry:

- Network Rail
- Train operating companies (TOCs)
- Freight operating companies (FOCs)

We model TFP growth for the three segments individually, and for the whole industry, using a standard growth-accounting approach, producing TFP time-series estimates from 2014/15 to 2023/24. The whole industry TFP estimates do not cover rolling stock leasing companies or HS1.

The analysis is based on publicly available and ORR-provided sources, including Network Rail regulatory and statutory accounts, train and freight operator statutory accounts, and official data published by ORR and the ONS.

1.2 The concept of TFP

TFP is a measure of how efficiently an organisation, sector, or economy converts inputs into outputs. As the name suggests, TFP takes account of all inputs (factors of production) used in the production process. This contrasts with partial productivity metrics, such as labour productivity, which focus on the relationship between a single input and output.

TFP growth captures the change in output that is not explained by changes in inputs. It is calculated as the residual of the growth in outputs less the weighted average growth in inputs. In the context of the rail industry, these inputs typically include labour, capital (measured as the flow of productive services from assets such as track, signalling, rolling stock, and depots), and intermediates (such as materials, energy, and purchased services). The residual change in output reflects gains in technical efficiency (such as through better management practices), disembodied technological change (improvements in production methods not tied to new capital), economies of scale, or other factors that enable more output to be produced from the same quantity of inputs.

Two output concepts can be used for TFP estimation. **Gross Output (GO)** treats intermediates as explicit inputs and therefore requires measures of labour, capital and intermediates for TFP estimation. **Gross Value Added (GVA)** nets out intermediates in the definition of output, such that only labour and capital appear as inputs in TFP calculations. Both perspectives are informative in rail: GO TFP reflects end-to-end production (including outsourced activity), while GVA TFP focuses on the efficiency of labour and capital in generating value added.

TFP is a relevant measure for the rail industry that can complement existing measures of rail productivity reported by ORR. Rail industry output is delivered through an integrated "track-and-train" system with a high fixed-cost base and multiple ways of combining inputs. The input mix can change over time (e.g. changes in the degree of outsourcing, capital-labour substitution, trade-offs between maintenance and renewals) but the underlying service delivered to passengers and freight customers remains comparable. Partial productivity measures can be distorted by input substitution. Secondly, TFP provides a common measure of productivity growth across Network Rail, passenger operators and freight operators, and the industry as a whole, improving comparability across segments and over time. Finally, a TFP framework separates price from quantity by deflating inputs and output which can avoid distortions when input prices move sharply.

1.3 Structure of report

The rest of the report is structured as follows:

- Chapter 2 sets out the methodology and data used to calculate outputs, inputs and TFP;
- Chapter 3 sets out the TFP estimates by segment and for the whole industry;
- Chapter 4 discusses the key findings from the TFP results and our advice on future use of TFP measures for the rail industry;
- Appendix 1 provides a brief literature review on TFP calculation methods;
- Appendix 2 presents the full set of results from sensitivity tests; and
- Appendix 3 contains descriptive data for operator capital inputs.

2 Methodology and data

2.1 Overall approach to calculating TFP

When calculating TFP, our objective is to measure how much of the change in rail output comes from using more (or less) in inputs, and how much comes from doing things more (or less) efficiently. We do this using a growth-accounting framework. For each year of our estimating period (2014/15 – 2023/24), we assemble consistent series for output and the main inputs (labour capital and, for GO TFP, intermediates). Monetary values are converted to "volumes" using appropriate price indices, and we calculate the cost share of each input (e.g. what percentage of total costs were incurred for labour, capital and intermediates). We can then split the change in output from one year to another into two parts. The first part is the part explained by a change in the volume of inputs (weighted by the cost shares) and the second part is a residual, the change in output not explained by a change in inputs. That residual is total factor productivity.

Formally, for a given period *t*, the growth rate in **GO** TFP ($\Delta lnTFP_t$) can be expressed as:

$$\Delta lnTFP_t = \Delta lnY_t - [\alpha_L \Delta lnL_t + \alpha_K \Delta lnK_t + \alpha_M \Delta lnM_t]$$

where:

- Y_t = output volume in period t (GO, possibly quality-adjusted)
- L_t = labour input volume (e.g. FTEs or hours worked)
- K_t = capital services volume
- M_t = intermediate inputs volume
- $\alpha_L, \alpha_K, \alpha_M$ = cost shares of labour, capital, and intermediates in total cost, typically calculated as two-period averages to smooth volatility
- Δln = the natural logarithm of the ratio between the value in period *t* and *t minus1* (approximating the percentage change)

This approach requires all input and output measures to be in *volume* terms, with nominal values deflated using appropriate indices that reflect changes in the price of the relevant output or input. It also requires cost shares to be measured on a consistent basis across time and entities, so that the contribution of each input to output growth is correctly weighted.

Similarly, for a given period *t*, the growth rate in **GVA** TFP ($\Delta lnTFP_t$) can be expressed as:

$$\Delta lnTFP_t = \Delta lnY_t - [\alpha_L \Delta lnL_t + \alpha_K \Delta lnK_t]$$

Where

- Y_t = output volume in period t (GVA, possibly quality-adjusted)

and other variables are defined in the same way as above.

As can be seen in the formulae, the key difference when estimating GVA TFP is that the output measure is in GVA terms, rather than in GO terms, and only the growth in labour and capital inputs are subtracted (with intermediates not appearing in the equation, since they have already been subtracted when calculating GVA output).

Mathematically, GVA TFP will be higher than (or equal to) GO TFP when both are measured in financial terms in a consistent way. This may not always hold, however, when the measure of GO is a physical quantity rather than a financial measure.

Our approach of weighting input growth using cost shares is a more robust approach than the alternative TFP approach that uses revenue shares to weight inputs. As explained by de Loecker and Syverson (2021), using revenue shares implicitly assumes that there are constant returns to scale and perfect competition, so that cost shares and revenue shares coincide because marginal cost must equal the price a producer receives.[2] By using cost shares, we avoid the need to make these strong (and in the case of the rail sector, unrealistic) assumptions.

2.2 Outputs

In this section we explain how we estimated output for each segment of the industry and for the industry as a whole. The approach varies for GVA and GO-based output measures, so we describe the data and construction process for each separately.

2.2.1 GVA data

We use four GVA series: total rail industry, passenger train operators (TOCs), freight operating companies (FOCs), and Network Rail (NR). For the financial years 2014-15 to 2022-23, we draw upon rail GVA figures estimated by ORR for its 2025 productivity report. To complete the final year in our time series, we undertake our own calculations to derive the GVA estimate for the missing financial year 2023-24, replicating the methodology applied by the ORR.

Operator GVA estimates are based on the approximate GVA at basic prices (aGVA) for the "land transport and transport via pipelines" sector published by ONS. These figures are converted from calendar years to financial years using GDP-weighted quarterly adjustments. ONS aGVA data for passenger rail transport, interurban (representing TOCs) and freight rail transport (representing FOCs) from the same dataset are used to estimate the proportion of total transport sector GVA attributable to TOCs and FOCs. These proportions are applied to GVA data for the land transport sector from ONS to calculate GVA values for TOCs and FOCs.

Annual GVA for Network Rail is calculated as the sum of total employee costs (including wages, salaries, social security, and pension costs) and depreciation reported in its annual accounts. We apply the same approach to estimate Network Rail GVA for 2023/24.

The GVA components for TOCs, FOCs, and NR are aggregated to obtain the total GVA for the rail industry.

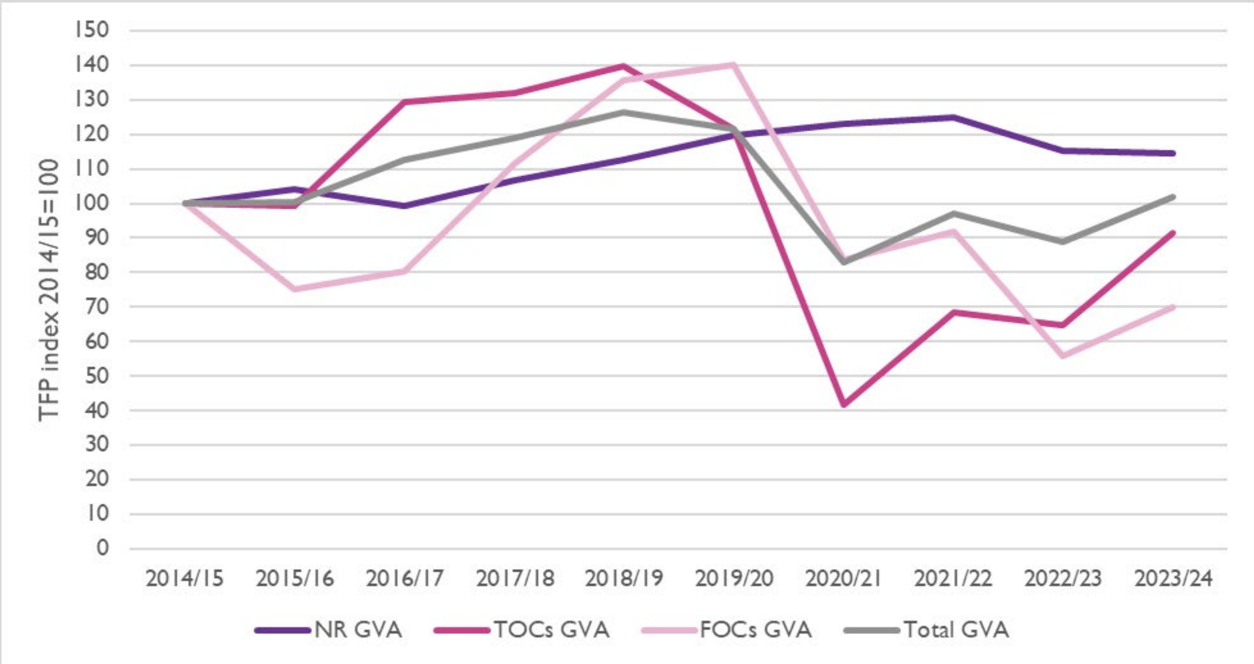
The table below presents the GVA values for all segments and the industry as a whole and annual percentage changes. The subsequent figure illustrates trends in GVA over our estimation period.

2 De Loecker, J., & Syverson, C. (2021). An industrial organization perspective on productivity. In *Handbook of industrial organization* (Vol. 4, No. 1, pp. 141-223). Elsevier. [online]

Table 2.1: GVA data (£ millions in 23/24 prices, and annual percentage change)

Year	NR GVA	Annual change (%)	TOCs GVA	Annual change (%)	FOCs GVA	Annual change (%)	Total GVA	Annual change (%)
2013/14	4,677		4,810		540		10,027	
2014/15	4,811	2.9	4,657	-3.2	441	-18.2	9,909	-1.2
2015/16	5,009	4.1	4,617	-0.8	331	-24.9	9,958	0.5
2016/17	4,784	-4.5	6,026	30.5	355	7.0	11,165	12.1
2017/18	5,137	7.4	6,141	1.9	493	38.9	11,771	5.4
2018/19	5,412	5.4	6,516	6.1	599	21.4	12,526	6.4
2019/20	5,763	6.5	5,664	-13.1	618	3.3	12,045	-3.8
2020/21	5,923	2.8	1,935	-65.8	369	-40.3	8,226	-31.7
2021/22	6,018	1.6	3,190	64.9	406	10.0	9,614	16.9
2022/23	5,536	-8.0	3,010	-5.7	247	-39.1	8,793	-8.5
2023/24	5,516	-0.4	4,264	41.7	309	25.2	10,090	14.8

Figure 2.1: GVA Index by segment (2014-15 = 100)



Source: Europe Economics calculations

As shown in Figure 2.1, operator GVA is more volatile than Network Rail GVA. TOC GVA increases sharply in 2016/17 (over 30 per cent), and FOC GVA increases sharply in 2017/18 (over 40 per cent). Both fall significantly during the pandemic. Network Rail GVA is much more stable over time.

2.2.2 GO data

For GO we use physical volumes rather than monetary measures. Reliable, consistent series exist for the key rail activity metrics, which allows us to strip out price effects and to align the output concept with what each segment actually produces.

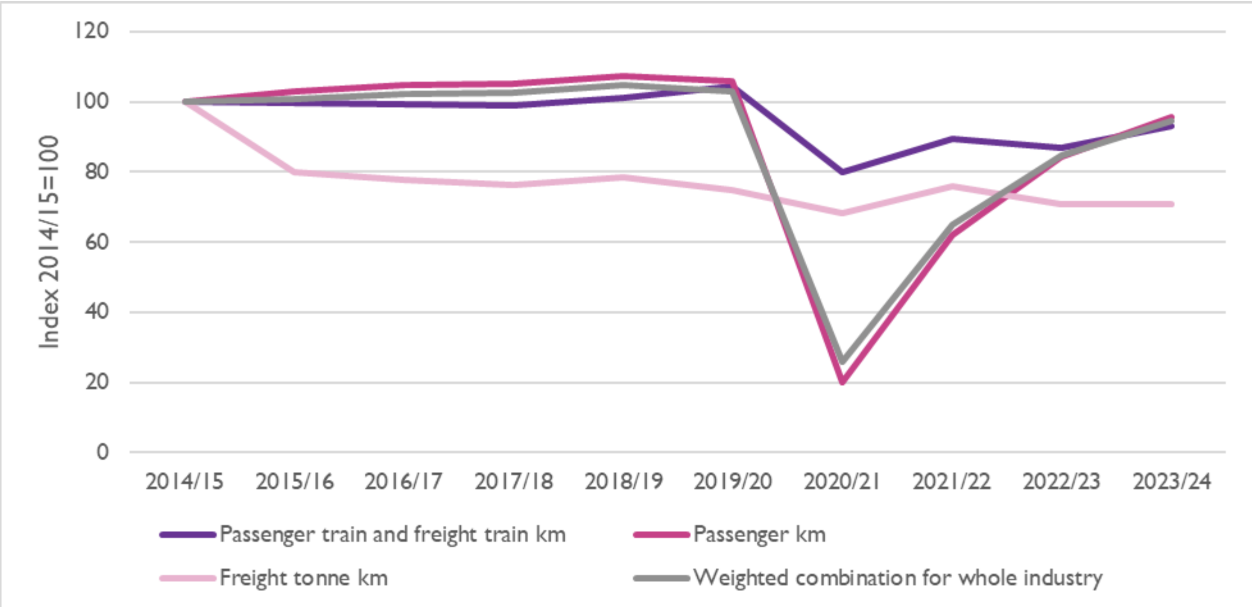
The physical volumes used in our core GO TFP measures and sensitivity tests for each segment are set out below.

Table 2.2: GO measures

	Core measure for GO	Alternative measures tested
Network Rail	Passenger train km + freight train km	Total train kilometres Renewals effective volumes
TOCs	Passenger km	Passenger train km Passenger vehicle km Passenger journeys
FOCs	Freight-tonne km	Freight train km Freight vehicle km
Whole industry	Weighted combination of passenger-kilometres and freight tonne-kilometres	Weighted combination of passenger vehicle km and freight vehicle km

Figure 2.2 sets out the trends in our core output measures. The whole industry measure of GO growth is a weighted combination of the growth in the measures used for TOCs and FOCs. The weights are based on the ratio of TOC fare income to freight income in each year, which is approximately 90:10 on average over our estimation period.

Figure 2.2: Indices of core GO measures



Source: Europe Economics calculations

As shown in Figure 2.2, passenger-kilometres and train-kilometres were broadly stable before 2019/20, followed by a sharp contraction in 2020/21 and a gradual recovery thereafter. Freight tonne-kilometres fell by much less and stabilised earlier. The whole-industry composite largely tracks passenger activity because passenger services account for the majority of operator income. The pattern in GO is important context for GO-based TFP.

Comparing Figure 2.1 and Figure 2.2 shows a significant divergence in the trends for GVA and GO. This is unsurprising, as GO tracks the physical quantity of service whereas GVA reflects the economic value created net of intermediates and is influenced by prices, revenue mix and margins. Divergence between the two sets of output series matters for interpretation. GO-based TFP tells us how efficiently inputs are turned into rail services, while GVA-based TFP shows how efficiently labour and capital generate value added.

2.2.3 Quality adjustments to GO

We adjust gross-output measures so that they reflect the quality of the service delivered, not just its volume. We apply quality adjustments for timeliness (punctuality) and also, for passenger services, rolling-stock quality.

For passenger activity we use the "On-time to 3" measure (annual percentage of trains arriving within three minutes) to adjust for timeliness. For freight we use the "Time to 15" timeliness measure. In both cases, the adjustment is multiplicative – passenger km / freight-tonne km in each year are multiplied by the percentage of on time trains in that year.

To proxy changes in passenger rolling-stock quality we use the average age of the fleet. Each year's GO is multiplied by the change in the average age of the rolling stock fleet relative to the 2014/15 baseline, with reduction in the average age of rolling stock proxying for a higher quality of customer experience.

For Network Rail's GO measure (train-kilometres), we combine the quality-adjusted measures of passenger train km and freight-train km. For whole industry GO, the quality adjusted measure is the income-weighted combination of the quality adjusted measures for TOCs and FOCs.

We do not quality-adjust the GVA series. Those data are taken from ONS national accounts-based sources and represent real GVA after deflation, and hence incorporate any quality adjustments that ONS applied in calculating the price indices that it used to deflate nominal GVA.

2.3 Data collection for inputs

Data on Network Rail's inputs was collected from its Regulatory Financial Statements and its Annual Accounts.

Labour, capital, and intermediate input data for each TOC and FOC in the GB rail industry was compiled using statutory accounts filed with Companies House. The dataset spans financial years 2014/15 to 2023/24.

Data was collected for each TOC and FOC individually in each year. Where operators merged, both were recorded separately up to the merger date, after which the merged or successor entity was treated as a single company. Where operators changed ownership or structure – for example, when a franchise was transferred or brought under an operator of last resort – data was traced through a lineage sheet that identified the relevant successor and predecessor entities. Financial data was therefore drawn from the appropriate company accounts in each period of operation.

In cases where accounts did not align with the financial year (April–March), adjustments were made to allocate data proportionally across years. For example, if an operator reported on a January–December basis, 75 per cent of the value for year 2020 and 25 per cent of the value for year 2021 was used to calculate the relevant measure for financial year 2020/21. For some operators, a downside of using this approach is that it will introduce Covid impacts into the figure for 2019/20 despite that financial year being almost entirely pre-pandemic, as 25 per cent of the 2020 figure (which will embody Covid impacts) is included.

All data collected from statutory accounts is in nominal terms. We discuss the conversion to real terms in Section 2.5.6.

2.4 Labour

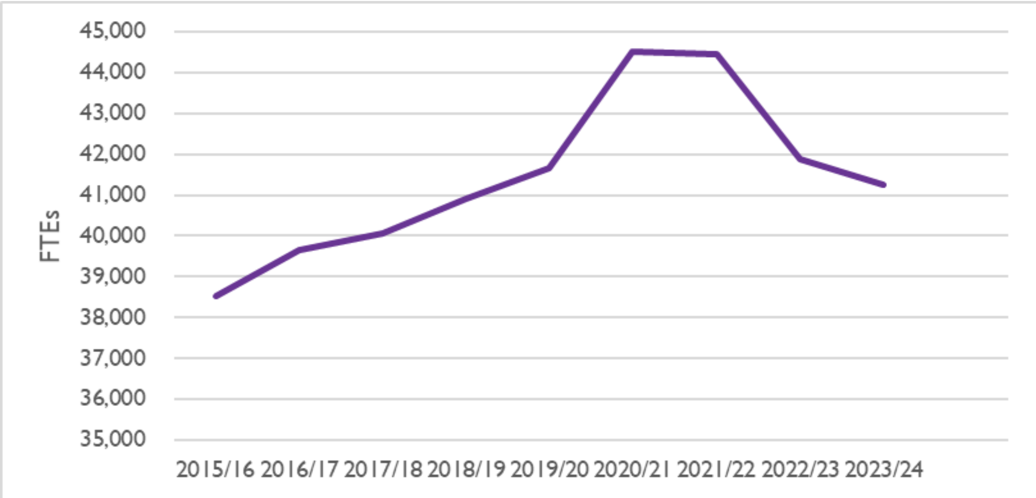
We estimate the quantity of labour inputs using annual full-time equivalents (FTEs) for Network Rail, TOCs and FOCs. To weight labour inputs in the TFP calculation, we use nominal staff costs (wages and salaries, employer NI, pensions, overtime and allowances).

We collect data on the number of Network Rail employees, reported on a full-time equivalent (FTE) basis, as well as total employee costs, from its Regulatory Financial Statements. For 2014/15, only headcount data is available. We convert the 2014/15 headcount to FTEs using the headcount:FTE ratio for 2015/16.

For TOCs and FOCs, total staff costs are taken from the statutory accounts, including wages and salaries, social security costs, and employer pension contributions. FTE employment data was obtained from the dataset underlying ORR's productivity report, which provided the number of full-time equivalent employees for each operator as of 31 March of each year. This ensures temporal alignment with the rail financial year and consistency across operators.

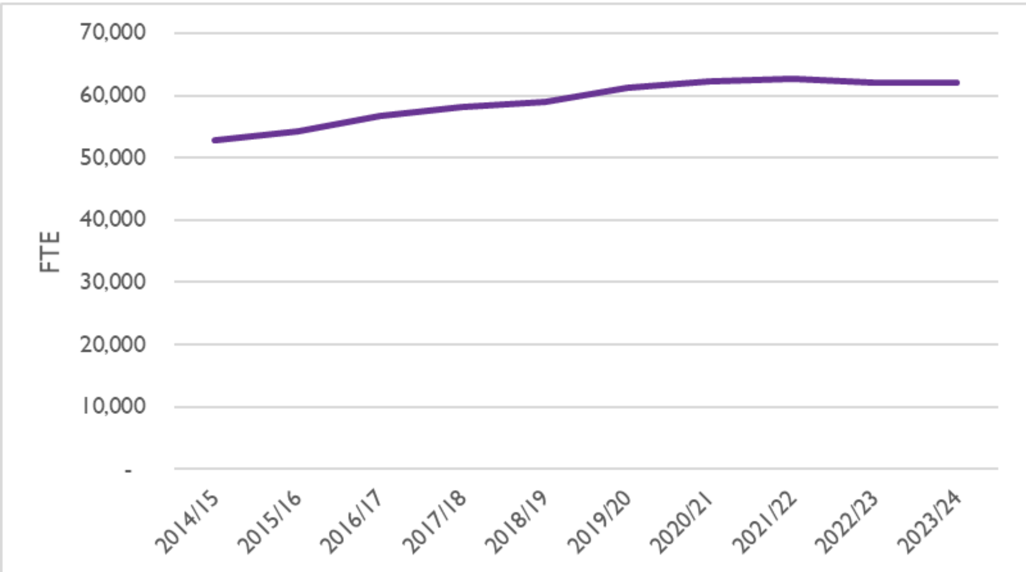
The figures below set out the annal FTEs over the reporting period for Network Rail, TOCs and FOCs.

Figure 2.3: Total labour quantity Network Rail



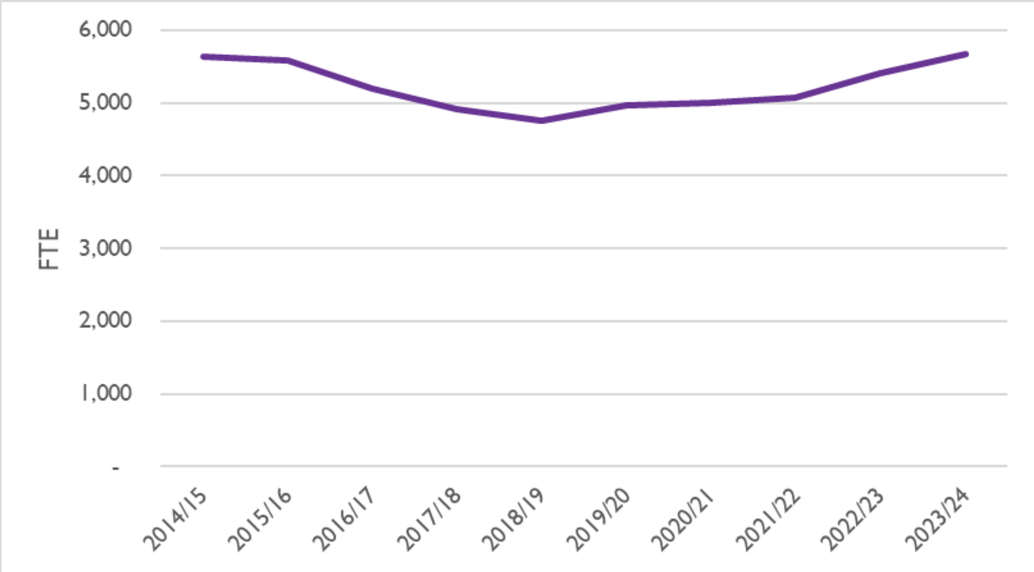
Source: Europe Economics calculations

Figure 2.4: Total labour quantity TOCs



Source: Europe Economics calculations

Figure 2.5: Total labour quantity FOCs



Source: Europe Economics calculations

2.5 Capital

As explained in Section 2.5, we measure capital inputs as a **flow of services** provided by assets**.** For owned assets, this requires constructing a time series of real capital stock and then applying our user-cost formula to estimate the annual cost of using that stock. For leased assets, where we do not observe the underlying capital stock directly, we take the annual lease payments as a proxy for the value of the capital services obtained in that year.

2.5.1 Capital inputs data for Network Rail

Data on capital inputs for Network Rail is collected from its Regulatory Financial Statements (RFS). We collect data on renewals expenditure, disaggregated into the following categories:

- Track
- Signalling
- Civils
- Earthworks
- Buildings
- Electrical power and fixed plant
- Telecoms
- IT
- Other (including wheeled plant and machinery and property)

We largely follow the organisation’s own asset categorisation, which is consistent across years and sufficiently granular for a perpetual-inventory model. It should be noted that, due to changes in reporting over time, the earthworks category does not appear in financial statements prior to the 2019-20 financial year (prior to this year, it sat within civils). Consequently, we include this category only for the years in which it is available.

We also collect data on annual enhancements expenditure. As neither the RFS nor the Annual Reports provide a disaggregated breakdown of enhancements expenditure by asset category, we apply the distribution of renewals expenditure across asset categories to enhancement expenditure to map enhancement spend to our asset categories. This assumes that the distribution of renewals and enhancements send across asset types is similar. We test the sensitivity of our results to changes in the assumed distribution of enhancements spend. In particular, we test the impact of significantly increasing the assumed share of enhancements expenditure that is spent on Network Rail's most short-lived, high depreciation asset categories, Telecoms and IT.

We also collect data on the estimated value of the railway network, because the estimated value of the railway network at the start of 2014/15 is used to calibrate our Perpetual Inventory Method (PIM) for Network Rail, which we explain in Section 2.5.3. We collect two differing estimates of the value of Britain railway network; estimates of the depreciated replacement cost (DRC) of the railway network from DfT's annual accounts and estimates of Network Rail's regulatory asset base (RAB) from the RFS. The estimates differ significantly, with the DRC valuation being several times larger than the RAB valuation. This is because the former are intended to measure the current replacement cost of the network rather than the regulatory capital base, which reflects the price at which the railway network was sold during privatisation. In our central specification we use the DRC valuation, given it is a better reflection of the economic value of the network.

The earliest available DRC estimate is for 31 March 2016. As explained in Section 2.5.3, we use the PIM with a weighted-average depreciation rate for the network as a whole along with observed renewals and enhancements to roll this valuation back to March 2014. All valuations are converted to 2023/24 prices using the ONS Construction Output Price Index for infrastructure.

To test the robustness of our Network Rail capital stock estimates to the choice of opening valuation, we also consider an alternative, more recent, valuation from the DfT 2023/24 accounts. We roll this valuation back to 2014/15 using the same PIM approach as for the 2015/16 valuation. However, because this requires rolling back over a longer period, it is more exposed to potential distortions from compounding measurement error (for example, from the depreciation assumptions and the treatment of renewals and enhancements over time). The resulting implied 2014/15 network value is materially higher than the estimate obtained when anchoring to the 2015/16 valuation, and we therefore retain the 2015/16-based calibration as our central specification given it relies on substantially less back-casting. The table below sets out the valuations of the railway network from Network Rail's RFS and DfT's accounts, along with the back-casted estimates of the value of the railway network at April 2014 that we have estimated.

Table 2.3: Estimates of the value of the railway network

	Estimate (£m)	Price base
April 2014 RAB estimate reported in Network Rail 2014-15 RFS	48,629	2014/15 prices
DfT valuation of railway network at March 2016 (excluding land)	186,143	2015/16 prices
DfT valuation of railway network at March 2024 (excluding land)	346,899	2023/24 prices
Rolled-back DfT 2015-16 valuation (Europe Economics estimate)	187,968	2014/15 prices
Rolled-back 2023-24 valuation (Europe Economics estimate)	310,753	2014/15 prices

In constructing the Network Rail capital input, we exclude land from the network valuation in our central specification, using the asset breakdown provided in the DfT accounts. This is consistent with standard productivity measurement practice, where land is typically treated as a non-produced asset and excluded from capital services measures. We nevertheless test the sensitivity of results to including land. In addition, we test alternative asset coverage assumptions that exclude civils and earthworks alongside land. These assets have relatively low depreciation rates and long service lives and can influence the measured growth of capital services and, in turn, TFP growth. We set out the quantitative implications of these choices in later sections.

2.5.2 Capital inputs data for operators

For operators, the data collection process for capital inputs is more complex than for Network Rail. Reporting styles vary across companies and over time (e.g. pre/post IFRS 16,[3] differing names for asset types, heterogenous breakdowns of "right-of-use assets"). To obtain consistent series we map reported line items into four economically meaningful asset groups (though there is a degree of judgement in some of the mapping):

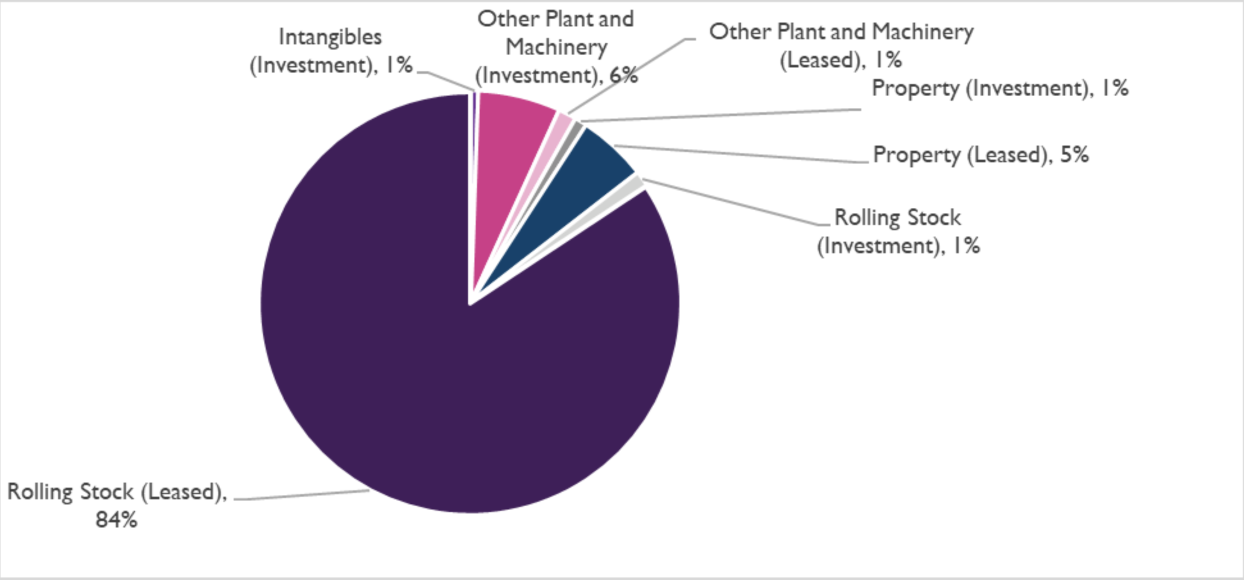
- Rolling stock
- Property
- Other equipment and vehicles
- Intangibles (software)

Operators lease a large amount of the capital inputs they use. Therefore, for each category, information was collected separately for owned and leased assets. For owned assets, we collected annual data on new investment. For leased assets, we collected data for lease-related payments (measured through operating lease payments or, post-IFRS 16, the depreciation and interest associated with right-of-use assets). For intangibles, assets are all owned, not leased.

Data for owned assets feeds into a perpetual-inventory model (PIM) for each asset type as discussed in Section 2.5.3. Nominal additions are first deflated to obtain real investment, and the capital stock for each asset class is then evolved by depreciating the entire existing stock and adding new investment, using service-life assumptions appropriate to each class. Lease payments are not entered into the PIM. Instead, they are used directly as a measure of capital services employed.

The charts below set out for TOCs and FOCs the breakdown of capital inputs across asset categories, distinguishing between owned (investment) and leased assets. In Appendix 3 we provide charts showing investment and leases for each category.

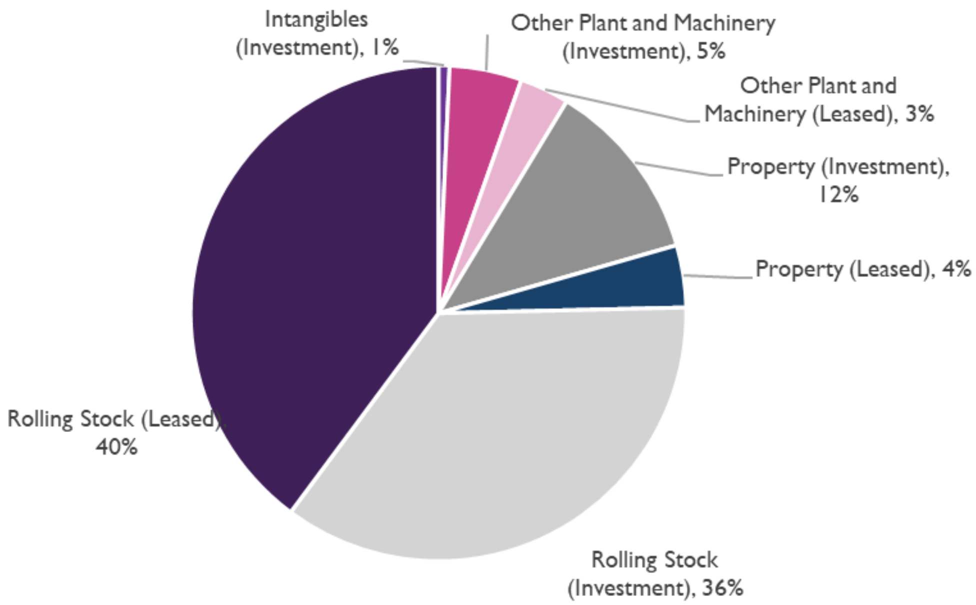
Figure 2.6: Average Shares of Asset Category (TOCs)



[3] IFRS 16 *Leases* is the accounting standard, introduced for reporting periods beginning in 2019, that requires lessees to recognise most leases on balance sheet as right-of-use assets with a corresponding lease liability. Under IFRS 16, lease costs in the profit and loss account are split into depreciation and interest, rather than reported as a single rental expense. For our purposes, this change means that post-IFRS 16 statutory accounts do not provide a lease-payment series that is directly comparable with earlier years, complicating the construction of a consistent rolling-stock lease and capital-services series from accounts data alone.

Source: Europe Economics calculations

Figure 2.7: Average Shares of Asset Category (FOCs)



Source: Europe Economics calculations

The resulting capital dataset provides, for each TOC and FOC and for each financial year from 2014/15 to 2023/24:

- New investment in intangibles, property, other equipment and vehicles, and rolling-stock; and
- The corresponding annual cost of using leased assets

In a small number of cases, it was evident that the statutory accounts had classified rolling stock under plant and machinery. In these instances, the reported level of investment in plant and machinery was implausibly high relative to other years, indicating that it primarily reflected rolling-stock expenditure. Where this occurred, the relevant investment amounts were reassigned in full to the rolling stock category.

2.5.3 Perpetual inventory method

For all Network Rail assets, and the subset of operator assets that are owned rather than leased, we use the perpetual inventory method (PIM) to convert our collected data into estimates of productive capital stock. The method applies the formula:

$$K_t = (1 - \delta) \cdot K_{t-1} + I_t$$

where K_t is the capital stock at time *t*, δ is the annual depreciation rate, and I_t is real investment (gross fixed capital formation) during year *t*. The first term represents the undepreciated portion of last year's stock, and the second term adds new investment in the current year. Our depreciation assumptions are set out in the next section. A separate PIM is used for each asset category. All monetary values are converted to 2023/24 prices using the capital price indices described in Section 2.5.6.

The PIM requires an estimate of the initial capital stock K_0 (the stock at the start of 2014/15 in our model). This can be estimated by assuming a steady-state relationship between investment, depreciation, and asset growth. However, the long-term asset growth rates implied by our investment data are implausible in several cases. We have also tested the use of assumptions for long-term asset growth. However, our preferred approach is to base our initial stock estimates on actual data.

For Network Rail, we use the Department for Transport's DRC valuation of the UK railway network as our anchor. The earliest available DRC estimate is for 31 March 2016. We deflate this valuation to 2023/24 prices using the Construction Output Price Index for infrastructure, and then use the PIM with a weighted-average depreciation rate for the network as a whole along with observed renewals and enhancements to roll the valuation back to March 2014. This provides an estimate of the total real capital stock for Network Rail at the start of 2014/15. We then allocate this total across asset categories in proportion to their average shares in Network Rail's capital expenditure over the period, and use the resulting category-level stocks as the starting values for the asset-specific PIMs. We also run sensitivity tests in which the initial stock is instead anchored on Network Rail's RAB as reported in its RFS.

For operators, we do not have an equivalent whole-network DRC valuation. We therefore take the reported net book values for each asset category from the 2014/15 statutory accounts of the train operating companies and freight operating companies and use these as the initial capital stocks in the PIM.

2.5.4 User cost of capital

The user cost of capital is the cost of using an asset in the production process for one period, incorporating the cost of financing the asset, depreciation, and any holding gains or losses from changes in asset prices. It The product of the user cost and the productive stock provides an estimate of each asset class's share in total capital compensation. These shares are used as weights in a Tornqvist index to aggregate the growth of asset-level stocks into an overall volume index of capital services. This is the approach used in the OECD productivity framework and in official productivity statistics (including ONS MFP via the Volume Index of Capital Services).

The user cost of capital depends on three parameters:

- Depreciation rate – the proportion of the asset's productive capacity that is consumed each year.
- Rate of return – the required return on capital, reflecting the opportunity cost of using funds in the asset.
- Holding gains/losses – changes in the value of the asset over time due to real asset price movements.

We discuss our estimates for each parameter in turn.

Depreciation

We model depreciation as geometric (declining-balance) consumption of asset capacity by class. We use declining-balance depreciation because we require a constant-rate depreciation schedule that is suitable for use in a perpetual inventory model. For operators, useful lives are taken from their statutory accounts (using the most common assumptions, because they vary across operators); for Network Rail, lives are taken from DfT accounts (these accounts use economic life assumptions to value Britain's railways). DfT and operator accounts use straight-line depreciation assumptions (where the amount of depreciation is constant each year in monetary terms). We have calibrated our constant percentage rates of depreciation to approximate the straight-line profiles assumed in DfT and operator accounts. A declining balance factor, the parameter that governs the shape of the depreciation profile (how front-loaded it is), of 1.5 yields declining-balance depreciation profiles that closely track the straight-line profiles while mildly front-loading depreciation, as is standard practice in productivity analysis.

The core depreciation assumptions used in our model are set out below. We have tested the sensitivity of the TFP results to varying the useful life assumptions by 10 per cent upwards and downwards, and report results for those sensitivity tests in Chapter 3.

Figure 2.8: Network Rail depreciation assumptions

Asset category	Useful life	Depreciation rate
Track	22	6.8%
Signalling	34	4.4%
Civils	62	2.4%
Earthworks	95	1.6%
Buildings	26	5.8%
Electrical power and fixed plant	34	4.4%
Telecoms	7	21.4%
IT	4	37.5%
Other	35	4.3%

Asset category	Useful life	Depreciation rate
Rolling stock	35	4.3%
Property (leasehold improvements)	7	21.4%
Other equipment and vehicles	7	21.4%
Intangible (software)	4	37.5%

Rate of return

For the rate of return, we use an exogenous allowance. Our core results use the weighted average cost of capital (WACC) applied by ORR for each of Network Rail's control period. In the user-cost formula we construct capital compensation in nominal terms – combining the nominal rate of return, economic depreciation and asset-price inflation – and then deflate to obtain real capital services. For consistency, we therefore require a nominal WACC.

Network Rail's WACC is specified in real terms, so we convert it to a nominal WACC. For the years covered by CP5, we use the PR13 vanilla WACC (4.31 per cent). For the years covered by CP6, we use the PR18 vanilla WACC (3.80 per cent). The PR13 WACC is in real RPI terms, so we convert it to nominal terms using RPI. CPI is used for the PR18 WACC.

We have tested high level adjustments to the WACC used for operators, as set out in Chapter 3. These are sensitivity tests only, and do not represent a WACC estimate for these firms (which would be outside the scope of this project). We are not aware of any external estimates of the WACC for passenger or freight operators that could be used as an alternative assumption.

Holding gains/losses

Asset price indices specific to each asset category are used to estimate holding gains and losses (i.e. real terms changes in asset prices). Given asset price indices are also used in other areas of our calculation, we discuss the choice of asset price indices in Section 2.5.6.

2.5.5 Approach to leases

As evidenced by Figure 2.6, rolling stock lease payments are comfortably the largest component of TOC capital inputs. One complication that arises for these payments is that rolling stock lease arrangements vary in the degree of maintenance costs embedded within the contract. In rail parlance, a dry lease prices the asset only; a wet lease bundles the asset with maintenance (often including heavy overhauls and mileage-based work); and a "soggy" lease sits between the two, with some maintenance embedded and some billed separately. This matters for TFP because maintenance is an intermediate input, not capital. If embedded maintenance is treated as capital, the weight on capital is overstated and the weight on intermediates is understated, biasing GO TFP and the labour-capital shares in GVA TFP. It is not always possible to identify rolling stock maintenance costs in company accounts. Therefore, we apply an adjustment for maintenance costs embedded within lease payments based on data reported in ORR's latest Rail Finance publication. The publication splits rolling stock costs into rolling stock leasing and rolling stock maintenance (for the latest financial year only), indicating that almost 35 per cent of rolling stock costs are maintenance. We therefore apply a 35 per cent reduction to rolling stock lease costs included in capital inputs in our preferred specification for operators.[4] We test the impact of this assumption in our sensitivity analysis.

There are other complexities in the reporting of rolling stock leases that limit the confidence that can be placed in our data from statutory accounts. Sub-leasing within groups, or leases held by DfT or TfL, can mean that the statutory accounts of the operating company may under-state lease flows – for some TOCs statutory accounts report zero rolling stock payments, which is not credible. IFRS 16 adds further noise where operators adopted different transition methods. Embedded non-lease services are sometimes not separated, and mid-term modifications can shift the split between depreciation and interest without any change in the underlying fleet.

Given the importance of rolling stock in TOC capital inputs, we also reviewed an alternative series of rolling stock payments from ORR's Rail Finance database (which goes back to 2015/16). For franchised operators, this dataset draws on management accounts and provides a more consistent reporting of rolling stock lease payments than the statutory accounts, though it does not address the issue of embedded maintenance costs. For non-franchised operators, the Rail Finance data is less comprehensive.

The preferred approach to rolling stock lease payments is to use the Rail Finance data for franchised operators, and use statutory accounts data for non-franchise operators. As the Rail Finance data only dates back to 2015/16, for the first year of our period (2014/15) we use statutory accounts data. For three franchise operators (ScotRail, CrossCountry and MerseyRail) we were not able to identify rolling stock lease payments from the 2014/15 accounts. Given the implausibility of using a zero value, we have estimated their rolling stock lease payments for 2014/15 by assuming the share of those three operators in total TOC rolling stock lease payments is the same as in 2015/16.

For other tangible assets (property and other equipment and vehicles), all TOC lease payment data is sourced from statutory accounts. These categories account for a much smaller share of capital inputs.

All FOC lease payment data is sourced from statutory accounts as we are not aware of any alternative data source.

2.5.6 Price indices

We convert all nominal series to real 2023/24 prices using ONS indices. Calendar-year indices are converted to financial-year averages (quarterly GDP weights), then rebased such that 2023/24 = 100.

For capital inputs, we use asset-specific ONS price indices (PPI, SPPI and COPI) so the deflator matches the economic character of each asset class as closely as possible. These same indices also provide the asset-price change term (holding gains/losses) in the user-cost calculations. Where no exact match exists, we select the closest plausible proxy from PPI/SPPI/COPI. Table 2.4 lists the baseline index chosen for each asset/intermediate category.

[4] We do not reallocate the reduced lease costs to intermediates as we understand many of the maintenance costs are already captured in the intermediate costs collected from Companies House accounts within the operating costs reported by operators.

For intermediates, we use CPI in the core results (with alternatives tested in sensitivity). Labour price indices are not used here because labour volumes are measured in FTEs and labour cost shares are based on nominal staff costs.

Table 2.4: Assets price indices used in core analysis

Asset category	Index used
Rolling stock	PPI Output domestic: Railway locomotives and rolling stock
Property	COPI: Private commercial index
Other equipment and vehicle	PPI Output domestic: Other transport equipment
Intangibles	SPPI Output domestic: Computer programming, consultancy and related services
Intermediates	Consumer Price Index (CPI)
Track	COPI: Infrastructure index
Signalling	PPI Output domestic: Electricity distribution and control apparatus
Civils	COPI: Infrastructure index
Earthworks	COPI: Infrastructure index
Buildings	COPI: Infrastructure index
Electrical power and fixed plant	PPI Output domestic: Electricity distribution and control apparatus
Telecoms	PPI Output domestic: Communication equipment
IT	PPI Output domestic: Computers and peripheral equipment
Other renewals	COPI: Infrastructure index
Railway network (valuation)	COPI: Infrastructure index

We also re-estimate results using alternative indices (Table 2.5) and a further sensitivity that applies CPI across selected categories; this checks that the TFP conclusions are not driven by any single deflator choice.

Table 2.5: Alternative asset price indices for sensitivity testing

Asset category	Indices used in sensitivity check
Rolling stock	PPI Import: Railway locomotives and rolling stock
Property	COPI: All construction (new work and repair and maintenance)
Other equipment and vehicle	PPI Output domestic: Machinery and equipment
Intangibles	SPPI Output domestic: Data processing, hosting and related services; web portals
Intermediates	GDP deflator
Track	COPI: Non-housing repair and maintenance
Signalling	PPI Output domestic: Electrical equipment
Civils	COPI: Non-housing repair and maintenance
Earthworks	COPI: Non-housing repair and maintenance
Buildings	COPI: Non-housing repair and maintenance
Electrical power and fixed plants	PPI Output domestic: Electrical equipment
Telecoms	PPI Output domestic: Electrical equipment
IT	PPI Export EU: Computers and peripheral equipment
Other renewals	COPI: Non-housing repair and maintenance
Railway network (valuation)	COPI: Non-housing repair and maintenance

2.6 Intermediates

Intermediates capture the goods and services used up within the year (e.g. energy, contracted maintenance, materials, outsourced services). They enter the GO TFP calculation alongside labour and capital; they do not enter GVA TFP (because GVA nets intermediates out of output). We construct intermediates from statutory/regulatory accounts as non-labour, non-capital operating costs.

For Network Rail, we take the annual sum of operations, support, and maintenance (OSM) expenditure, plus expenditure on traction electricity, industry costs, and rates. Schedule 4 and Schedule 8 costs are excluded. We subtract staff costs to derive our estimate of Network Rail's intermediate inputs. Capital expenditure is already excluded and reported under renewals / enhancements.

For operators, the approach is slightly more complicated due to reporting inconsistency. The following variables were extracted from the profit and loss and operating cost notes of the statutory accounts:

- Total cost of sales / operating costs for the financial year
- Staff costs, as reported in the employment or operating cost note
- Depreciation and amortisation (including impairment, where applicable)
- Exceptional operating cost items that do not relate to inputs, such as franchise payments, performance payments, or gains/losses on disposals

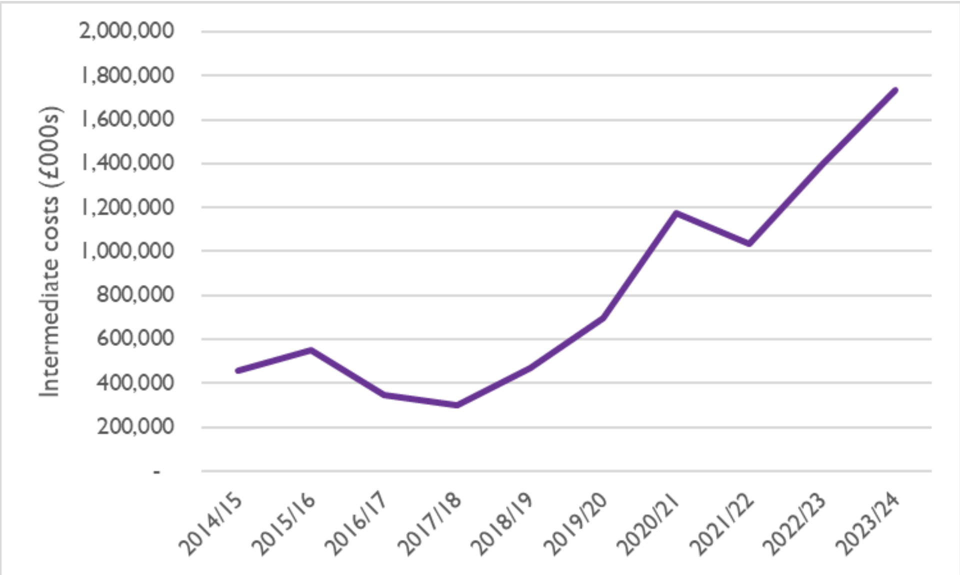
From this, we calculate intermediate inputs as:

Total Costs – Staff Costs – Depreciation/Amortisation – Exceptions/Adjustments

For sector-level GO TFP calculations (TOCs and FOCs), track access and network payments are included as intermediate inputs, as these represent genuine intermediate inputs required for train operation. When estimating whole industry GO TFP, we calculate intermediates by summing intermediates across Network Rail, TOCs and FOCs and then subtracting intra-industry transfers. Specifically, we subtract Network Rail's access charge income as reported in ORR's Rail Finance database. We do not subtract performance income because it is already excluded from Network Rail's intermediates, and (where identifiable) from operators intermediates.

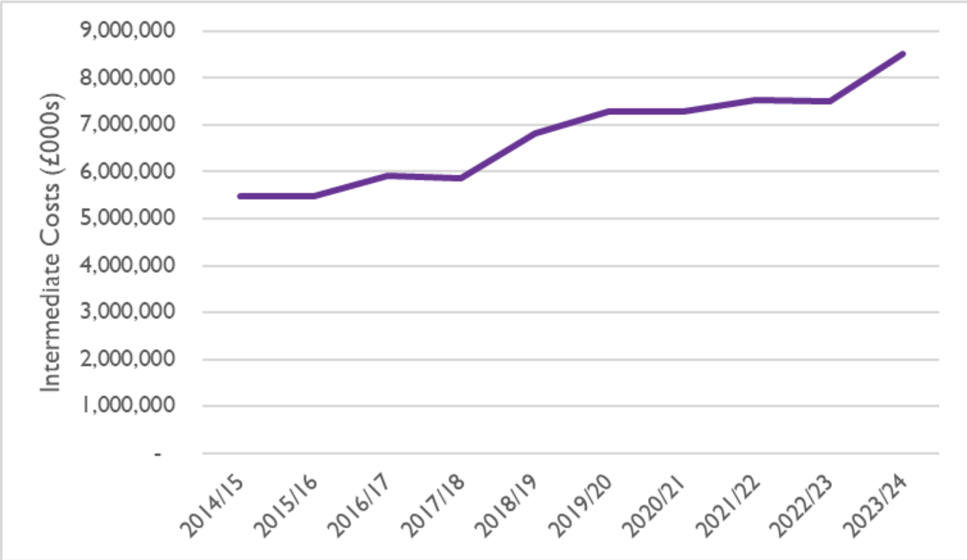
All intermediate series are converted to real 2023/24 prices using CPI to estimate changes in intermediate quantities. The share of intermediates is based on its nominal value each year. The figures below present the nominal value of intermediates for Network Rail, TOCs and FOCs.

Figure 2.9: Intermediate costs Network Rail (£000s)



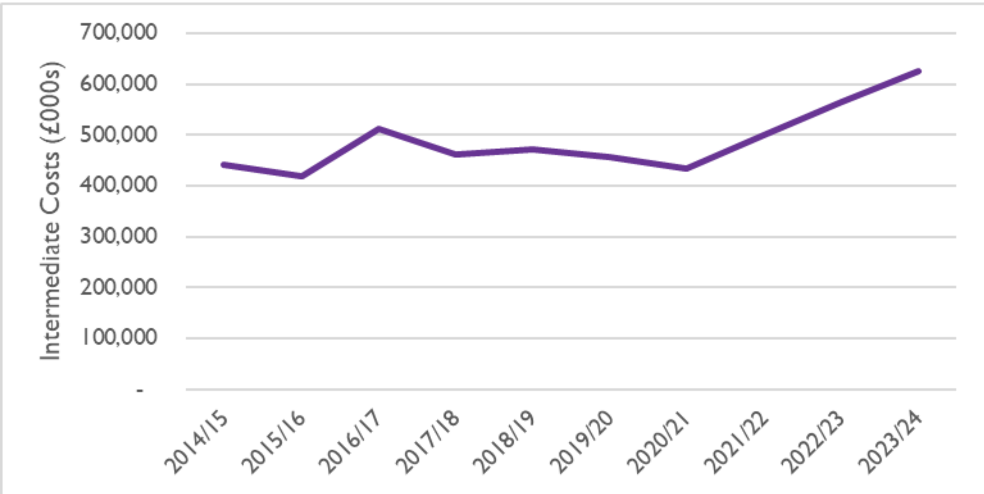
Source: Europe Economics calculations

Figure 2.10: Intermediate Costs TOCs (£000s)



Source: Europe Economics calculations

Figure 2.11: Intermediate Costs FOCs (£000s)



Source: Europe Economics calculations

2.7 Sensitivity testing

We run sensitivity tests to check that our main findings are robust to reasonable alternative assumptions and are not overly driven by any one data source, index, or parameter choice. Sensitivities also signal where uncertainty is greatest and provide plausible bounds around central estimates.

In Chapter 3, we set out our core results and results for sensitivity tests. Full tables of results from sensitivity tests are in Appendix 2.

Our sensitivity tests cover:

- Alternative measures of GO
- Alternative quality adjustments
- Alternative price indices

- Alternative depreciation assumptions
- Alternative rate of return for operators
- Alternative cost share averaging periods in the TFP calculations
- An adjustment for capacity utilisation (for TOCs and the whole industry)
- Alternative estimate of the value of the railway network (for Network Rail and the whole industry)
- Alternative disaggregation of enhancements expenditure (for Network Rail and the whole industry)
- Alternative rolling stock lease data (for franchised TOCs)

3 Results

In this chapter we set out the results of our TFP calculations. Results are presented separately for:

- Whole industry
- Network Rail
- Passenger operators (TOCs)
- Freight operators (FOCs)

In each case, we present three sets of TFP results:

- GO TFP
- Quality-adjusted GO TFP
- GVA TFP

We also present the results of various sensitivity tests for each segment. A full set of sensitivity results are provided in Appendix 2.

Our discussion of the findings is set out in Chapter 4.

3.1 Whole industry

This section presents TFP results for the industry as a whole.

3.1.1 GO TFP results

For the industry as a whole, our preferred measure of GO is a weighted combination of passenger km and freight tonne km. The annual growth in total passenger km and freight tonne km is weighted according to the total annual income for TOCs and FOCs respectively. Table 3.1 sets out the annual change in GO TFP for the industry as a whole over our estimation period.

Table 3.1: Whole industry annual GO TFP growth (%)

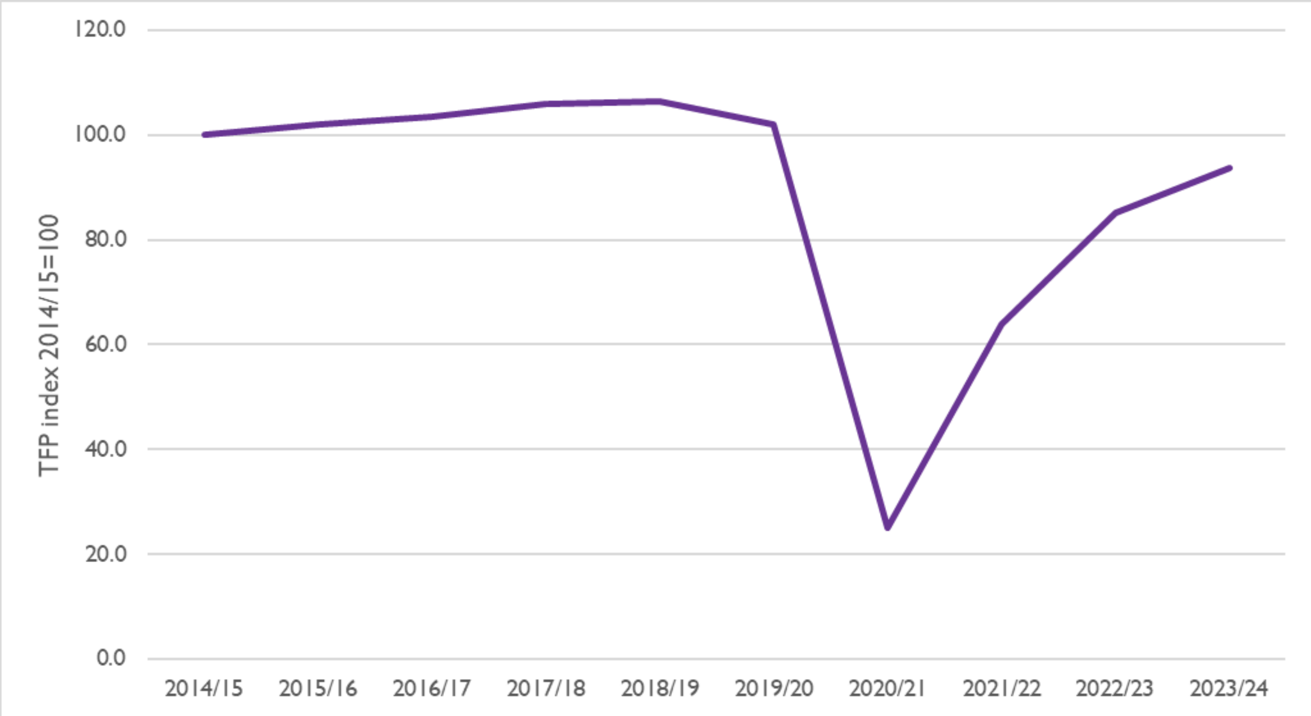
	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	2.0	1.4	2.5	0.5	-4.2	-75.5	156.1	33.3	9.9

Source: Europe Economics calculations

The year-on-year GO TFP growth rates in Table 3.1 are presented as an index in Figure 3.1. This provides an illustration of the cumulative change in the industry's GO TFP over our estimation period. Figure 3.1 shows that whole industry GO TFP was generally increasing year-on-year pre-pandemic, such that by 2018/19, whole-industry GO TFP is around 17 per cent higher than in 2014/15. There is a decline in productivity 2019/20, followed by a very sharp fall in 2020/21 as passenger and freight volumes collapsed during the pandemic while inputs adjusted only slowly. The index drops to around 25 in 2020/21 – a reduction of roughly three-quarters relative to 2019/20.

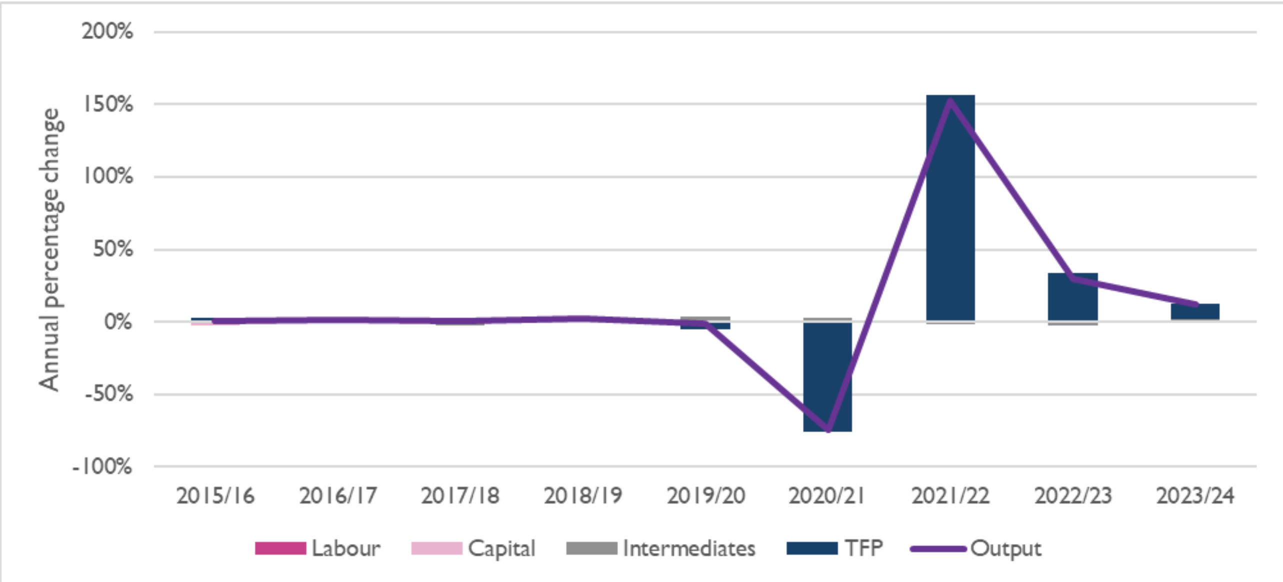
As demand recovered, TFP rebounded strongly, increasing by around 156 per cent in 2021/22 and a further 33 per cent in 2022/23. By 2023/24 the index stands at around 93.7, around 6 per cent below its 2014/15 level. The very large swings during and immediately after the pandemic period mainly reflect changes in capacity utilisation rather than rapid changes in underlying technical efficiency. This is consistent with our decomposition, which shows relatively smooth trends in labour, capital and intermediate inputs over time, with most of the volatility in output growth being absorbed in the TFP residual.

Figure 3.1: Whole industry GO TFP index, 2014/15=100



Source: Europe Economics calculations

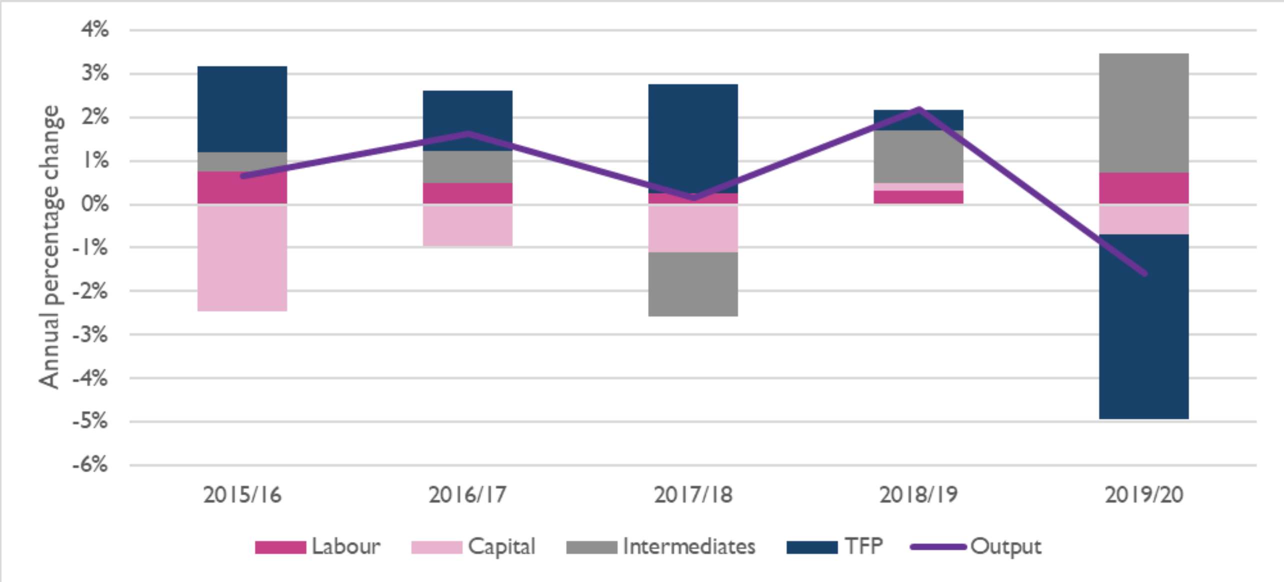
Figure 3.2: Decomposition of whole industry output growth (GO), full period



Source: Europe Economics calculations

The large negative and positive TFP contributions in 2020/21 and 2021/22 dominate Figure 3.2 and make the pre-pandemic movements hard to see. To provide a clearer view of the underlying drivers of TFP growth in more typical years, Figure 3.3 zooms in on the decomposition for 2015/16 to 2019/20.

Figure 3.3: Decomposition of whole industry output growth (GO), 2014/15 – 2019/20



Source: Europe Economics calculations

Figure 3.3 shows that, over the pre-pandemic period, TFP growth is mainly associated with a gradual reduction in capital services alongside broadly flat or increasing output. Labour input is roughly stable or rising slightly, while intermediate inputs are flat or increasing in most years, with a large increase in 2019/20 despite a drop in output. Taken together, this suggests that up to 2019/20 the industry was able to sustain modest growth in gross output while reducing its use of capital (and, to a lesser extent, other inputs), which is reflected in positive TFP growth. Since capital services at the whole-industry level are dominated by Network Rail (around 95 per cent of total capital services in 2014/15 and still over 80 per cent throughout the period), this reduction in capital inputs primarily reflects a reduction in Network Rail's capital services.

3.1.2 Quality-adjusted GO TFP results

The next set of results applies a quality adjustment to our whole industry GO (passenger km and freight tonne km). Both passenger km and freight tonne km are adjusted for timeliness, while the passenger km component is also adjusted for rolling stock quality.

Table 3.2: Whole industry annual quality-adjusted GO TFP growth (%)

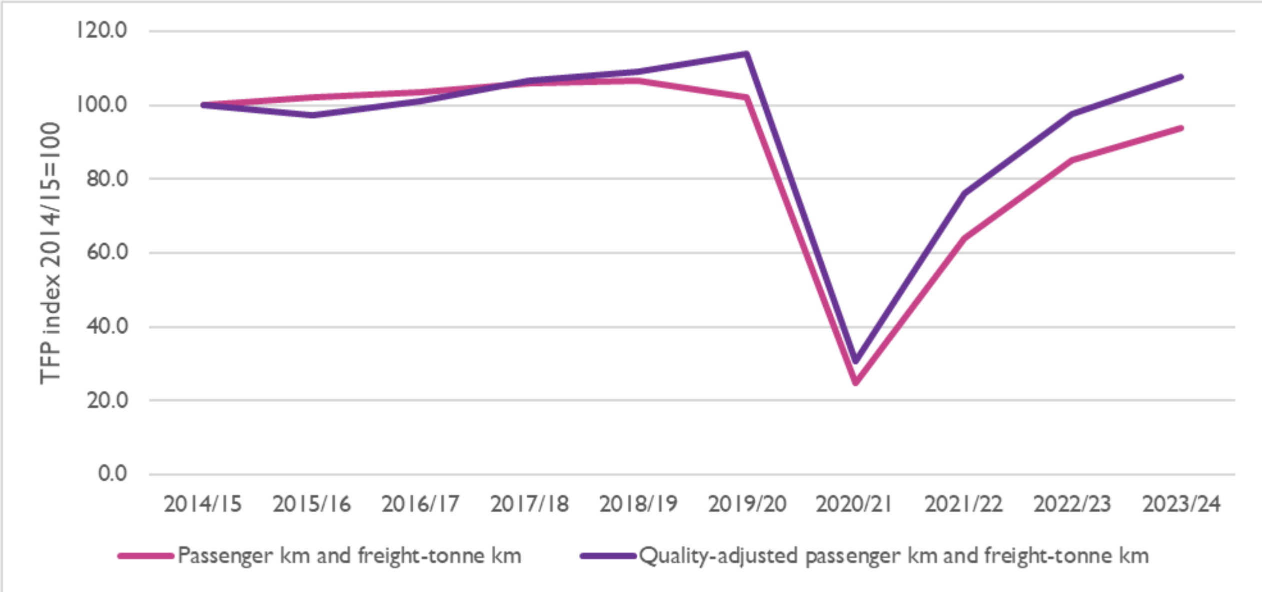
	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	-2.7	3.9	5.6	2.1	4.6	-73.1	148.8	27.8	10.6

Source: Europe Economics calculations

Adjusting for quality reduces TFP growth in 2015/16 such that it is now negative, but from 2016/17 onwards the quality-adjusted series grows more quickly. Pre-pandemic, the quality-adjusted TFP index continues to rise through to 2019/20, whereas the unadjusted index peaks in 2018/19 and then falls back. The particularly strong quality-adjusted TFP growth in 2019/20 largely reflects the rolling-stock quality adjustment, which boosts measured output.

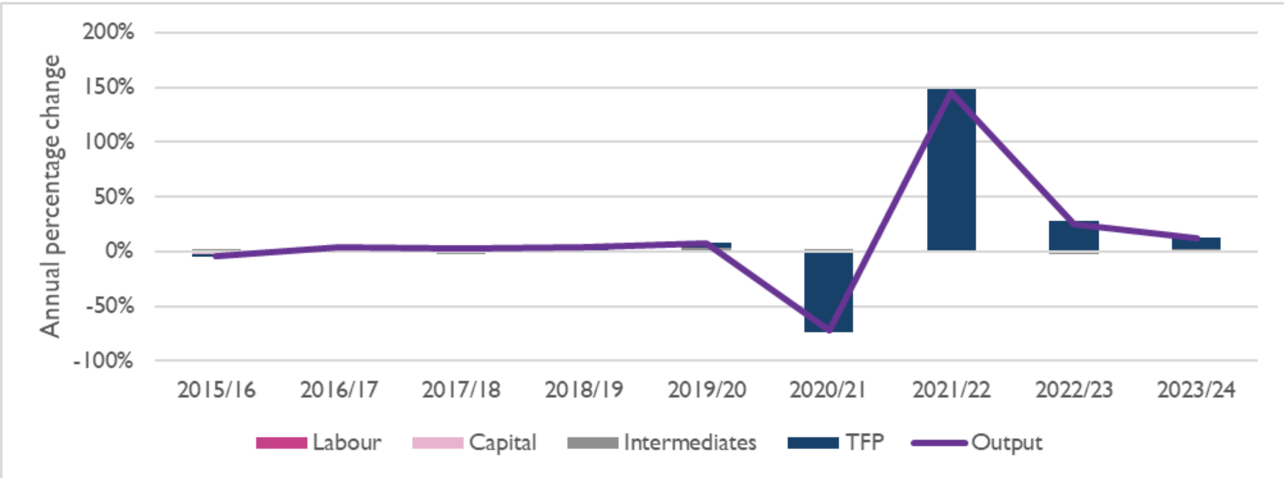
During the pandemic, the quality-adjusted series still shows a very sharp decline in 2020/21 and a strong rebound in 2021/22, though the trough is slightly less deep and the subsequent recovery somewhat smoother than for the unadjusted measure. By 2023/24, cumulative growth in quality-adjusted whole-industry GO TFP is markedly higher than for the unadjusted series, with TFP around 8 per cent above its 2014/15 starting point, and level with the 2019/20 peak.

Figure 3.4: Whole industry quality-adjusted GO TFP index, 2014/15=100



Source: Europe Economics calculations

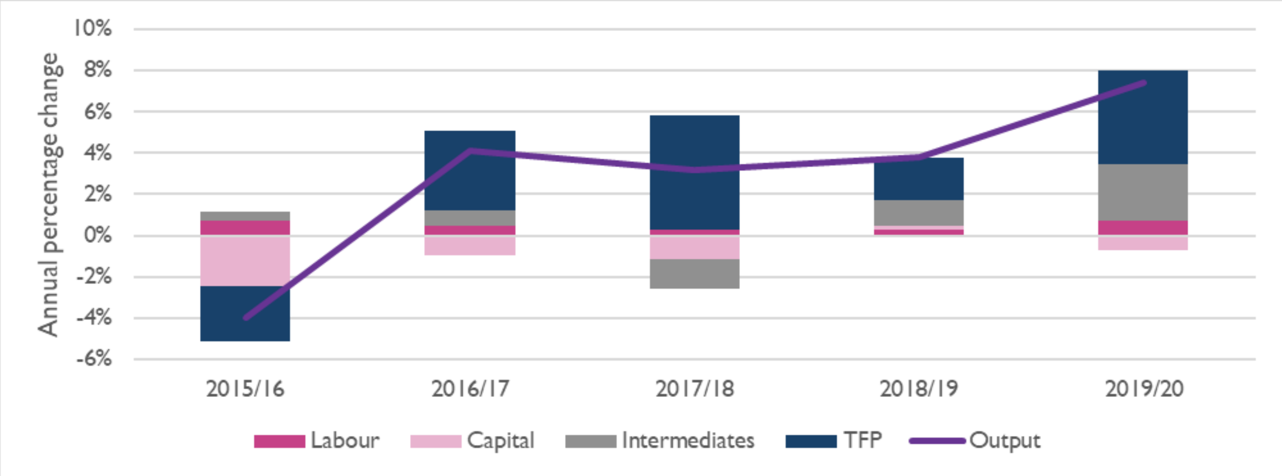
Figure 3.5: Decomposition of whole industry output growth (quality-adjusted GO), full period



Source: Europe Economics calculations

As with the non-quality-adjusted GO TFP results, it is useful to examine the decomposition of TFP growth in pre-pandemic years. Figure 3.6 presents the decomposition of quality-adjusted whole-industry GO growth over the pre-pandemic period. As with the unadjusted series, TFP provides the main positive contribution to output growth in most years, offsetting falling capital inputs. The key difference to the unadjusted series is in 2019/20. When quality adjustments are included, output growth is positive rather than negative. This reflects the effect of improvements in service quality – in particular, the rolling-stock quality adjustment – which raise measured output over and above the change in passenger-km and freight-tonne-km alone.

Figure 3.6: Decomposition of whole industry output growth (quality-adjusted GO), 2014/14 to 2019/20



Source: Europe Economics calculations

3.1.3 GVA TFP results

Whole industry GVA TFP results use the combined GVA of Network Rail, TOCs and FOCs. When interpreting the GVA TFP results, it is worth noting that GVA is measured in financial terms, whereas GO is measured using physical indicators of activity – train-km for Network Rail, passenger-km for TOCs and freight tonne-km for FOCs.

For the operators, GVA comes from the ONS Annual Business Survey (ABS), where it is derived from financial data on turnover, other operating income and intermediate costs rather than from physical volumes. This means GVA estimates can be affected by revenue effects that do not appear in the GO measures, such as ticket-mix. For Network Rail, GVA is not taken from ONS but is instead constructed directly from cost data as the sum of staff costs and depreciation.

As noted in Section 1, GVA TFP will be higher than (or equal to) GO TFP when both are measured in financial terms in a consistent way. This may not always hold, however, when the measure of GO is a physical quantity rather than a financial measure. We discuss the differences in our estimated GO TFP and GVA TFP in Section 4.1.2.

Table 3.3 presents the year-on-year changes in GVA TFP for the industry.

Table 3.3: Whole industry annual GVA TFP growth (%)

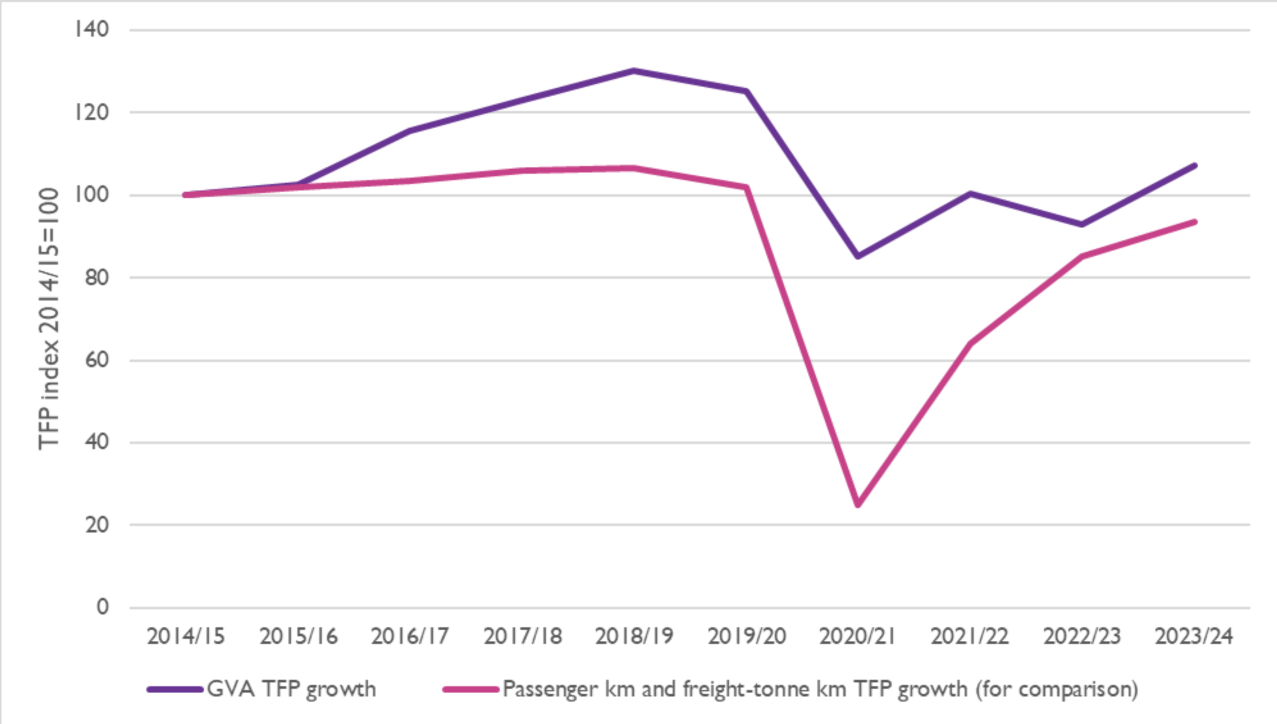
	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	2.6	12.7	6.5	5.8	-3.9	-32.0	17.6	-7.3	15.2

Source: Europe Economics calculations

Figure 3.7 shows that whole-industry GVA TFP rises strongly in the pre-pandemic period. Annual GVA TFP growth is between around 3 and 13 per cent from 2015/16 to 2018/19, so that by 2018/19 the GVA-based index is roughly 30 per cent above its 2014/15 level, compared with a much smaller increase for the GO-based TFP measure. There is a decline in 2019/20, followed by a sharp fall in 2020/21 as the pandemic hits. However, the trough in 2020/21 is much less deep than for GO TFP: the GVA TFP index falls back to around 15 per cent below its 2014/15 level, rather than to about one-third of it. GVA TFP then recovers in 2021/22, dips in 2022/23 and rises sharply again in 2023/24, ending the period around 8 per cent above its 2014/15 level but well below its 2018/19 peak.

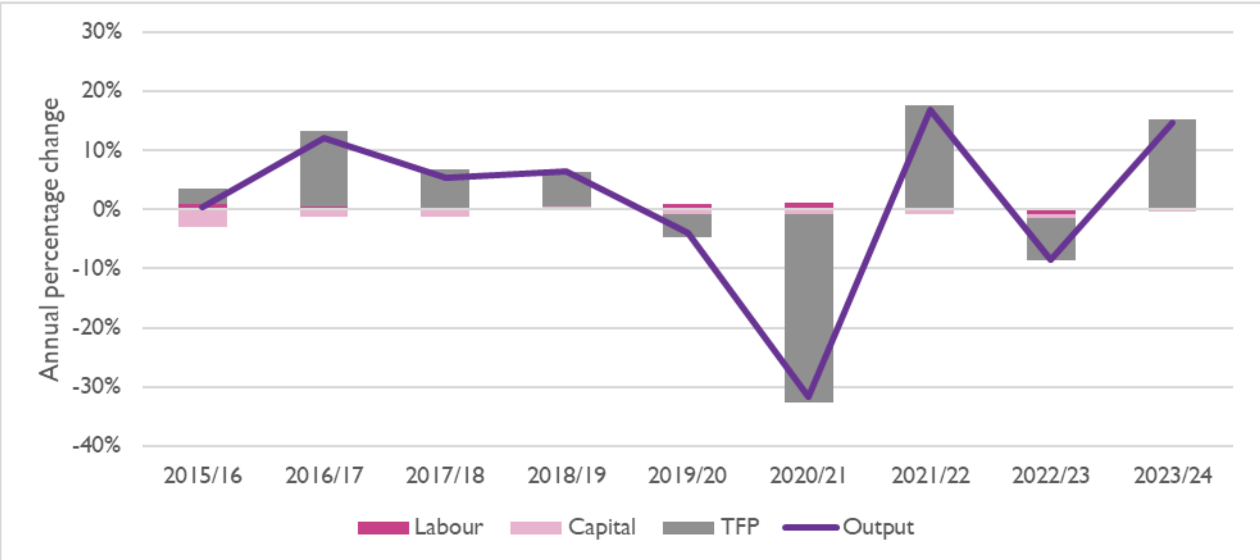
The decomposition in Figure 3.8 indicates that most of the variation in whole-industry GVA growth is captured in the TFP term. Negative contributions from capital inputs are still significant, while contributions from labour and intermediate inputs are relatively small and stable. The pronounced swings in TFP therefore largely reflect volatility in GVA (in financial terms), rather than large changes in measured input volumes.

Figure 3.7: Whole industry GVA TFP index, 2014/15=100



Source: Europe Economics calculations

Figure 3.8: Decomposition of whole industry output growth (GVA)



Source: Europe Economics calculations

3.1.4 Sensitivities

This section tests the robustness of the industry TFP results to alternative assumptions and data sources. The baseline is the quality-adjusted GO measure using our preferred input deflators, regulatory WACC, depreciation rates, and two-period-average Törnqvist weights. Each chart compares this baseline with one sensitivity at a time to assess whether the direction and timing of TFP movements are materially affected.

The sensitivities include:

- **Output definition:** alternative traffic-based measures to test dependence on the specific output proxy used.
- **Quality adjustment:** a timeliness-only quality adjustment for passenger-km excluding rolling-stock age, to isolate the effect of each quality adjustment.
- **Initial capital stock:** using the RAB-based measure of Network Rail's capital stock at the start of 2014/15, instead of the DfT DRC valuation, and using a more recent DfT DRC valuation.
- **Price indices:** alternative deflators for capital and intermediates.
- **Depreciation assumptions:** higher and lower depreciation rates to test the impact of capital-service growth.
- **Törnqvist weighting:** full-period average cost shares rather than two-year average cost shares.
- **Cost of capital:** applies an uplift to the regulatory WACC to test the sensitivity of user-cost estimates for capital.
- **Capacity-utilisation adjustment:** an approach following an established method used in productivity literature[5] to distinguish utilisation changes from underlying efficiency.
- **Network Rail enhancement expenditure:** adjusting the assumed split of enhancements expenditure across Network Rail's asset categories.

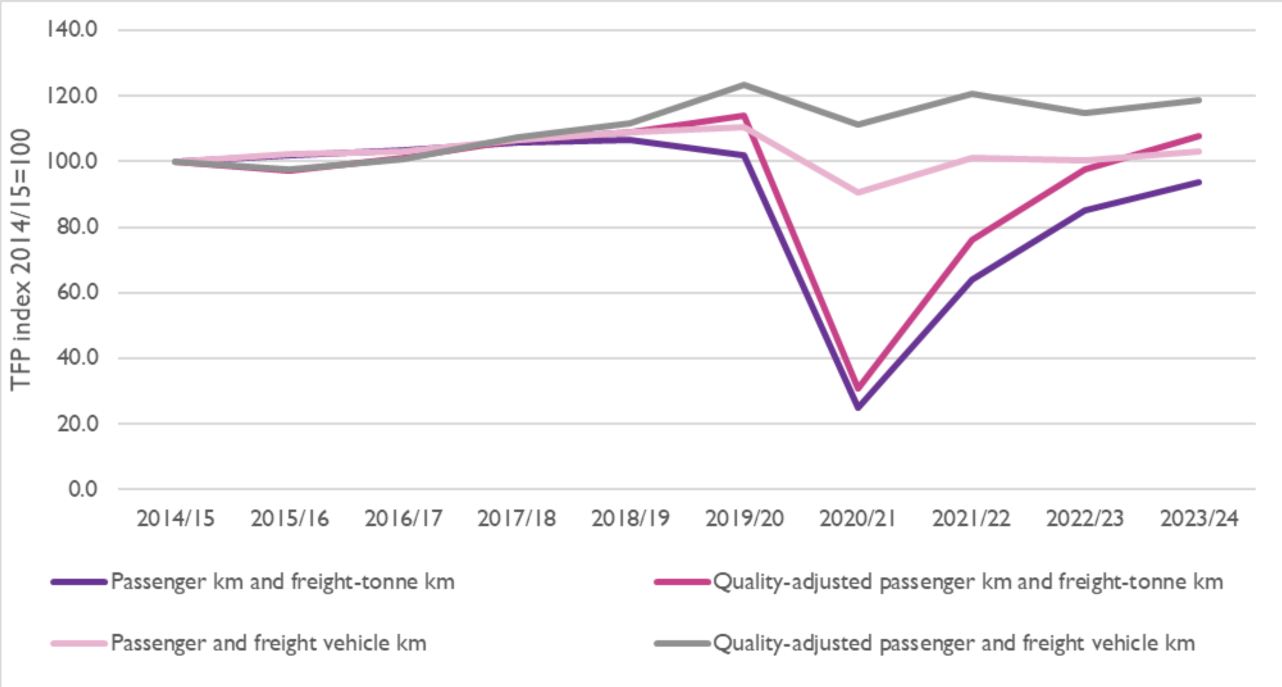
Alternative GO measures

Figure 3.9 presents TFP results for the whole industry using vehicle km (passenger and freight) instead of passenger km and freight tonne km. The results differ significantly during the pandemic years, because vehicle km declined far less sharply than passenger km. Adjusting vehicle km for quality makes the divergence even more pronounced.

Vehicle-km is a useful indicator of service supply, but it is a less suitable measure of economic output for the industry as a whole. It treats a train running empty as delivering the same output as a fully-loaded train and does not reflect changes in average load factors. By contrast, passenger-km and freight-tonne-km scale with the volume of passengers and freight actually carried and therefore better capture the services delivered to end users. For this reason, we take the passenger-km and freight-tonne-km specification (and its quality-adjusted variant) as our preferred measure of whole-industry GO TFP. Nonetheless, the vehicle-km sensitivity gives an indication of what TFP growth looks like when the effects of Covid on utilisation are removed.

[5] Griffith, R., Redding, S., & Reenen, J. V. (2004). Mapping the two faces of R&D: Productivity growth in a panel of OECD industries. *Review of economics and statistics*, *86*(4), 883-895. Appendix 2.3.

Figure 3.9: Whole industry GO TFP for alternative measures of GO

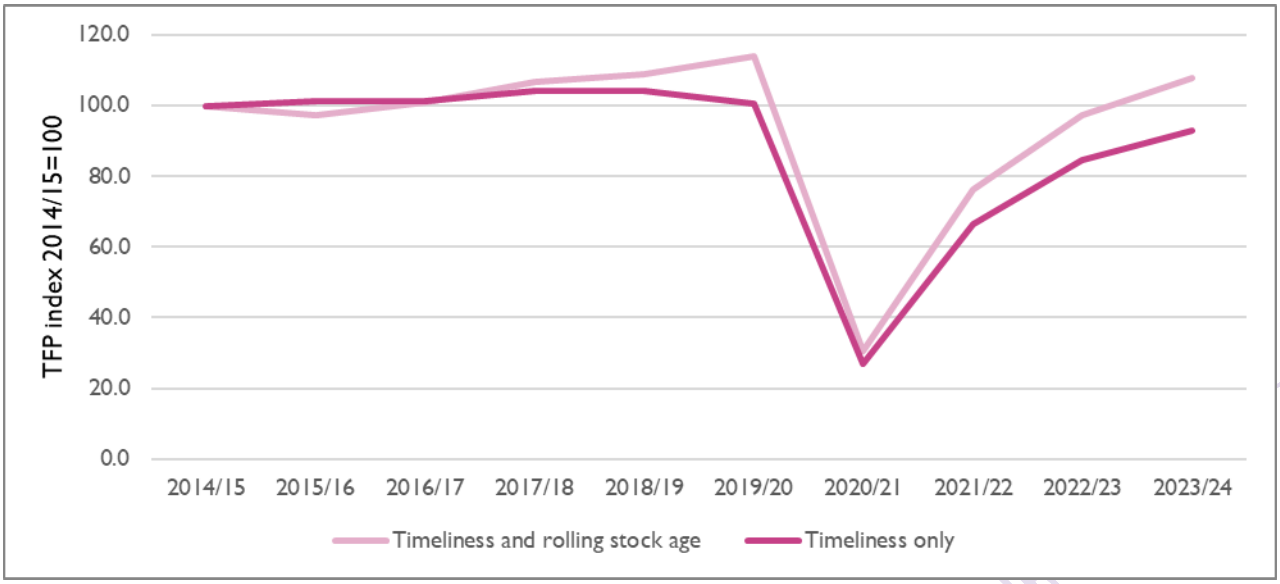


Source: Europe Economics calculations

Alternative GO quality adjustment

In this sensitivity we test the impact of only adjusting passenger rail output for timeliness (i.e. not making a quality adjustment for rolling-stock age). As can be seen from the figure below, the quality adjustment for rolling stock makes a material positive impact to industry TFP figures.

Figure 3.10: Industry TFP indices using alternative quality adjustments



Source: Europe Economics calculations

Alternative measure of Network Rail's initial capital stock

A key modelling choice in our framework is the opening (start-of-period) value used to calibrate the Perpetual Inventory Method (PIM) for Network Rail's capital stock. This is important because the PIM constructs the capital stock time series by combining an initial valuation with subsequent renewals and enhancements and assumptions on depreciation. The choice of opening valuation therefore affects the level and growth rate of the resulting capital services series. Since TFP is calculated as output growth minus cost-weighted input growth, any change to measured capital input growth feeds directly into measured TFP.

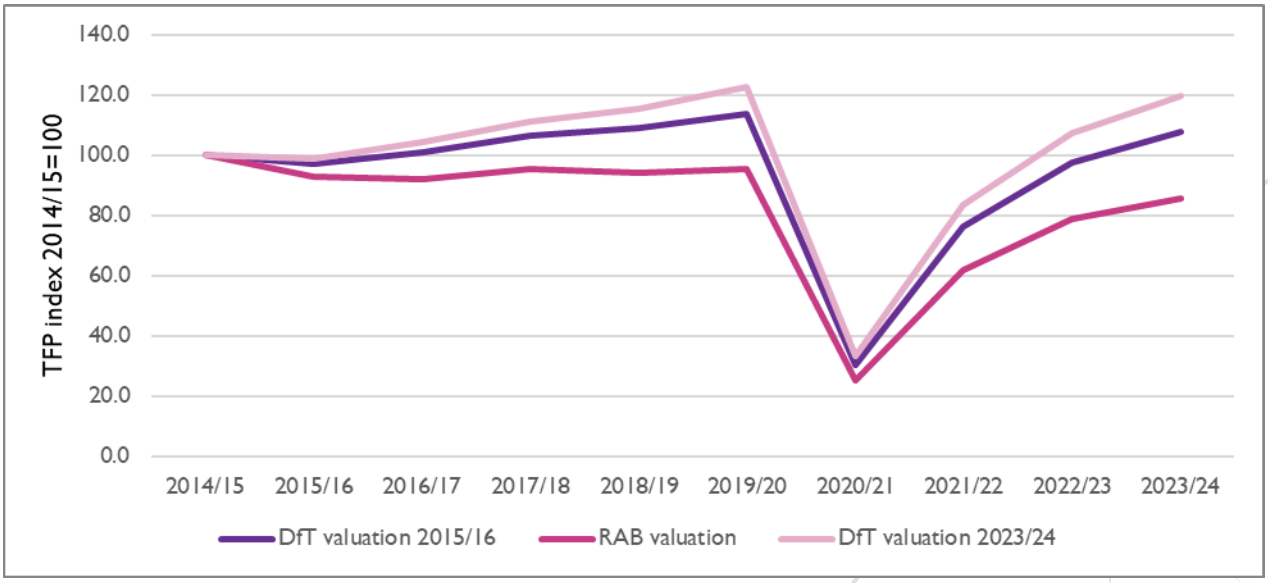
In our preferred specification, Network Rail's initial capital stock in 2014/15 is anchored to the Department for Transport's DRC valuation of the rail network, as reported in its 2015/16 annual accounts. As a sensitivity test, we re-estimate capital services and whole-industry TFP using two alternative valuations:

- **Network Rail RAB valuation –** This uses the RAB as the opening valuation. The RAB is a regulatory construct designed for price control purposes and is not intended to measure replacement cost. It reflects historical transfer values and subsequent regulatory adjustments, and therefore diverges materially from the DfT DRC valuations.
- **DfT DRC valuation (2023/24) –** This uses a more recent DRC estimate from the DfT's 2023/24 accounts and rolls it back to 2014/15 using the PIM approach, as described in Section 2.5.3. This provides a useful cross-check on the effect of anchoring the PIM on a later valuation.

Figure 3.11 compares the resulting TFP indices, which differ substantially. Using the default 2015/16 DRC valuation, whole-industry TFP rises steadily in the pre-pandemic period, but using the 2023/24 valuation leads to faster TFP growth. Under the RAB-based specification, by contrast, TFP drifts down over the same period and remains below its 2014/15 level even by 2023/24. All specifications show a sharp fall in 2020/21 and a subsequent recovery, but the longer-term trends differs markedly: the DRC series point to modest underlying productivity growth (particularly using the 2023/24 valuation), whereas the RAB series suggests a gradual deterioration in productivity.

These differences arise because the RAB is materially lower than the DRC valuation in 2014/15, which in turn is materially lower than the 2023/24 valuation. This means that the annual depreciation of the capital stock is much lower when using the RAB, and is highest for the 2023/24 valuation, while annual investment in new capital (renewals and enhancements expenditure) is the same in all scenarios. Therefore, under the DRC valuations, depreciation of the network each year is larger than new investment, and the flow of capital services gets smaller each year, while the reverse is true under the RAB valuation. Given output is the same in each sensitivity, the result is that under the DRC scenarios, Network Rail (and the industry as a whole) is producing a steady flow of output with a reducing flow of capital services, while in the RAB scenario the flow of capital services is increasing faster than output. As is clear from the figure, the choice for the estimated value of the initial capital stock has a significant impact on the overall findings for industry TFP.

Figure 3.11: Industry TFP indices using alternative measure of Network Rail's initial capital stock



Source: Europe Economics calculations

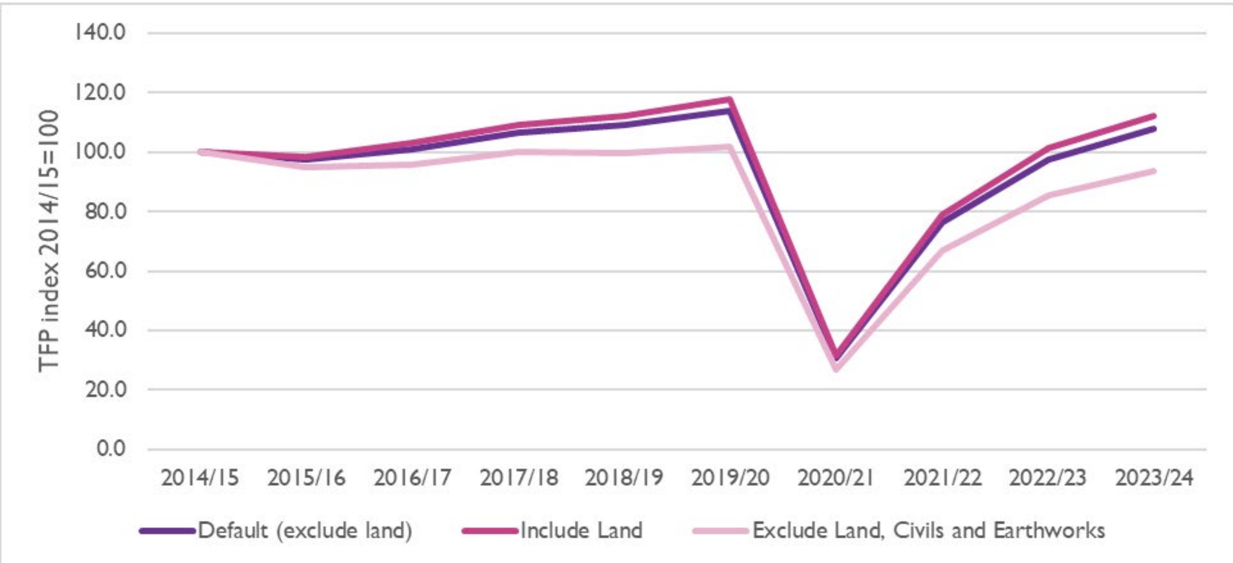
We regard the DRC-based results as the more appropriate measure of economic productivity. The DRC valuations are explicitly designed to reflect the current replacement cost of the physical railway assets and hence the scale of the real resources embodied in the network. The RAB, by contrast, is a regulatory construct used for price-control purposes. It is influenced by the fact that the assets were sold at below their replacement cost at privatisation, and does not correspond directly to productive capital. Using the RAB as a measure of capital input mixes regulatory accounting with economic measurement in a way that is not well aligned with the concept of TFP.

We adopt the **DfT 2015/16 DRC valuation** as our central calibration because is the earliest available DRC anchor and therefore requires the least back-casting to reach the start of our estimating period (2014/15). Using the 2023/24 DRC valuation requires rolling back the capital stock over a much longer horizon. Doing so compounds the influence of modelling assumptions (for example, depreciation rates and the treatment of renewals and enhancements) and increases exposure to any inconsistencies in recorded investment series over time. In practice, the implied 2014/15 value generated from the 2023/24 anchor is materially higher than the implied value generated from the 2015/16 anchor, and we interpret this as indicating greater sensitivity to back-casting over longer periods rather than necessarily being a more reliable estimate of the network's value at the start of our period.

In addition to the choice of opening valuation source (DfT DRC versus RAB, and the choice of anchor year), results are also sensitive to the **asset coverage** of the Network Rail opening capital stock. The DfT DRC valuation can be decomposed into land and several other components, and we use this breakdown to test the effect of excluding specific asset classes from the opening stock used to calibrate the PIM. In our preferred specification, land is excluded from the asset base.

This choice matters because excluding an asset class reduces the level of the opening stock. For a given profile of renewals and enhancements, a lower opening stock implies faster proportional growth in capital services, increasing measured input growth and therefore reducing measured TFP (all else being equal). Conversely, including additional assets (such as land) raises the opening stock and tends to increase measured TFP. The figure below shows two additional sensitivities, one where land is included, and one where Civils and Earthworks are excluded alongside land.

Figure 3.12: Industry GO TFP using alternative asset coverage for the railway network valuation



Including land in the railway network valuation increases measured TFP growth across each year. By 2023/24 the whole-industry TFP index is around 5 points higher with land included. This is consistent with the higher opening stock implying slower measured capital services growth (or faster reduction in capital services) and therefore a larger residual attributed to TFP.

We have also tested excluding Civils and Earthworks from the valuation, along with land. These are assets with very long lives and low depreciation, and a low rate of renewals expenditure. Excluding civils and earthworks (in addition to land) materially reduces measured TFP growth because is significantly reduces the initial capital stock value. TFP in 2023/24 is below its 2014/15 value under this sensitivity, which is not the case for the other specifications.

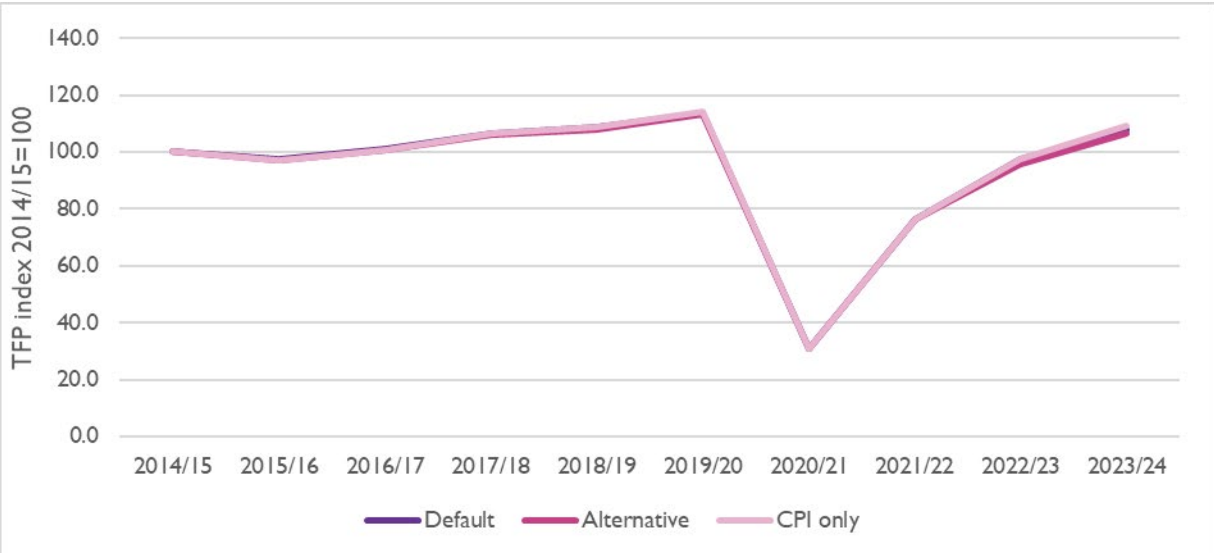
Network Rail capital is a large component of total industry inputs, which means the opening valuation is a first-order driver of both Network Rail TFP and whole-industry TFP. We therefore treat this as a key uncertainty and present these sensitivities so that readers can see the extent to which results depend on the calibration choice. The sensitivities show that the more that is excluded from the opening valuation, the lower measured TFP growth tends to be.

Alternative price indices

Figure 3.13 presents quality-adjusted gross TFP results when the price indices used to deflate nominal costs for capital and intermediate inputs are changed. This also changes the index used to convert monetary valuations of the railway network into 23/24 prices. The core ("default") and alternative sets of asset price indices are set out in Section 2.5.6. We also present results when all prices are assumed to move in line with CPI (i.e. real asset price inflation is zero).

The TFP results for the alternative index set are marginally lower than the core results, on average, and the TFP results for the CPI-only sensitivity are marginally higher than the core and alternative sets.

Figure 3.13: Quality-adjusted industry GO TFP index with alternative price indices



Source: Europe Economics calculations

Alternative depreciation assumptions

The next sensitivity examines the impact of alternative depreciation assumptions on industry capital-services growth and the resulting TFP estimates.

In the baseline, depreciation rates are derived from asset-specific assumptions on average lives (those used to value Britain's railway network in the Department for Transport annual accounts) converted from straight-line depreciation assumptions to declining-balance depreciation assumptions.[6]

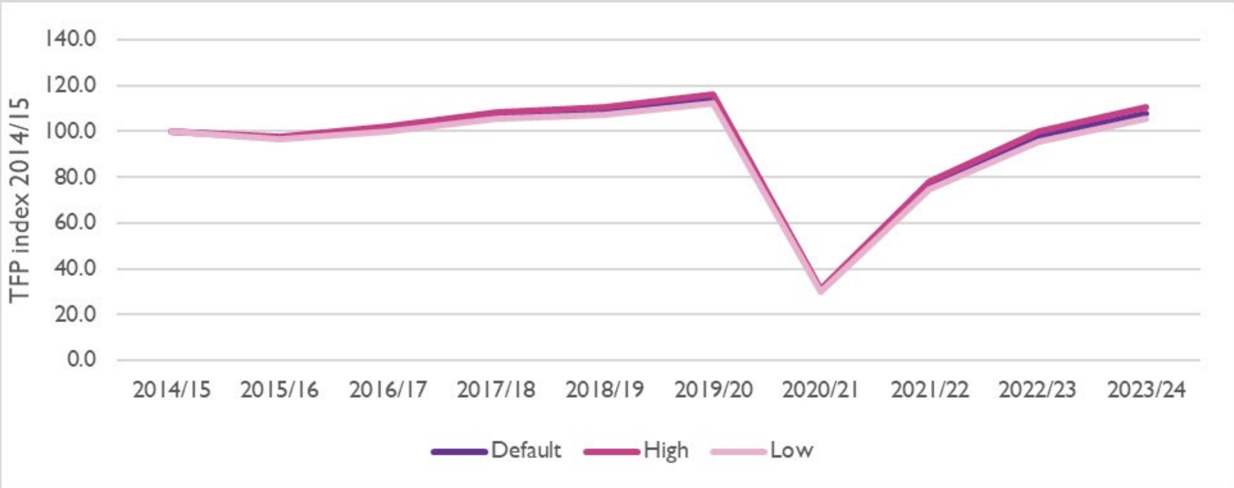
[6] DfT Annual Report and Accounts 2024-25 p. 247 [online]

To test sensitivity, we apply two variants:

- **High depreciation scenario:** assumes 10 per cent shorter asset lives. This changes the path of capital stocks and the user cost of capital, and hence the profile of capital services.
- **Low depreciation scenario:** assumes 10 per cent longer asset lives.

The industry TFP results are reasonably stable to changes in the depreciation assumptions. TFP growth is higher in the high depreciation scenario, and lower in the low depreciation scenario. This is because the reduction in capital inputs (particularly for Network Rail) is more (less) pronounced when depreciation is higher (lower), while output and other inputs are unaffected. However, the impacts on the TFP results are relatively minor.

Figure 3.14: Quality-adjusted industry GO TFP index with alternative depreciation assumptions



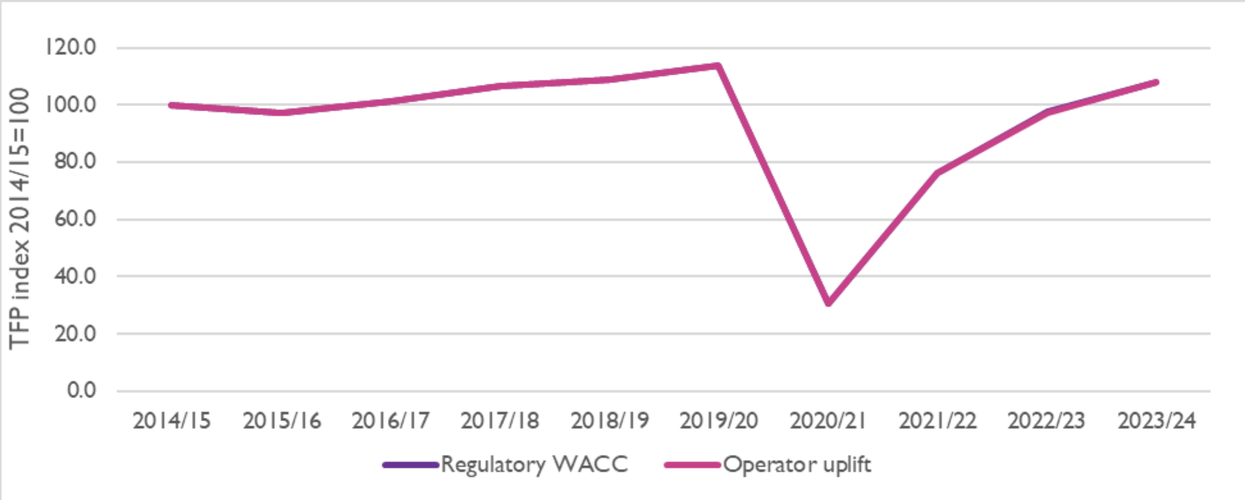
Source: Europe Economics calculations

Alternative rate of return

This sensitivity alters the rate of return assumption used to estimate the user cost of capital inputs for operators. The default assumption is the regulatory WACC set by ORR for Network Rail. Given this WACC is set specifically for Network Rail, and investors in operators may incur higher systematic risks and thus demand higher returns, we apply a 2 per cent uplift to the regulatory WACC as a sensitivity test. To be clear, this is not an estimate of what the appropriate WACC is for TOCs. The uplift is purely intended to test the sensitivity of the results to movements in the assumed rate of return. Industry TFP results are stable to changes in the rate of return assumptions for operators.

One limitation to this sensitivity is that the key capital input for operators is rolling stock, and our modelling approach (which is to use lease payments as a proxy for the flow of capital services) does not allow us to change the implicit WACC embodied in the rolling stock element of capital services.

Figure 3.15: Quality-adjusted industry GO TFP index with alternative rate of return for operators



Source: Europe Economics calculations

Capacity utilisation adjustments

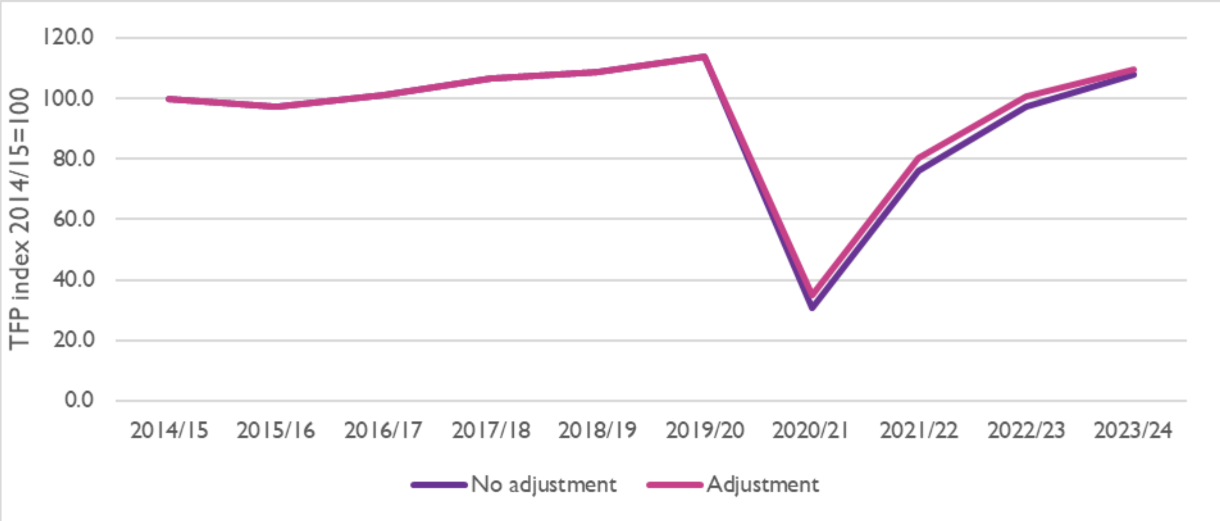
We test whether the extreme Covid-era swings in TFP reflect under-utilisation of a largely fixed capital base rather than changes in technical efficiency. Following the approach used by Griffith et al (2004),[7] we adjust capital services by the deviation of GO from its pre-Covid trend: for each year, we compare output with a trend fitted over 2014/15–2019/20 and scale capital inputs down in proportion to the shortfall. The adjustment is applied only when output is more than 20 per cent below trend. For TOCs (and the whole industry) this criterion is met in 2020/21, 2021/22 and 2022/23 (it is not triggered for Network Rail or freight in any years). Figure 3.45Figure 3.16 shows the effect: the 2020/21 trough in whole industry TFP is marginally less severe, However, the adjustment does not appear to fully capture the fall in capacity utilisation, likely because only TOC capital inputs are adjusted, which account for a small portion of industry capital inputs (as industry capital inputs are dominated by Network Rail's capital inputs). We do not adjust Network Rail's capital inputs because Network Rail output (train km) did not drop as substantially from its trend level during the pandemic.[8]

We adjust only TOC capital services for capacity utilisation and leave labour and intermediates unchanged. This follows the standard approach in the productivity literature, which treats capital as the main quasi-fixed factor whose effective services vary with utilisation, and labour and intermediates as more flexible inputs. If the adjustment were also applied to labour and intermediates, the TFP drop during Covid would again get smaller.

[7] Griffith, R., Redding, S., & Reenen, J. V. (2004). Mapping the two faces of R&D: Productivity growth in a panel of OECD industries. *Review of economics and statistics*, *86*(4), 883-895. Appendix 2.3. [online]

[8] Train km was around 14 per cent below its pre-pandemic trend in 2020/21. Passenger-km was around 80 per cent below trend.

Figure 3.16: Quality-adjusted industry GO TFP index with capacity utilisation adjustment for TOCs



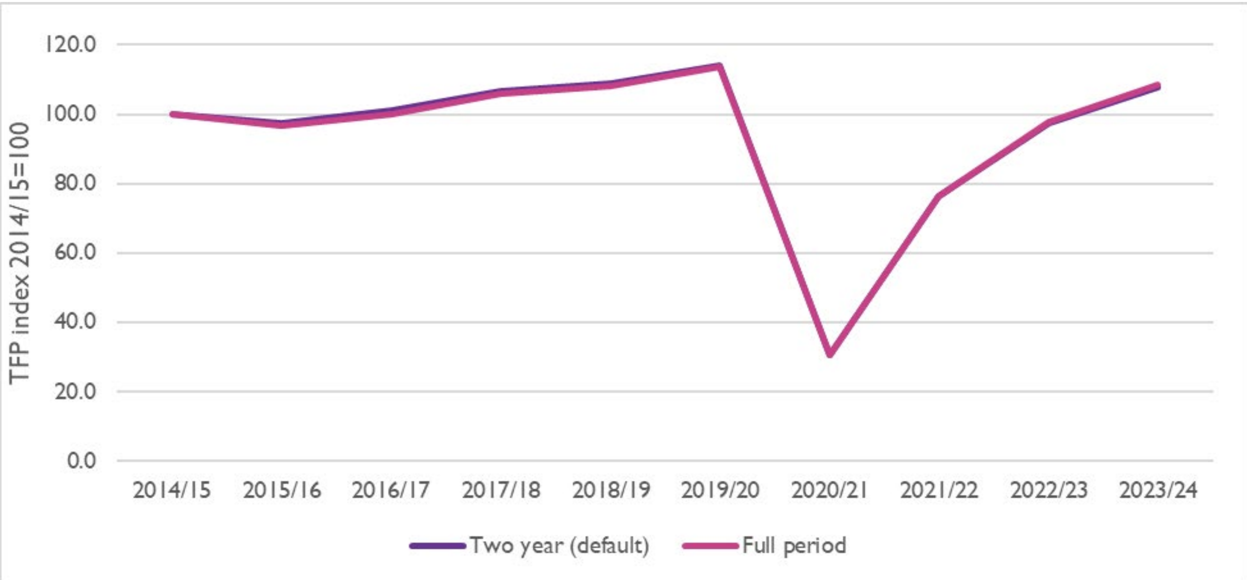
Source: Europe Economics calculations

Alternative Törnqvist weights

This sensitivity tests the effect of alternative Törnqvist weighting on TFP. In the baseline, cost shares for labour, capital and intermediates are averaged over two consecutive years, giving greater weight to short-term variation in input composition. The alternative approach uses average cost shares across the full estimation period, smoothing out year-to-year fluctuations in cost shares.

As input cost shares for the industry are relatively stable across time, the impact of the Törnqvist averaging period sensitivity test is limited for industry TFP, such that there is no material change from the core results.

Figure 3.17: Quality-adjusted industry GO TFP index with alternative Tornqvist assumptions



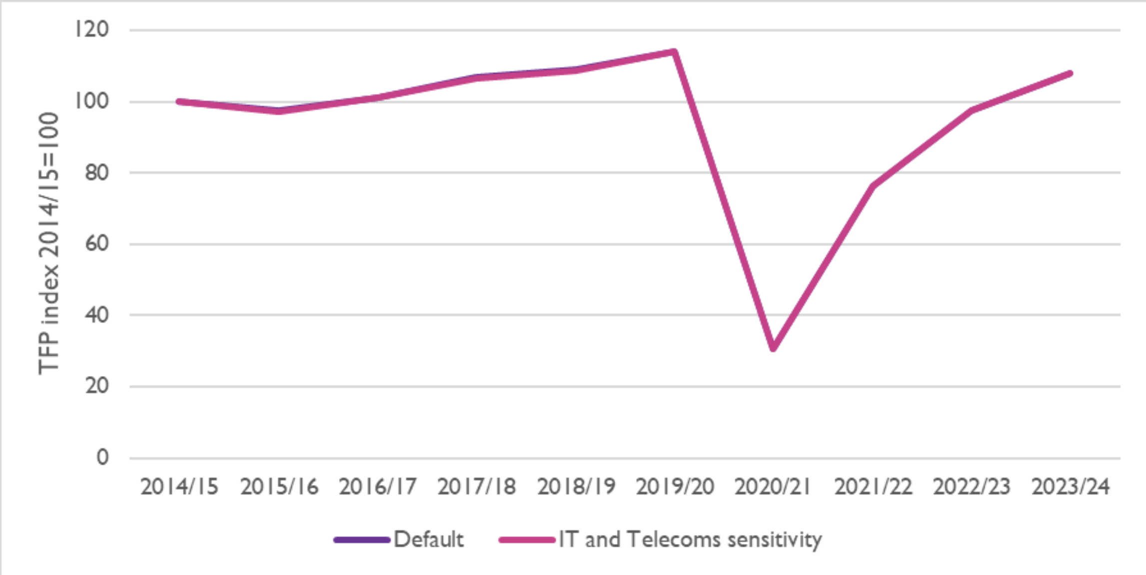
Source: Europe Economics calculations

Network Rail enhancement spending distribution

The final sensitivity tests the impact of varying the assumed split of enhancement expenditure across asset categories. The default assumption is to split enhancement expenditure across asset categories (track, signalling etc.) in line with the split that is observed for renewals expenditure. In the sensitivity, we increase the assumed weight for IT and Telecoms assets by 50 per cent (so Telecoms share rises from around 5 per cent to around 7.5 per cent, for example). We vary the weight for these categories because they are the fastest depreciating categories of assets in Network Rail's breakdown and therefore changes to these categories will have the largest relative impact on overall capital services (as the user cost of a given asset increases with depreciation).

As shown in the figure below, varying the assumed enhancements spend in this way does not materially impact TFP results.

Figure 3.18: Quality-adjusted industry GO TFP index with alternative enhancement distribution



Source: Europe Economics calculations

3.2 Network Rail

This section presents TFP results for Network Rail.

3.2.1 GO TFP results

Our preferred measure of GO for Network Rail is the annual combined total of passenger train km and freight train km. Table 3.4 sets out the annual change in GO TFP for Network Rail over our estimation period.

Table 3.4: Network Rail annual GO TFP growth (%)

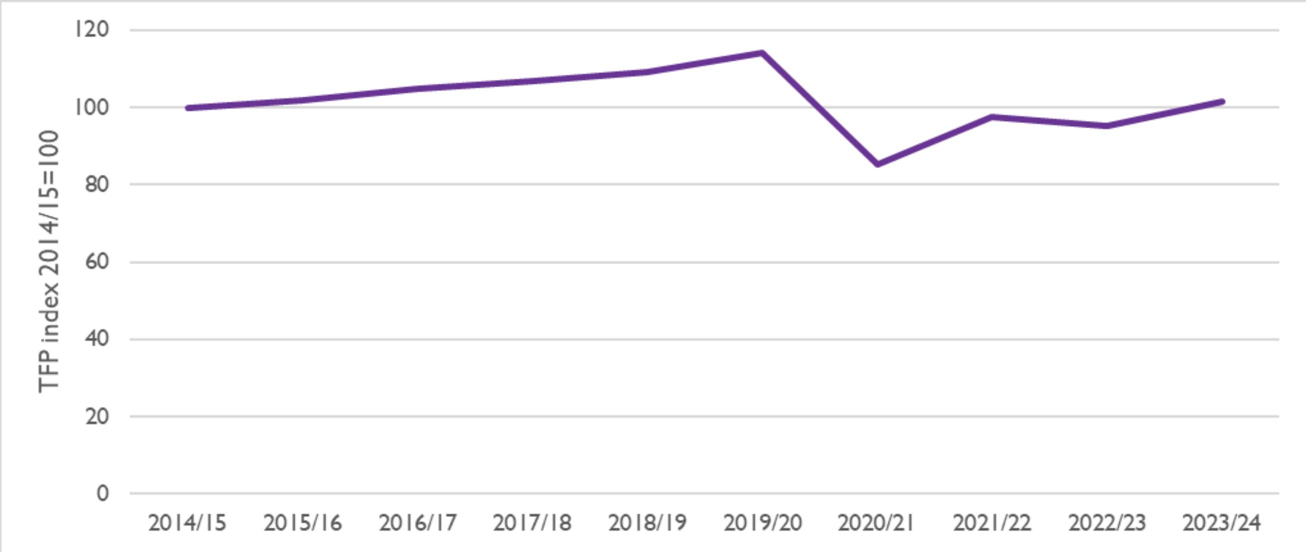
	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	1.8	2.9	2.1	2.1	4.5	-25.3	14.2	-2.3	6.8

Source: Europe Economics calculations

Figure 3.19 shows that Network Rail's GO TFP increases steadily from 2014/15 up to the pandemic in 2020/21. As shown in Figure 3.20, which decomposes output growth into changes in capital, labour, intermediates and TFP, this is because GO was relatively flat during this period, while inputs (particularly capital) were decreasing in real terms. This is similar to the whole industry findings.

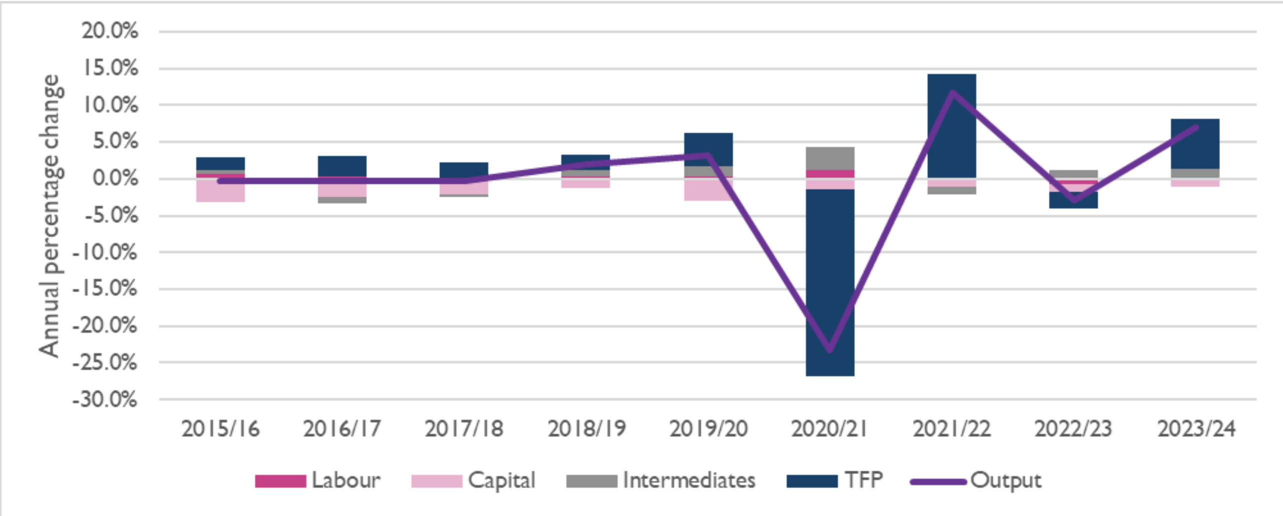
The fall in TFP in 2020/21 reflects a drop in train-kilometres due to the pandemic, though it is far less pronounced than the output drop for operators. The TFP rebound in 2021/22 is consistent with the restoration of services. TFP fell marginally in 2022/23, then rose significantly in the final year of our period. By the end of the period, the TFP index is marginally above its 2014/15 level.

Figure 3.19: Network Rail GO TFP index, 2014/15=100



Source: Europe Economics calculations

Figure 3.20: Decomposition of Network Rail output growth (GO)



Source: Europe Economics calculations

3.2.2 Quality adjusted GO TFP results

We next report quality-adjusted GO TFP for Network Rail. The output measure is the combined passenger and freight train-kilometres, adjusted for timeliness (T-3 for passenger services; T-15 for freight). Table 3.5 presents the year-on-year growth in quality-adjusted GO TFP over the estimation period.

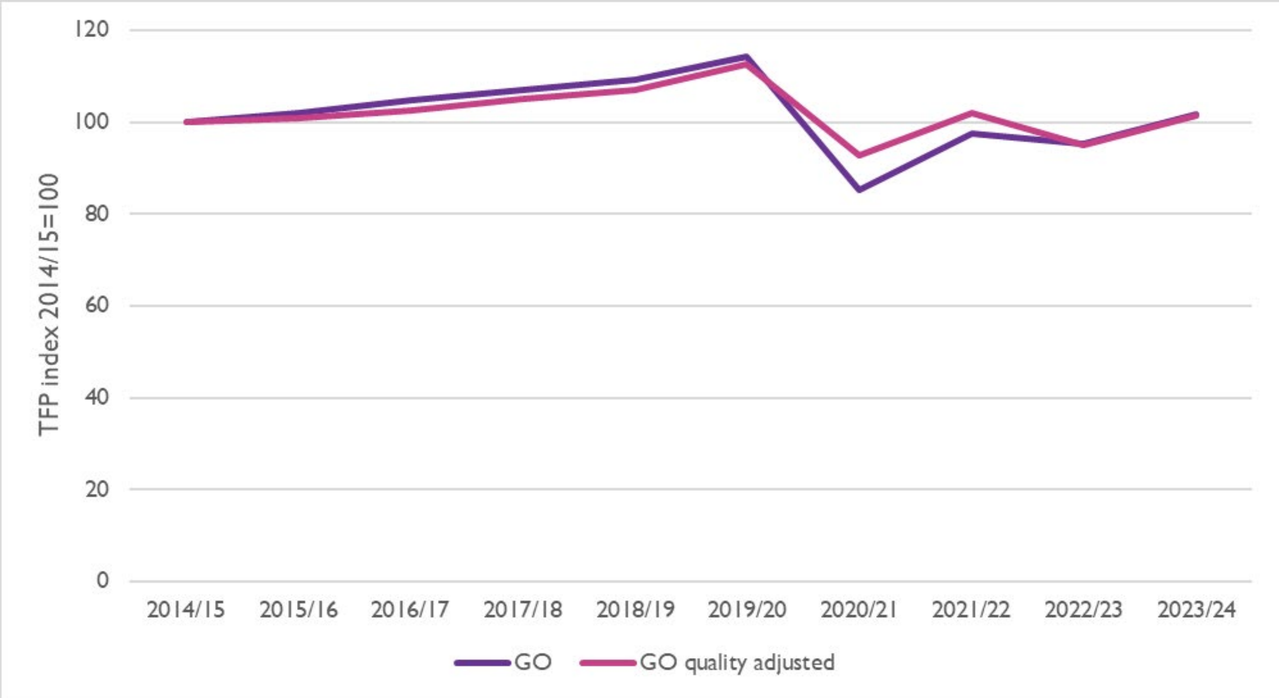
Table 3.5: Network Rail annual quality-adjusted GO TFP growth (%)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	0.9	1.6	2.5	1.7	5.4	-17.7	9.9	-6.8	6.7

Source: Europe Economics calculations

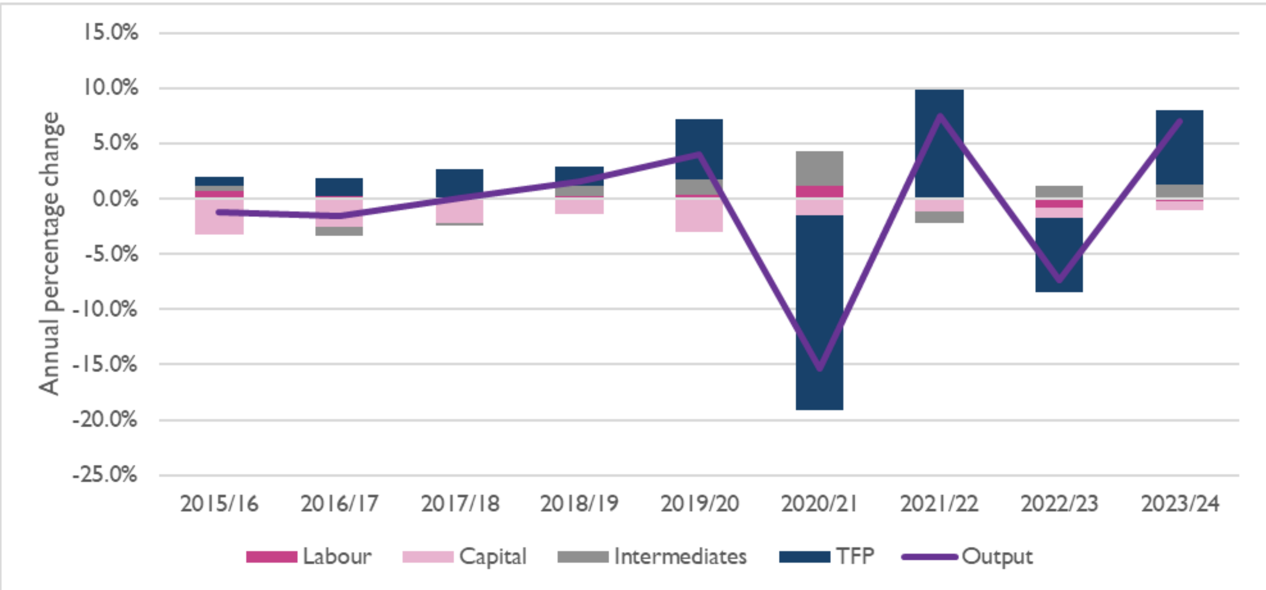
Figure 3.21 presents the quality-adjusted TFP index and the unadjusted GO TFP index in the previous section, for comparison. The pattern is similar for both indices, though the pandemic drop in TFP is smaller for the quality-adjusted index. This is due to the reduction in traffic during the pandemic leading to an improvement in timeliness. Figure 3.22 decomposes quality-adjusted output growth, showing that the year-to-year swings in quality-adjusted train km are predominantly TFP-driven, with increases in TFP offsetting annual reductions in capital inputs.

Figure 3.21: Network Rail quality-adjusted GO TFP index, 2014/15=100



Source: Europe Economics calculations

Figure 3.22: Decomposition of Network Rail output growth (quality-adjusted GO)



Source: Europe Economics calculations

3.2.3 GVA TFP results

Table 3.6 reports the year-on-year growth in GVA TFP over the estimation period. As discussed in Section 2.2.1, annual GVA for Network Rail is calculated as the sum of total employee costs and depreciation.

Table 3.6: Network Rail annual GVA TFP growth (%)

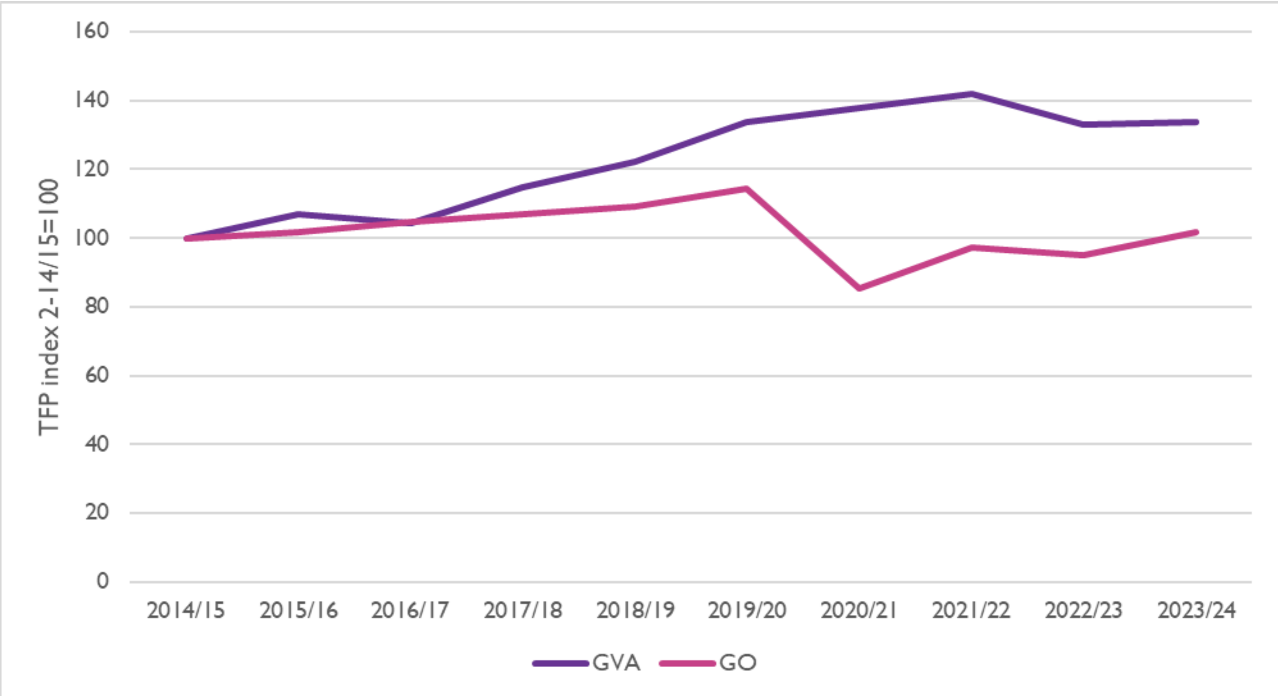
	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	6.8	-2.2	9.7	6.5	9.6	3.1	2.9	-6.3	0.8

Source: Europe Economics calculations

As seen in Figure 3.23, Network Rail's GVA-based TFP index rises strongly over the period. Annual GVA TFP growth is positive in every year except 2016/17 and 2022/23. By 2019/20 the index is more than 30 per cent above its 2014/15 level and it finishes the period at a similar level. This contrasts with the GO-based TFP index constructed using passenger and freight train-km, which grows more slowly pre-pandemic, falls back towards 2014/15 levels in 2020/21, and is only around 1.5 per cent above its 2014/15 level by 2023/24. Figure 3.24 shows one of the key drivers of the difference – GVA output actually grew in 2020/21, despite the large fall in rail traffic.

The divergence between GVA- and GO-based TFP reflects, in part, the way we construct GVA for Network Rail. In the absence of an official National Accounts series, we define Network Rail's GVA as the sum of staff costs and depreciation – an approach that is consistent with that taken by other studies of the rail industry.[9] This approach is closer to an income-based measure of value added than a production-based measure (gross output less intermediate consumption). As a result, movements in the proxy GVA series can be driven by changes in labour costs and the recorded depreciation charge. even where the underlying volume of rail services is relatively stable. GO-based TFP, by contrast, is anchored to physical volumes of rail activity (with quality adjustments).

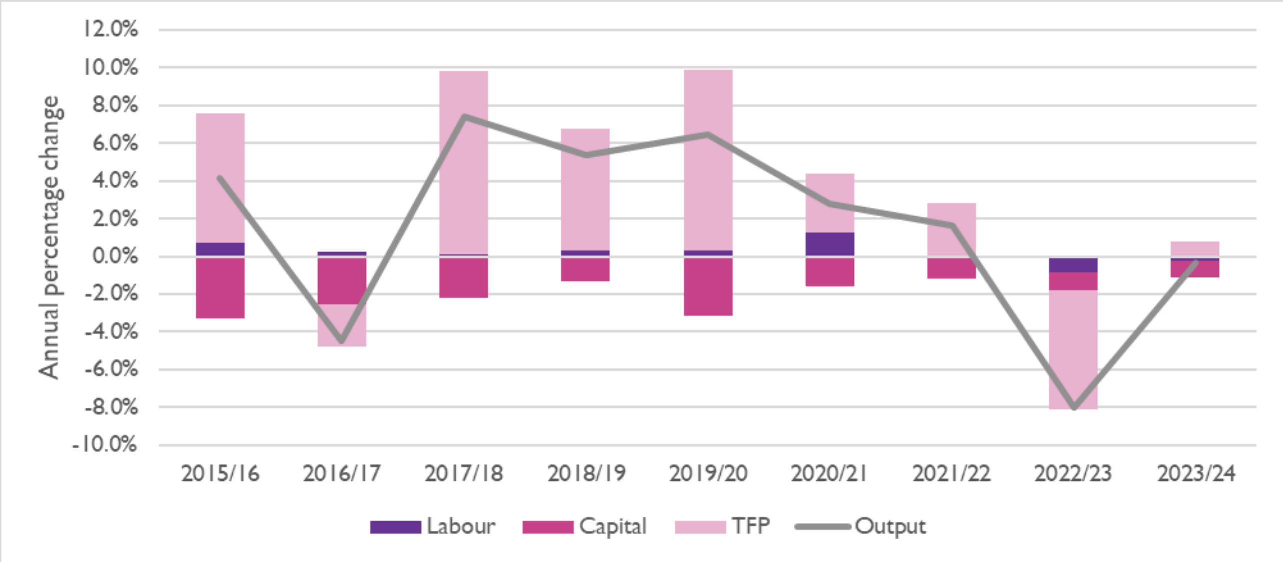
Figure 3.23: Network Rail GVA TFP index, 2014/15=100



Source: Europe Economics calculations

[9] The same approach was used in Oxford Economics 2018 report for the Rail Industry Association "The Economic Contribution of UK Rail" when measuring Network Rail's GVA [online]

Figure 3.24: Decomposition of Network Rail output growth (GVA)



Source: Europe Economics calculations

3.2.4 Sensitivities

We consider the following sensitivities for Network Rail's TFP results:

- **Output definition:** alternative traffic-based measures (including the unadjusted series) to test whether results depend on the measure of services or the quality adjustment that is applied.
- **Initial capital stock:** using alternative measures of Network Rail's capital stock at the start of 2014/15.
- **Network Rail enhancement expenditure:** adjusting the assumed split of enhancements expenditure across Network Rail's asset categories.
- **Price indices:** alternative deflators for intermediates and for capital asset prices to test the effect of different inflation measures on real input growth.
- **Depreciation assumptions:** alternative asset life assumptions that feed into the user cost of capital for capital services.
- **Törnqvist weighting:** full-period-average cost shares for inputs rather than two-period averages to test the influence of weight smoothing.

Alternative measures of GO

Figure 3.25 presents GO TFP results for two alternative measures of Network Rail's GO. The first is total train km, which adds infrastructure train km to passenger and freight train km. The second is renewals volumes, a measure used in ORR's productivity report, for which data is only available from 2019/20. Neither of the alternative GO measures provide much additional information of use. TFP results for total train km are very similar to our core results, because infrastructure train km are a very low share of total train km. The renewals volumes series is difficult to compare directly to the train km measures given the smaller sample period. It is also a less appropriate measure of output, given that renewals is arguably better thought of as an input for Network Rail.

Figure 3.25: TFP indices for alternative GO measures

Source: Europe Economics calculations

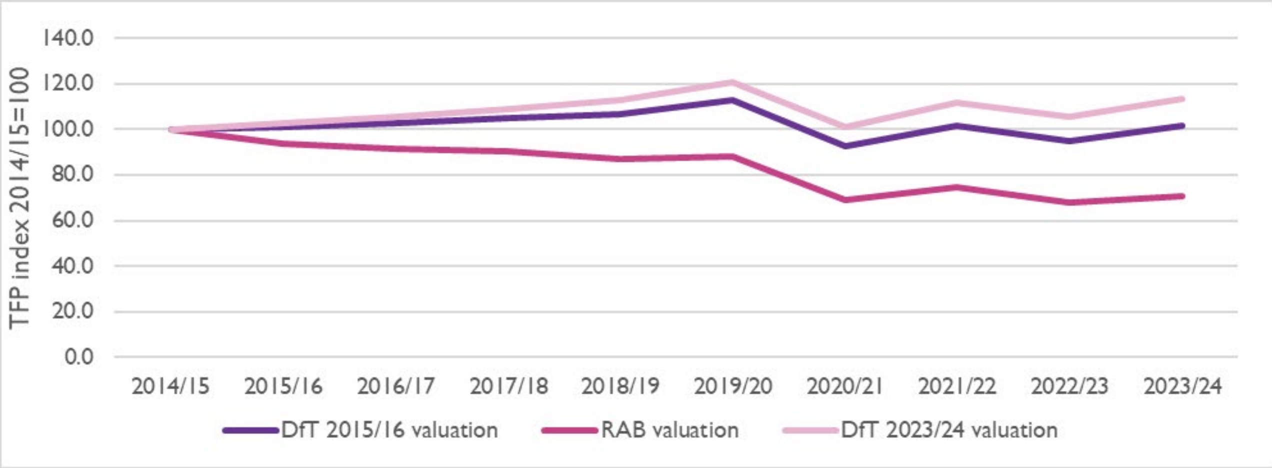
Alternative measure of Network Rail's initial capital stock

In this sensitivity, we test alternative measures for Network Rail's initial capital stock in 2014/15, following the same sensitivities as for the whole industry. As was the case for whole industry TFP, the choice for the estimated value of the initial capital stock has a significant impact on the overall findings for Network Rail's TFP.

Figure 3.26 shows that using the RAB valuation leads to Network Rail's TFP trending downwards over the period, such that by 2023/24 it is 30 per cent lower than its starting point in 2014/15. This is in direct contrast to our core results using the DRC valuation for Network Rail's initial capital stock, which show TFP increasing over the period. As discussed in the whole industry section, the difference is driven by the fact that DfT's DRC valuations are several times larger than the RAB, leading to capital services decreasing over time in the core results, while under the RAB sensitivity capital services are increasing each year. We view the DfT valuation as more appropriate for TFP analysis, for the reasons discussed when reporting this same sensitivity for the whole industry results.

Using the 2023/23 DfT valuation leads to materially higher TFP growth estimates for Network Rail, because the valuation is materially higher (when rolled back to 2014/15) than the 2015/16 valuation. As for the whole industry, we prefer the 2015/16 valuation because it requires less back-casting and therefore is less dependent on depreciation assumptions.

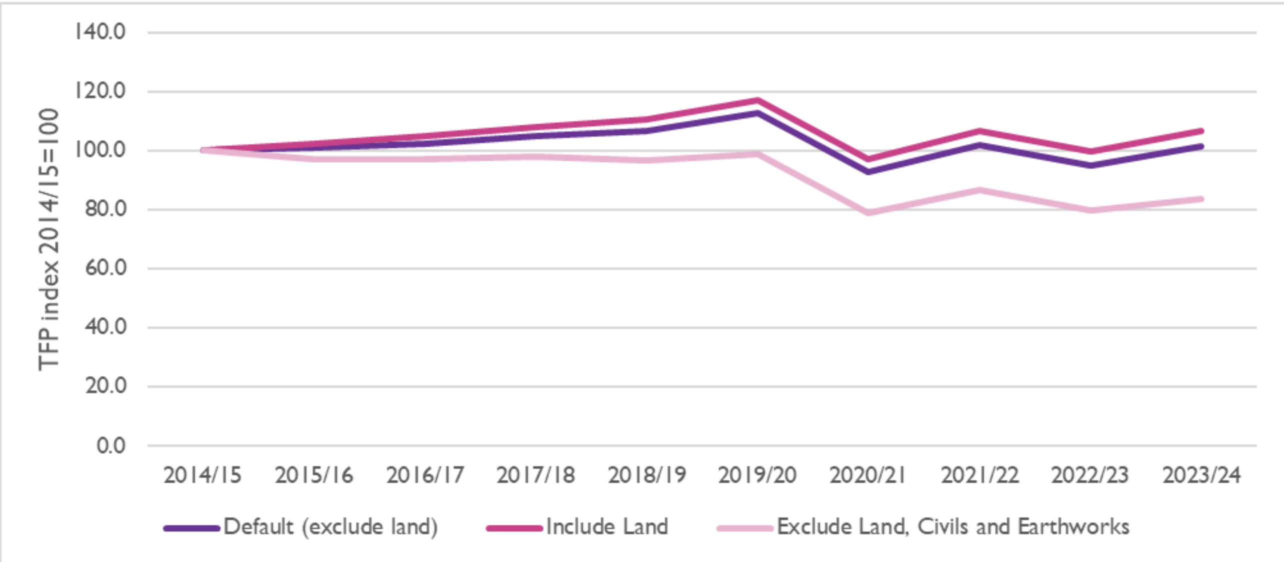
Figure 3.26: Quality-adjusted GO TFP index with alternative initial capital stock for Network Rail



Source: Europe Economics calculations

We also replicate the sensitivities in which we alter the assets included in the initial valuation (from 2015/16). We test including land, and then excluding land, civils and earthworks. We find the same pattern as for whole industry, which is that the more that is excluded from the initial valuation, the lower TFP growth is.

Figure 3.27: Industry GO TFP using alternative asset coverage for the railway network valuation

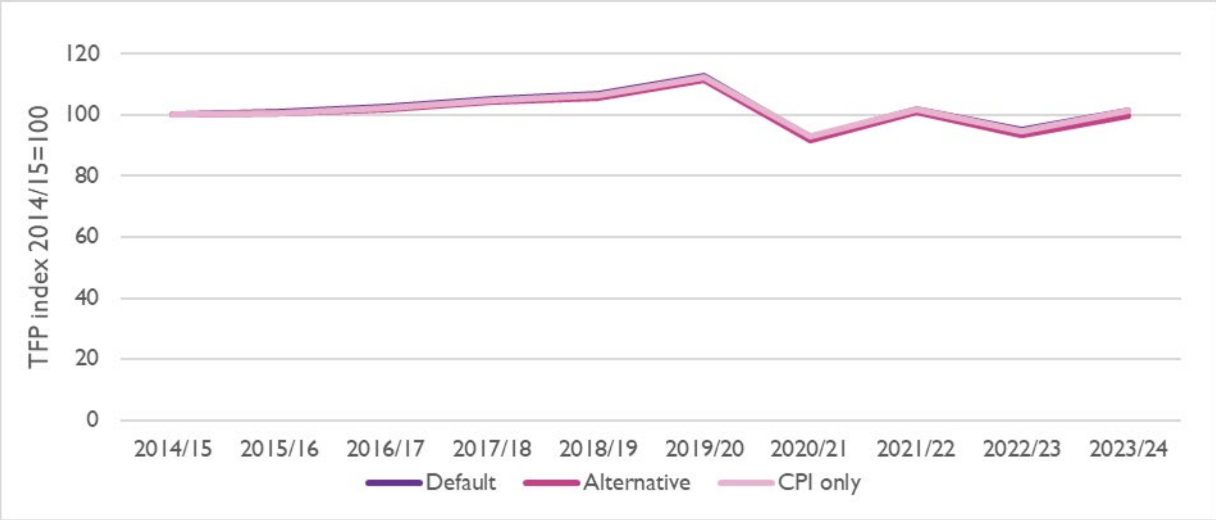


Source: Europe Economics calculations

Alternative price indices

Figure 3.28 presents quality-adjusted gross TFP results when the price indices used to deflate nominal costs for capital and intermediate inputs are changed. As seen from the chart, the results are fairly robust to the choice of indices. The TFP results for the alternative index set are marginally lower than the core results, on average, as are the TFP results for the CPI-only sensitivity.

Figure 3.28: Quality-adjusted GO TFP index with alternative asset price indices for Network Rail

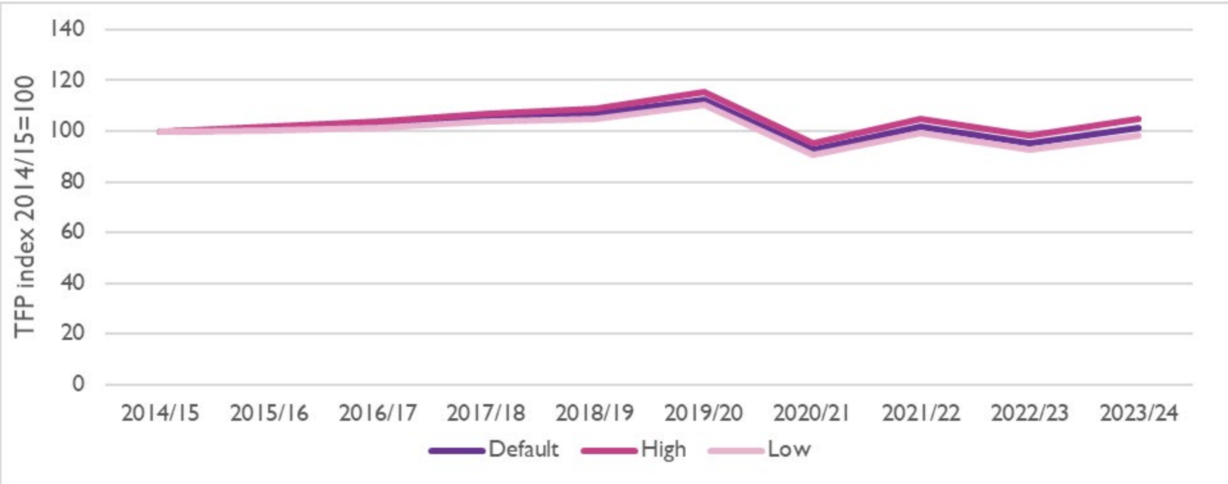


Source: Europe Economics calculations

Alternative depreciation assumptions

This next sensitivity examines the impact of alternative depreciation assumptions on Network Rail's capital-services growth and the resulting TFP estimates. Figure 3.29 compares the resulting quality-adjusted GO TFP indices under each assumption with the default depreciation rates in our core results. TFP growth is higher in the high depreciation scenario, and lower in the low depreciation scenario.

Figure 3.29: Quality-adjusted GO TFP index with alternative depreciation assumptions for Network Rail

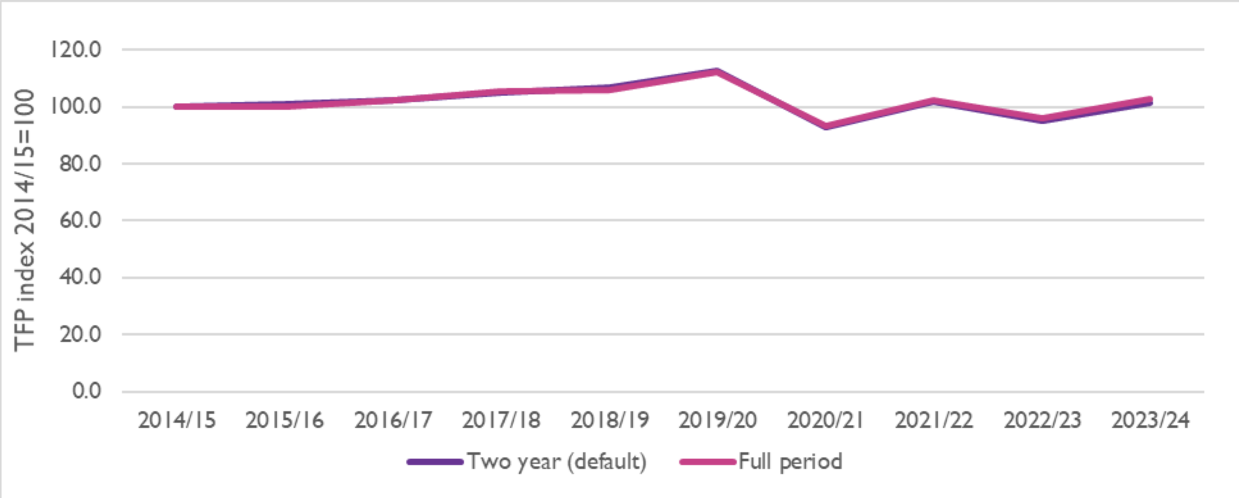


Source: Europe Economics calculations

Alternative Törnqvist weights

As with the whole industry results, this sensitivity tests the effect of alternative Törnqvist weighting on TFP. Over the period as a whole, TFP growth is marginally higher using the full period average weightings.

Figure 3.30: Quality-adjusted GO TFP index with alternative Törnqvist averaging for Network Rail



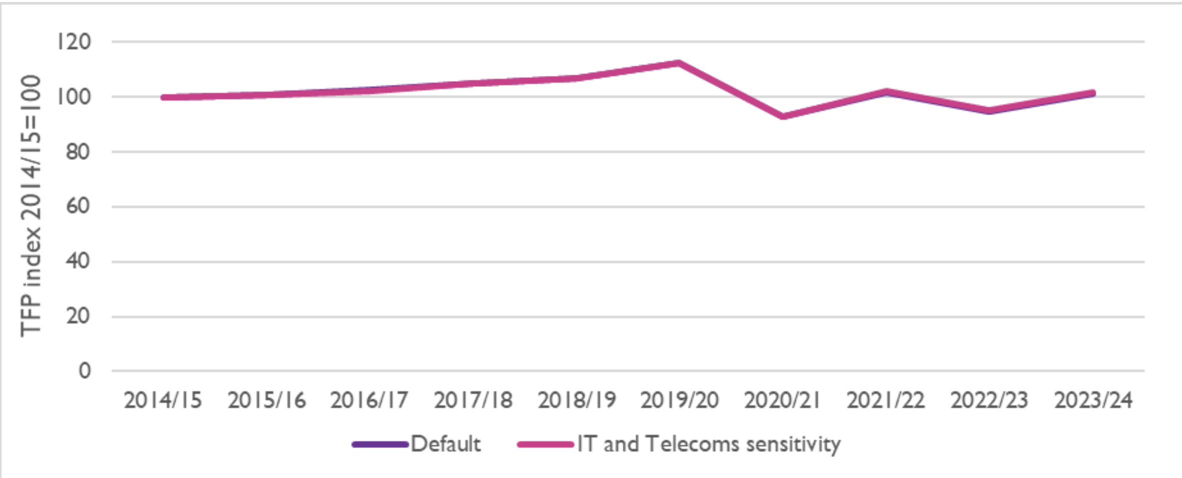
Source: Europe Economics calculations

Network Rail enhancement spending distribution

As with the whole industry results, the final sensitivity tests the impact of varying the assumed split of enhancement expenditure across asset categories. The default assumption is to split enhancement expenditure across asset categories (track, signalling etc.) in line with the split that is observed for renewals expenditure. In the sensitivity, we increase the assumed weight for IT and Telecoms assets by 50 per cent.

As shown in the figure below, varying the assumed enhancements spend in this way does not materially impact Network Rail's TFP results.

Figure 3.31: Quality-adjusted GO TFP index with alternative enhancements spend distribution



Source: Europe Economics calculations

3.3 TOCs

This section presents TFP results for TOCs.

3.3.1 GO TFP results

Our preferred measure of GO for TOCs is annual passenger km. Table 3.7 sets out the annual change in GO TFP for TOCs over our estimation period.

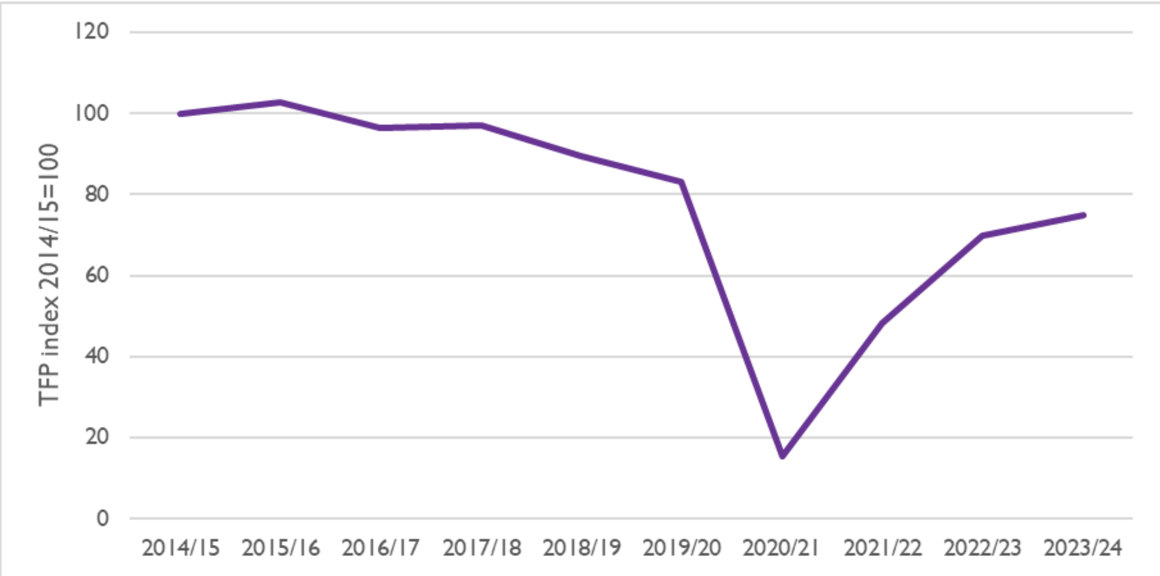
Table 3.7: TOC annual GO TFP growth (%)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	2.7	-6.0	0.6	-7.8	-7.2	-81.4	214.3	44.1	7.3

Source: Europe Economics calculations

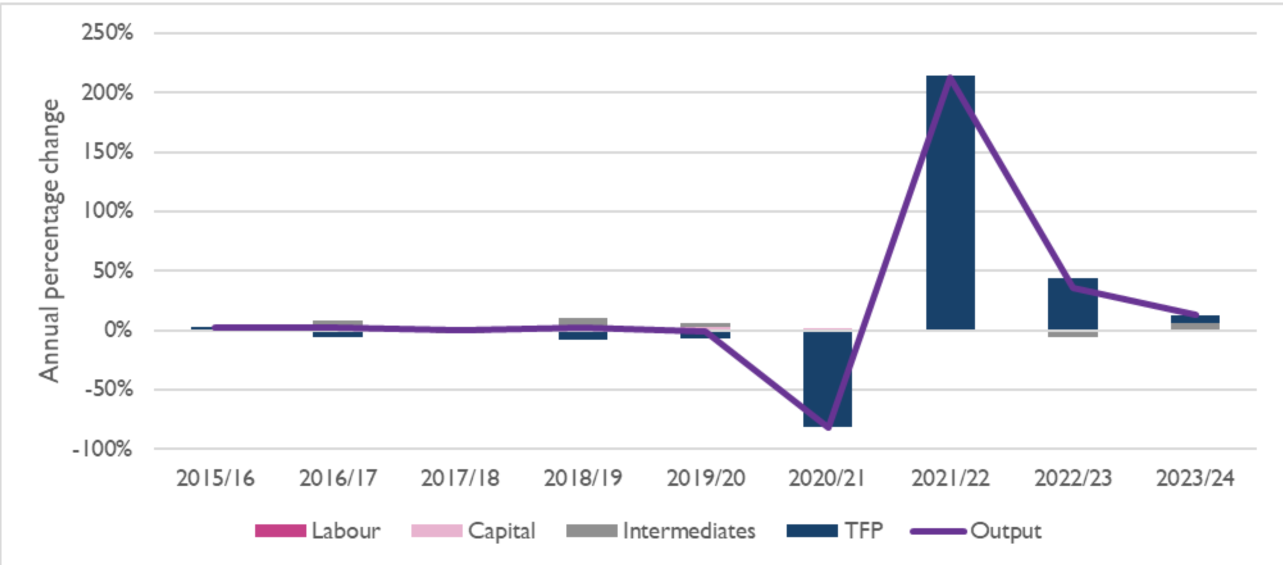
Figure 3.32 illustrates the cumulative GO TFP trend and Figure 3.33 illustrates the underlying drivers. TFP declines steadily from 2015/16 to 2019/20 before a sharp collapse in 2020/21 corresponding to the dramatic fall in passenger train km during Covid-19. This a followed by a large rebound in TFP in 2021/22 as output grew from a very low base. TFP remains below pre-pandemic levels in 2023/24. The decomposition attributes output volatility almost entirely to TFP as inputs remained relatively stable. Given the implausibility of such dramatic swings in underlying efficiency, the TFP results are likely to be capturing changes in capacity utilisation. We attempt to address this with a utilisation adjustment in our sensitivity analysis.

Figure 3.32: TOC GO TFP index, 2014/15=100



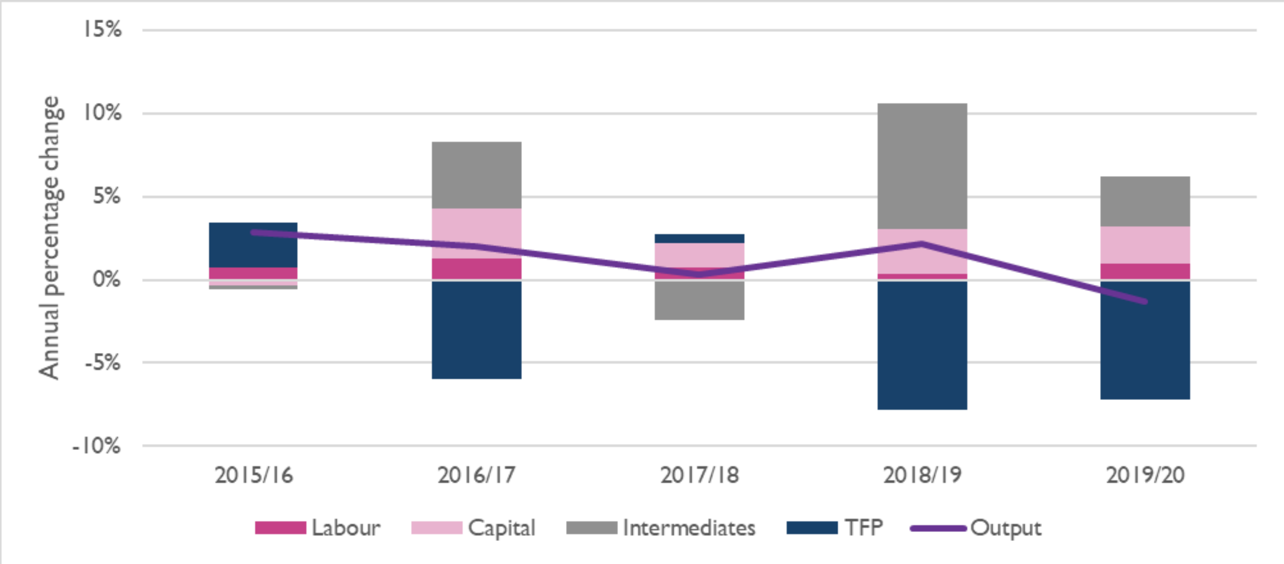
Source: Europe Economics calculations

Figure 3.33: Decomposition of TOC output growth (GO)



Source: Europe Economics calculations

Figure 3.34: Decomposition of TOC output growth (GO), 2014/15 to 2019/20



Source: Europe Economics calculations

Focusing on the decomposition of output in pre-pandemic years shown in Figure 3.34, we can see that in 2016/17, 2018/19 and 2019/20 capital inputs and intermediate inputs increased, without commensurate increases in output. This drives the negative TFP residuals estimated for those years.

3.3.2 Quality-adjusted GO TFP results

The next set of results applies a quality adjustment to TOC GO (passenger km), reflecting changes in service timeliness (measured by passenger arrivals within three minutes of schedule) and the quality of the rolling stock fleet (measured by average age of rolling stock). Table 3.8 presents the resulting year-on-year growth in quality-adjusted GO TFP.

Table 3.8: TOC annual quality-adjusted GO TFP growth (%)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	-2.4	-3.5	3.9	-6.3	2.2	-79.3	204.4	38.9	7.5

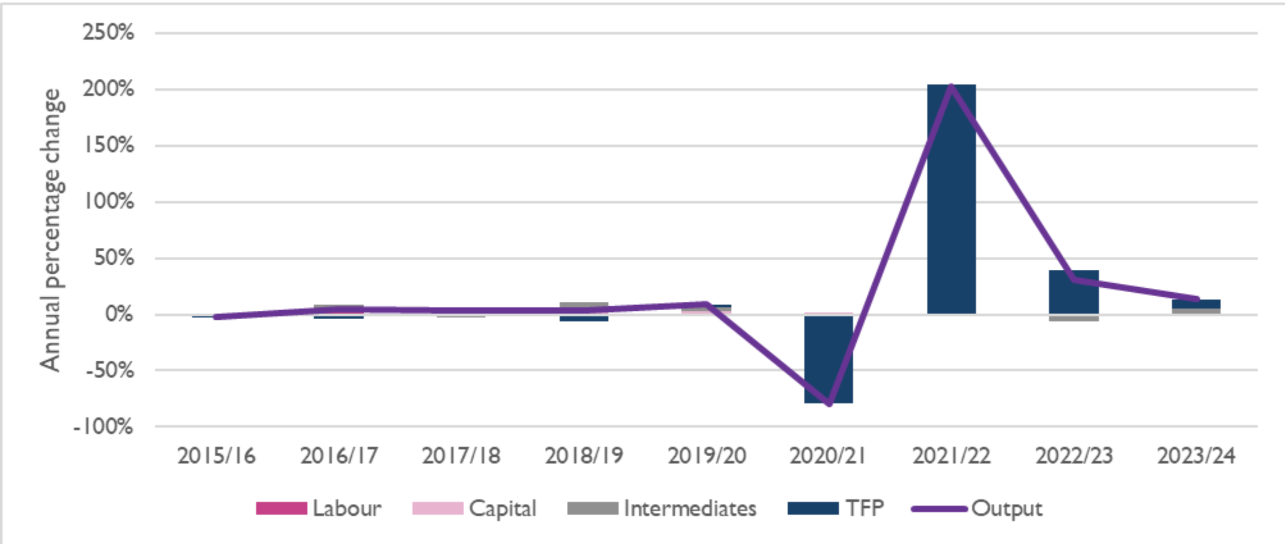
Source: Europe Economics calculations

Figure 3.35 shows that incorporating quality alters the pre-pandemic profile and moderates the extreme swings during the Covid-19 years. In the early years of the period TFP falls more rapidly when adjusting for quality, but by 2019/20 the situation is reversed (mostly due to increases in the quality of the rolling stock). The timeliness adjustment reduces the extent of the Covid-19 drop in TFP. Post-pandemic, improvements in rolling stock quality have led to quality-adjusted GO TFP being substantially above the unadjusted figures (though still below 2014/15 levels). The decomposition again shows that output volatility is driven almost entirely by the TFP component, with inputs broadly stable across the period. As with the unadjusted series, these large movements are better interpreted as reflecting shifts in capacity utilisation rather than genuine changes in underlying efficiency.

Figure 3.35: TOC quality-adjusted GO TFP index, 2014/15=100

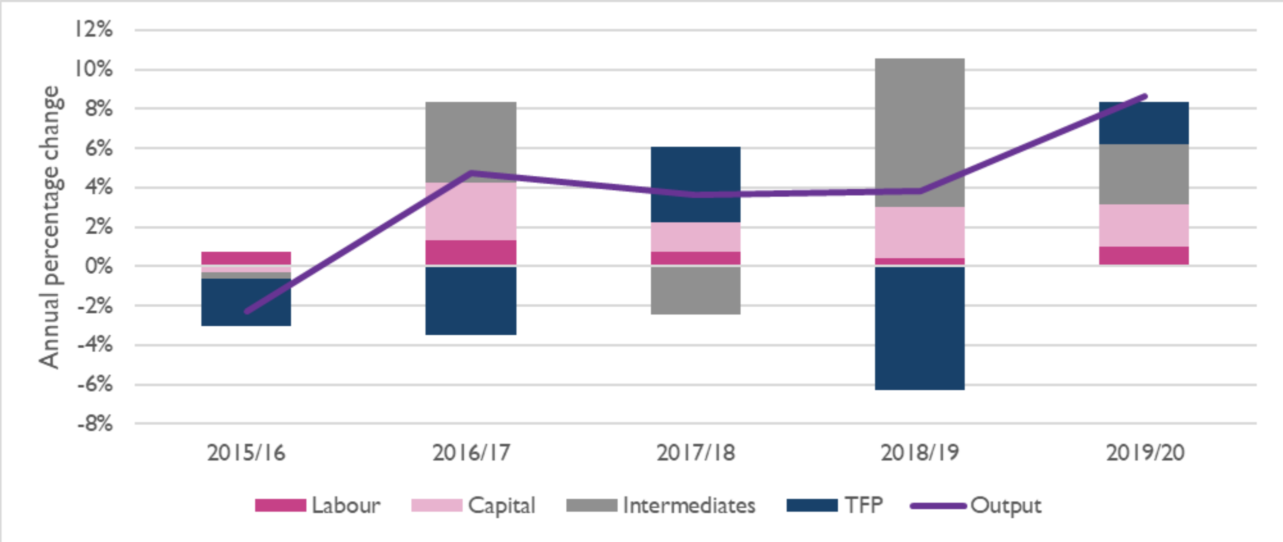
Source: Europe Economics calculations

Figure 3.36: Decomposition of TOC output growth (quality-adjusted GO)



Source: Europe Economics calculations

Figure 3.37: Decomposition of TOC output growth (quality-adjusted GO), 2014/15 to 2019/20



Source: Europe Economics calculations

Focusing on decomposing output changes in the pre-pandemic years, we can see from Figure 3.37 that output fell in 2015/16 despite increases in inputs, leading to a negative TFP residual. In 2016/17 and 2018/19, output grew but there was also significant growth in capital and intermediate inputs, meaning the TFP residual is negative for both years. TFP growth is positive in 2017/18 and 2019/20 for quality-adjusted GO, unlike unadjusted GO, because output growth is strong (particularly in 2019/20 where rolling stock quality improved materially) and cannot be entirely explained by increases in inputs.

3.3.3 GVA TFP results

Table 3.9 shows year-on-year GVA TFP growth for TOCs. As discussed in Section 2.2.1, the GVA output measure for operators is derived from ONS Annual Business Survey (ABS) data.

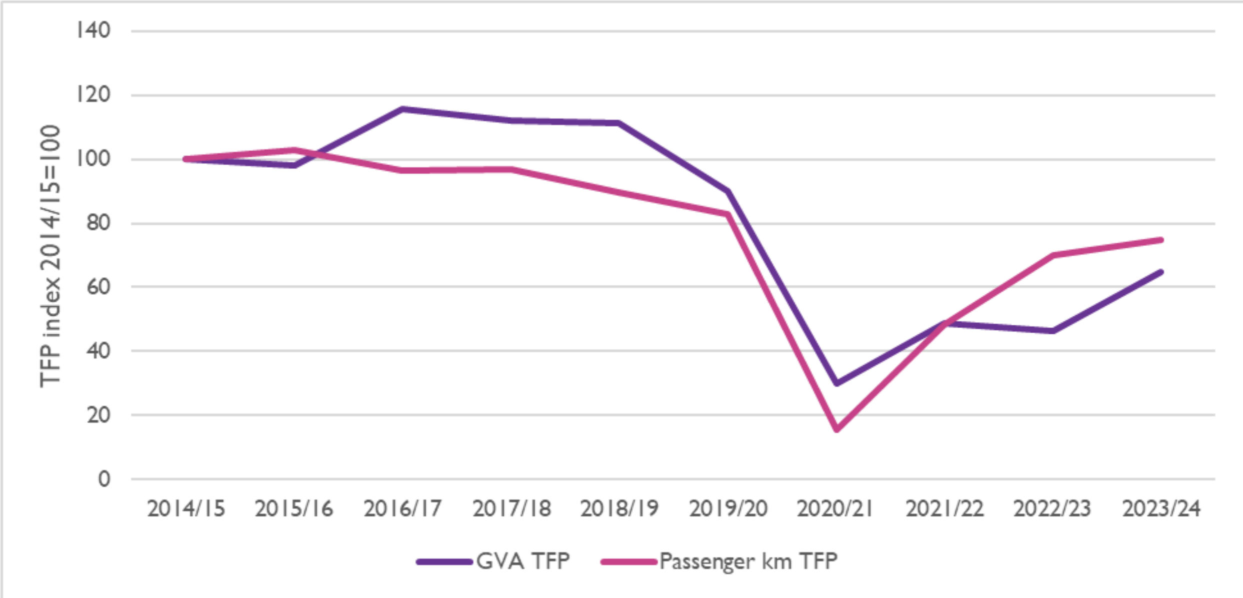
Table 3.9: TOC annual GVA TFP growth (%)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	-1.9	18.1	-3.1	-0.9	-19.1	-66.7	63.2	-5.3	39.5

Source: Europe Economics calculations

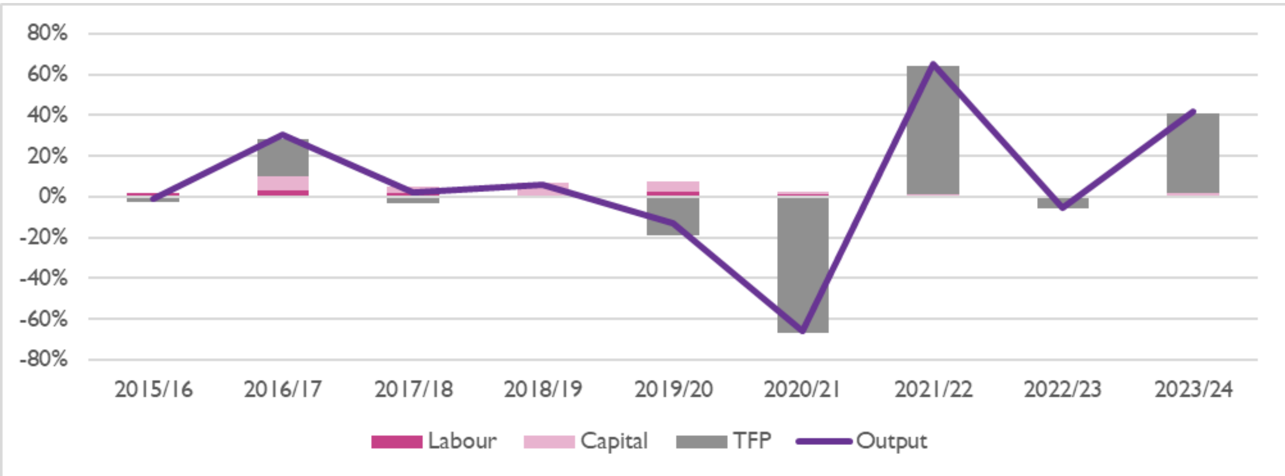
The GVA TFP profile differs from the GO TFP results. There is strong positive GVA TFP growth in 2016/17, driven by a sharp increase in GVA for TOCs in that year. The pandemic drop is slightly less pronounced for GVA TFP than for GO TFP, as is the subsequent rebound. There is a significant rise in GVA TFP in 2023/24, driven by an increase in output. The decomposition suggests the GVA TFP measure is primarily capturing swings in revenue and capacity utilisation, while the underlying factor inputs adjusted only slowly.

Figure 3.38: TOC GVA TFP index, 2014/15=100



Source: Europe Economics calculations

Figure 3.39: Decomposition of TOC output growth (GVA)



Source: Europe Economics calculations

3.3.4 Sensitivities

This section tests the robustness of the TOC TFP results to alternative assumptions and data sources. The baseline is the quality-adjusted GO measure (passenger train-kilometres adjusted for timeliness and rolling-stock age) using our preferred input deflators, regulatory WACC, depreciation rates, and two-period-average Törnqvist weights. Each chart compares this baseline with one sensitivity at a time to assess whether the direction and timing of TFP movements are materially affected.

The sensitivities include:

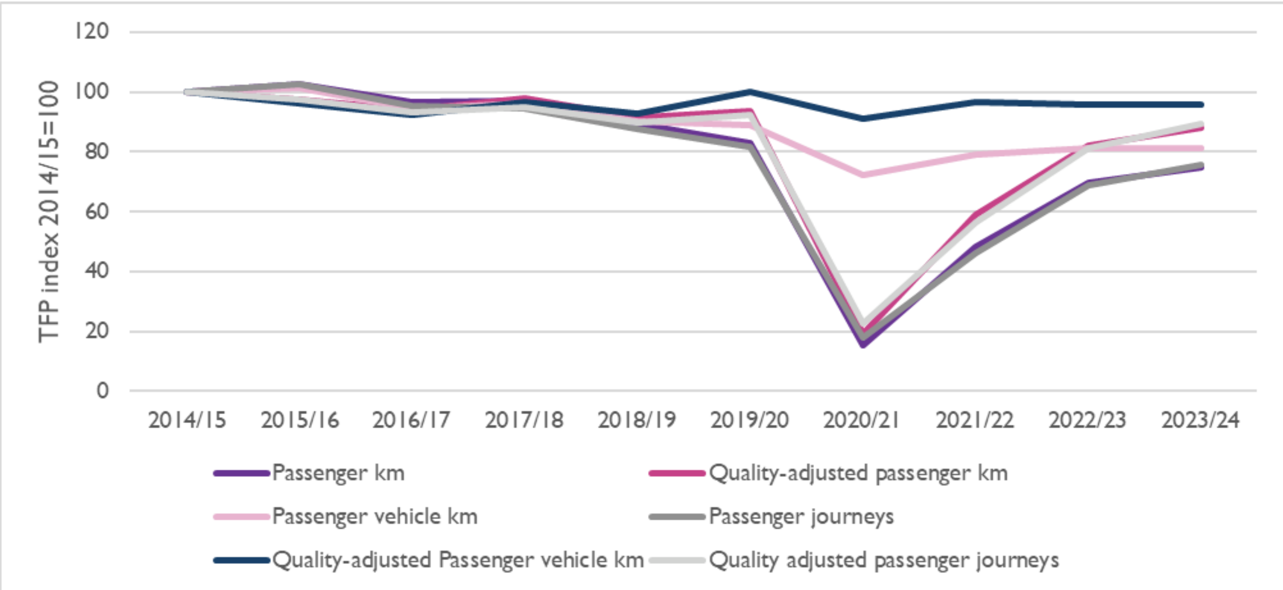
- **Output definition:** alternative traffic-based measures to test dependence on the specific output proxy used.
- **Quality adjustment:** a timeliness-only quality adjustment excluding rolling-stock age, to isolate the effect of each quality adjustment.
- **Price indices:** alternative deflators for capital and intermediates.

- **Depreciation assumptions:** higher and lower depreciation rates to test the impact of capital-service growth.
- **Törnqvist weighting:** full-period average cost shares rather than two-year average cost shares.
- **Cost of capital:** applies an uplift to the regulatory WACC to test the sensitivity of user-cost estimates for capital.
- **Capacity-utilisation adjustment:** an approach following an established method used in productivity literature[10] to distinguish utilisation changes from underlying efficiency.
- **Rolling stock maintenance adjustment:** tests the impact of the adjustment made to rolling stock lease payments based on rolling stock maintenance costs reported in ORR's latest Rail Finance dataset.

Alternative GO measures

Figure 3.40 presents GO TFP results for two alternative measures of TOC's GO, with and without quality-adjustments. The first alternative is passenger journeys. The TFP results using passenger journeys closely mirror our core results using passenger km. The second alternative is passenger vehicle km. Here, the results differ significantly during the pandemic years, because vehicle km declined far less sharply than journeys or passenger km. Adjusting vehicle km for quality makes the divergence even more pronounced.

Figure 3.40: TFP indices for alternative GO measures



Source: Europe Economics calculations

Alternative quality adjustments

This sensitivity assesses the impact of the second quality adjustment we make for TOC GO, which is based on the average age of the rolling stock fleet. As can be seen in Table 3.10, after 2015/16, the rolling stock age adjustment increases the estimated TOC TFP in every year, with a particularly significant impact in 2019/20.

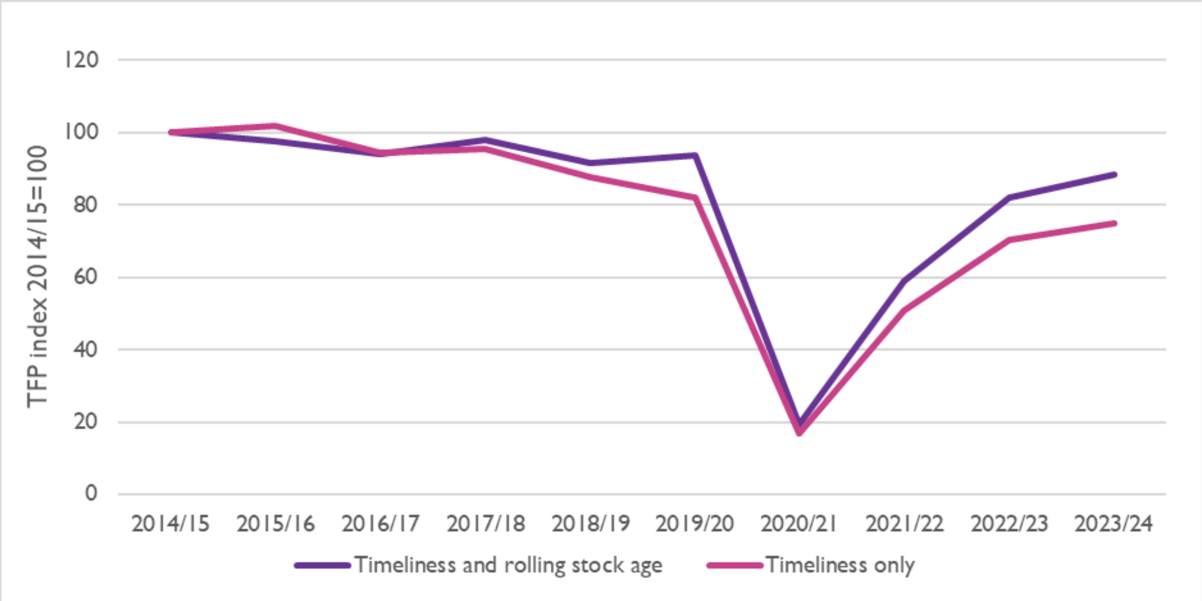
[10] Griffith, R., Redding, S., & Reenen, J. V. (2004). Mapping the two faces of R&D: Productivity growth in a panel of OECD industries. *Review of economics and statistics*, *86*(4), 883-895. Appendix 2.3.

Table 3.10: Annual TOC GO TFP growth for different quality adjustments (%)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Timeliness and rolling stock age	-3.3	-4.4	3.3	-6.8	1.7	-79.3	203.7	38.1	7.6
Timeliness only	0.8	-8.1	0.5	-8.8	-6.8	-79.5	201.4	37.1	7.1

Source: Europe Economics calculations

Figure 3.41: TOC TFP indices using alternative quality adjustments

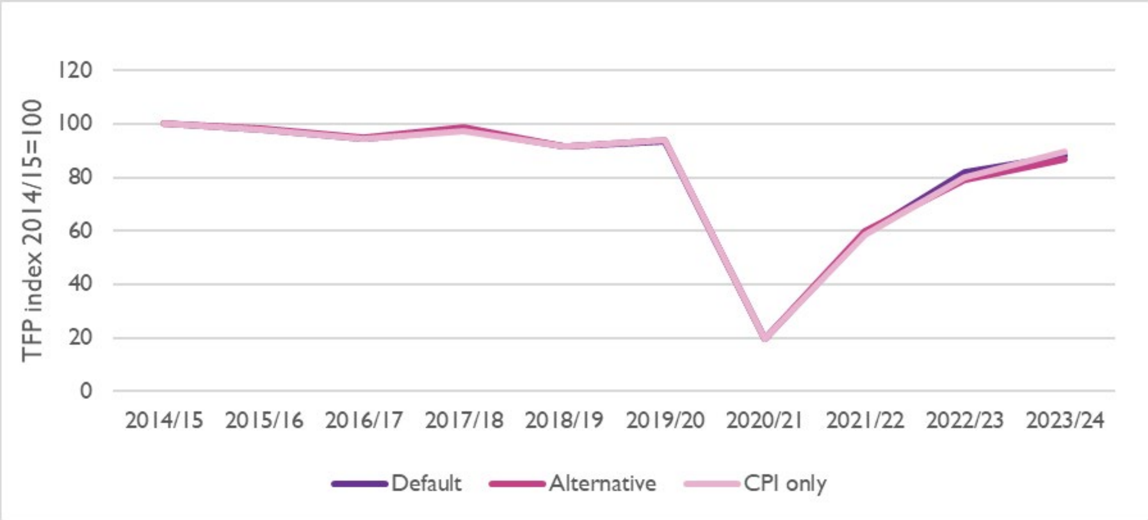


Source: Europe Economics calculations

Alternative deflators

Figure 3.42 presents quality-adjusted gross TFP results when the price indices used to deflate nominal costs for capital and intermediate inputs are changed to the alternative set or when CPI is used for all assets. The TFP results for the alternative index set are marginally lower than the core results, on average, while the TFP results for the CPI-only sensitivity are slightly higher.

Figure 3.42: Quality-adjusted GO TFP index with alternative asset price indices for TOCs

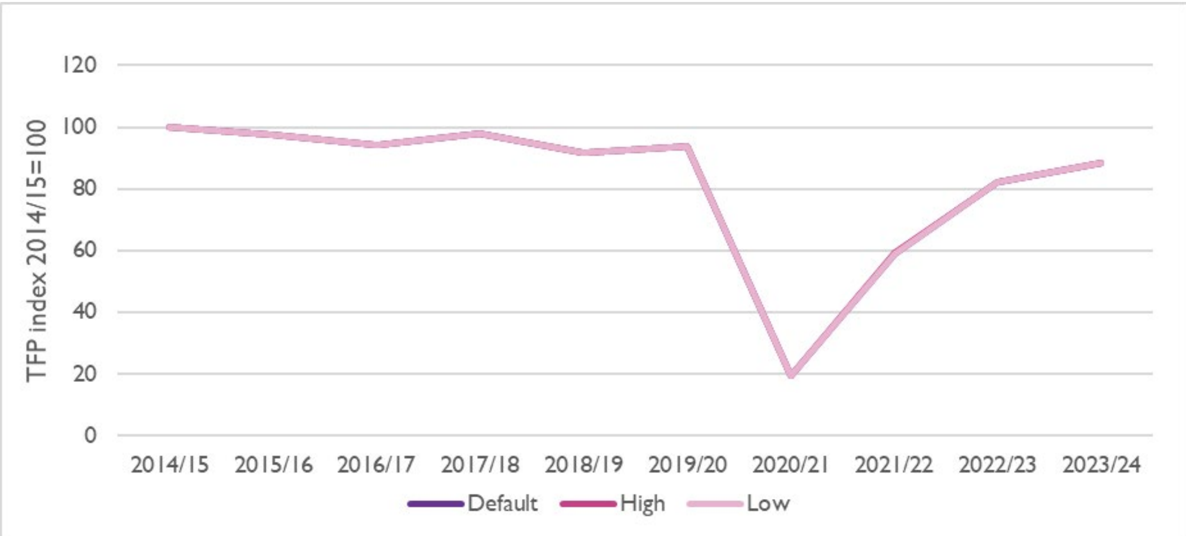


Source: Europe Economics calculations

Alternative depreciation assumptions

As with Network Rail, we test sensitivity to depreciation by varying the assumed asset life by 10 per cent in either direction. Figure 3.43 compares the resulting quality-adjusted GO TFP indices under each assumption with the default depreciation rates in our core results. The impacts are very minor, because the vast majority of capital inputs are rolling stock leases which are unaffected by depreciation assumptions because we take lease payments directly as a measure of the value of capital inputs.

Figure 3.43: Quality-adjusted GO TFP index with alternative depreciation assumptions for TOCs

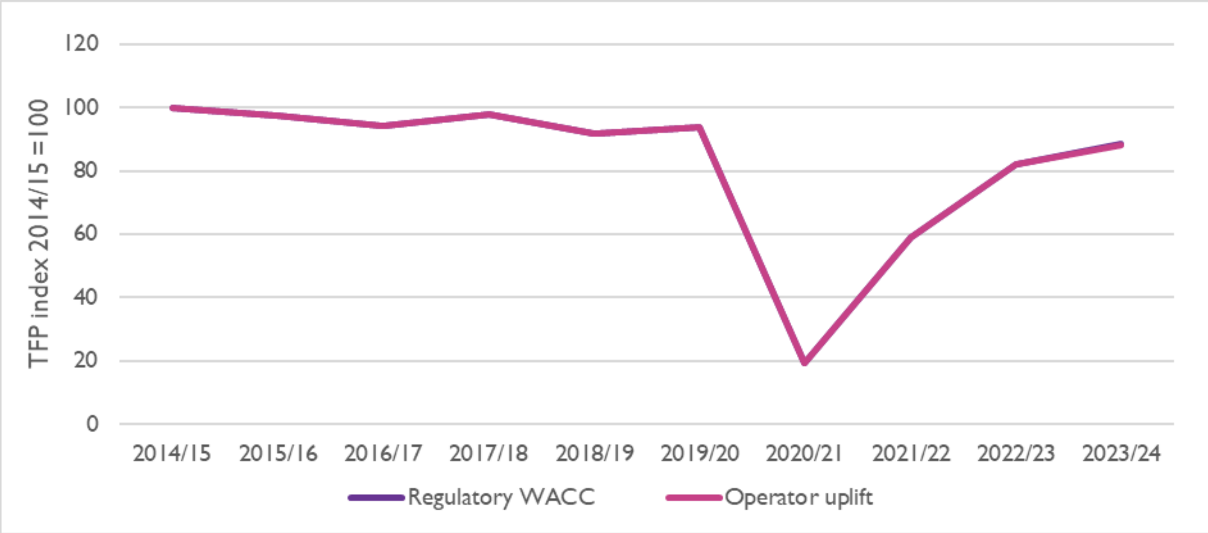


Source: Europe Economics calculations

Alternative rate of return

This sensitivity applies a 2 per cent uplift to the regulatory WACC for Network Rail that we used for the operators' rate of return in our core results. To be clear, this is not an estimate of what the appropriate WACC is for TOCs. The uplift is purely intended to test the sensitivity of the results to movements in the assumed rate of return. As with the depreciation sensitivity, the impacts are minor due to the high share of lease payments that are unaffected by altering the assumptions that feed into the user cost of capital.

Figure 3.44: Quality-adjusted GO TFP index with alternative rate of return assumptions for TOCs

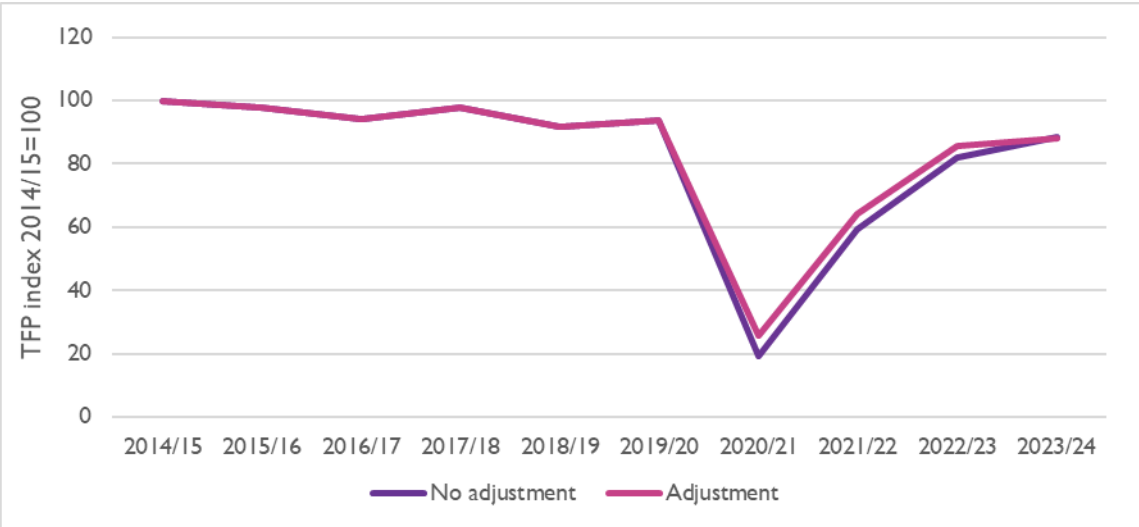


Source: Europe Economics calculations

Capacity utilisation adjustments

This sensitivity applies the same utilisation adjustment to TOC capital inputs as set out in Section 3.1.4. As when applying this adjustment for whole industry TFP, the 2020/21 trough in TOC TFP is slightly less severe, and the subsequent rebound is correspondingly smaller; by 2023/24 the adjusted and unadjusted indices converge.

Figure 3.45: Quality-adjusted GO TFP index with capacity utilisation adjustment for TOCs

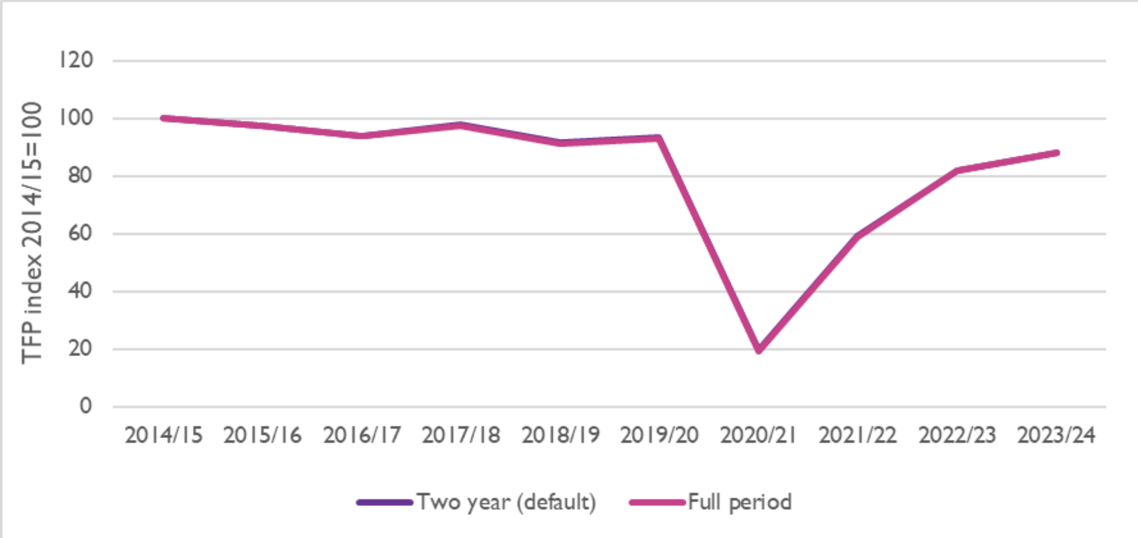


Source: Europe Economics calculations

Alternative Törnqvist weights

We apply the same Törnqvist sensitivity to TOC TFP as for Network Rail. For TOCs, the impact of using full period averaging rather than two period averaging is very small, with overall TFP growth slightly lower when using full period averaging.

Figure 3.46: Quality-adjusted GO TFP index with alternative Törnqvist averaging for TOCs

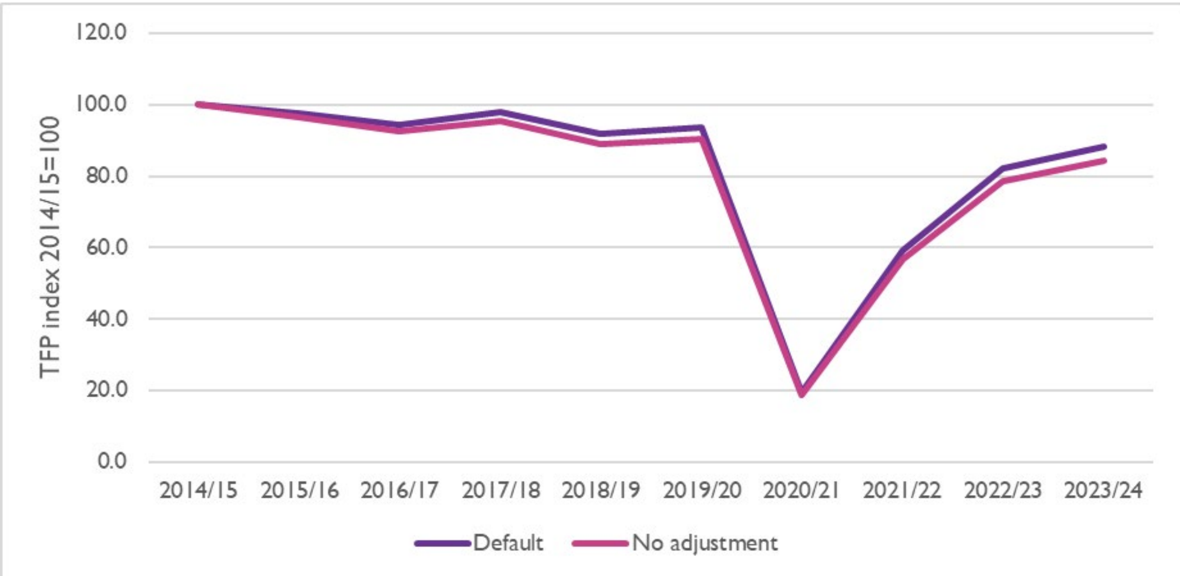


Source: Europe Economics calculations

Rolling stock maintenance adjustment

This sensitivity tests the impact of the adjustment made for rolling stock maintenance in our preferred specification. The figure below reports the TFP results if no adjustment is made to rolling stock lease payments, as opposed to the 35 per cent reduction we apply in our preferred specification. As seen in the chart, the rolling stock maintenance adjustment has a moderate impact on TFP growth, raising it slightly.

Figure 3.47: GO TFP for TOCs when rolling stock maintenance adjust not applied



Source: Europe Economics calculations

3.4 FOCs

This section presents TFP results for TOCs.

3.4.1 GO TFP results

Our preferred measure of GO for FOCs is annual freight-tonne km. Table 3.7 sets out the annual change in GO TFP for TOCs over our estimation period.

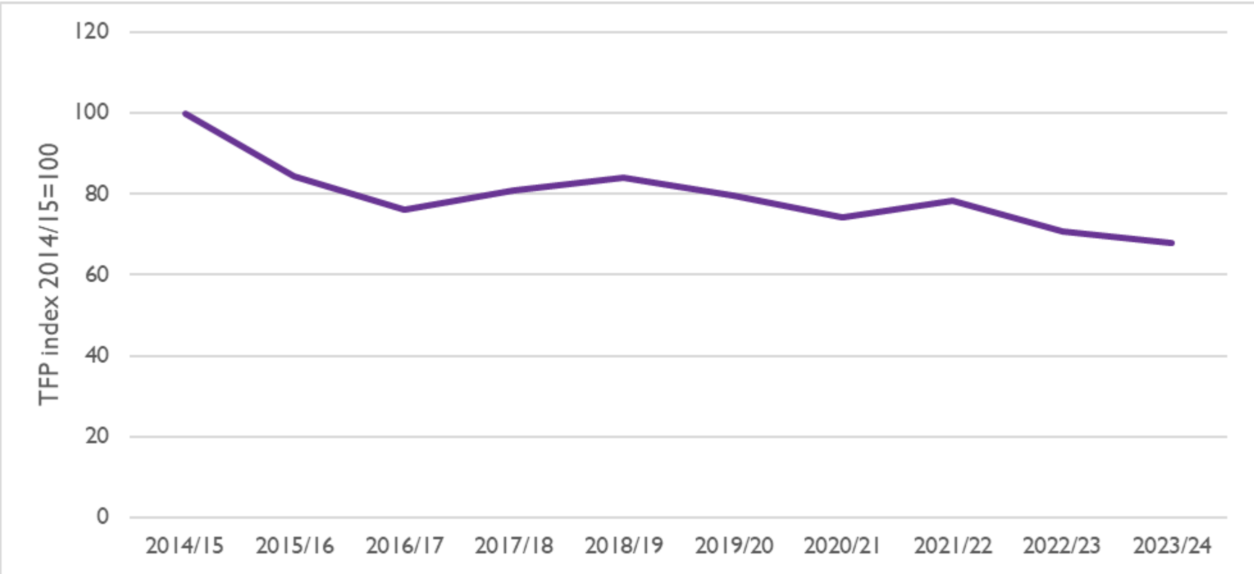
Table 3.11: FOC annual GO TFP growth (%)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	-15.6	-10.0	6.6	3.6	-5.2	-6.6	5.3	-9.7	-3.9

Source: Europe Economics calculations

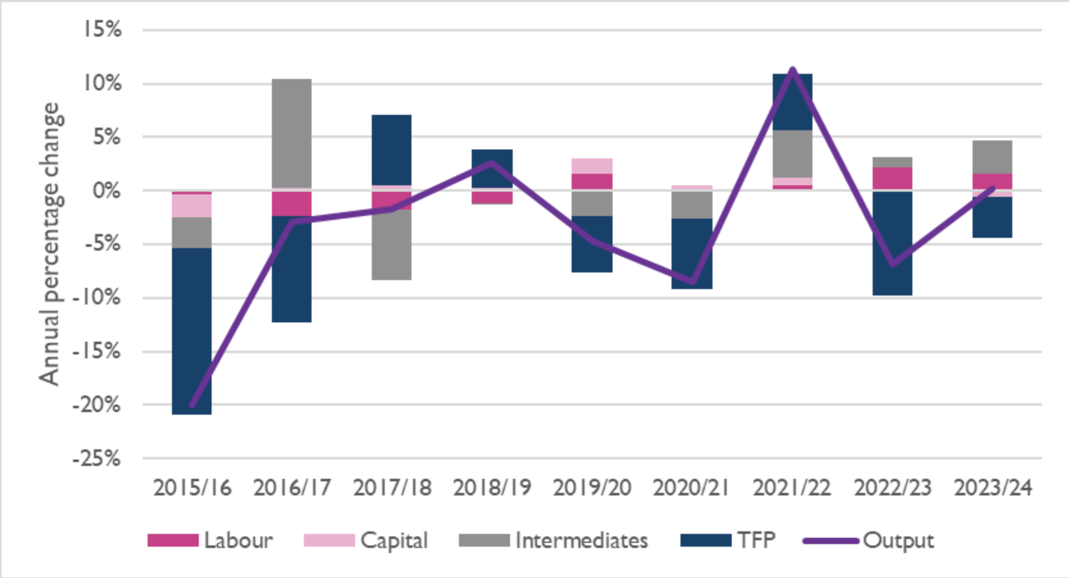
Figure 3.48 indicates a broadly downward trend in FOC productivity, though TFP increases in 2017/18-2018/19 and in 2021/22. The impact of the pandemic on FOC TFP is much smaller than it was for TOCs, which is expected given freight output was less affected. The decomposition in Figure 3.49 shows volatility in the contribution of intermediates to output changes, while labour and capital contributions are small and relatively stable throughout.

Figure 3.48: FOC GO TFP index, 2014/15=100



Source: Europe Economics calculations

Figure 3.49: Decomposition of FOC output growth (GO)



Source: Europe Economics calculations

3.4.2 Quality adjusted GO TFP results

Table 3.12 presents annual growth in quality-adjusted GO TFP for FOCs, where the adjustment applied to freight-tonne km is based on time-to-15 punctuality.

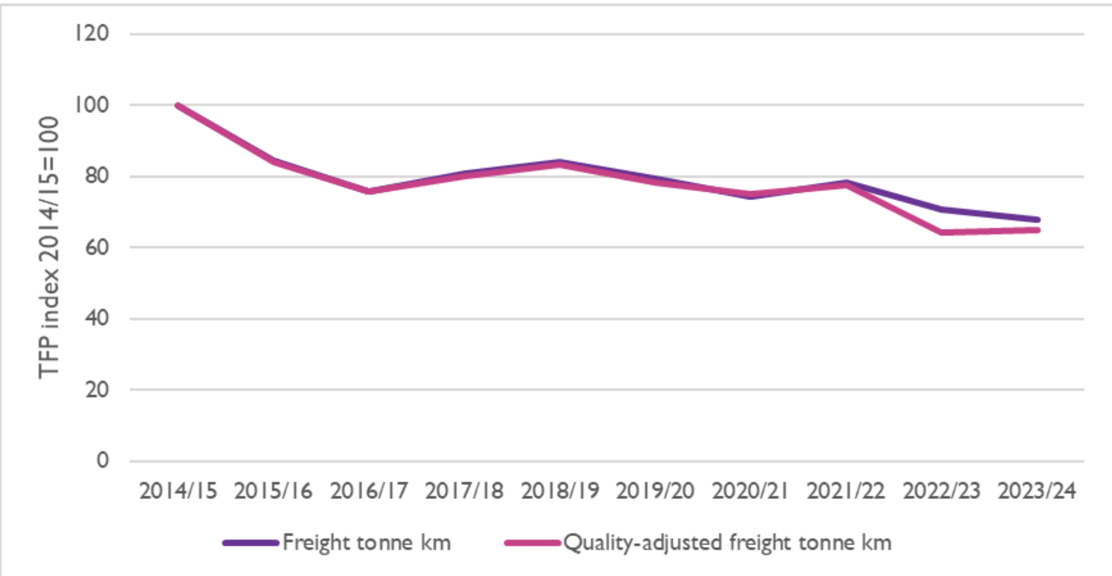
Table 3.12: FOC annual quality-adjusted GO TFP growth (%)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	-15.9	-9.9	5.9	4.0	-6.2	-4.1	3.5	-17.0	1.0

Source: Europe Economics calculations

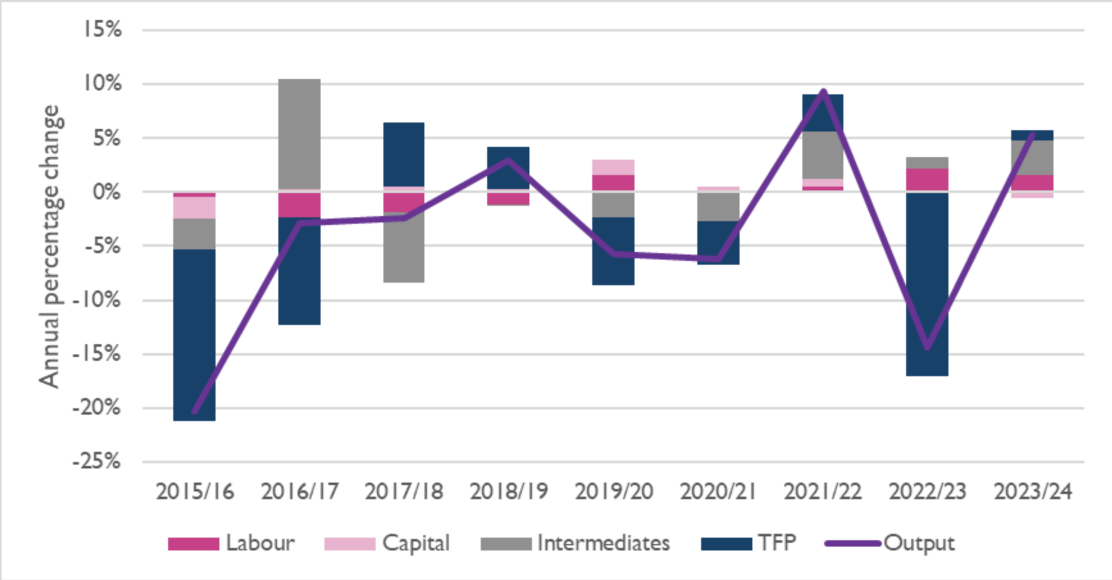
As shown in Figure 3.50, the impact of the quality-adjustment for FOC TFP growth is small, with the only material differences being a larger decline in quality-adjusted TFP in 2022/23 partially offset by higher quality-adjusted TFP growth in 2023/24.

Figure 3.50: FOC quality-adjusted GO TFP index, 2014/15=100



Source: Europe Economics calculations

Figure 3.51: Decomposition of FOC output growth (GO)



Source: Europe Economics calculations

3.4.3 GVA TFP results

Table 3.13 shows year-on-year GVA TFP growth for FOCs. As discussed in Section 2.2.1, the GVA output measure for operators is derived from ONS Annual Business Survey (ABS) data.

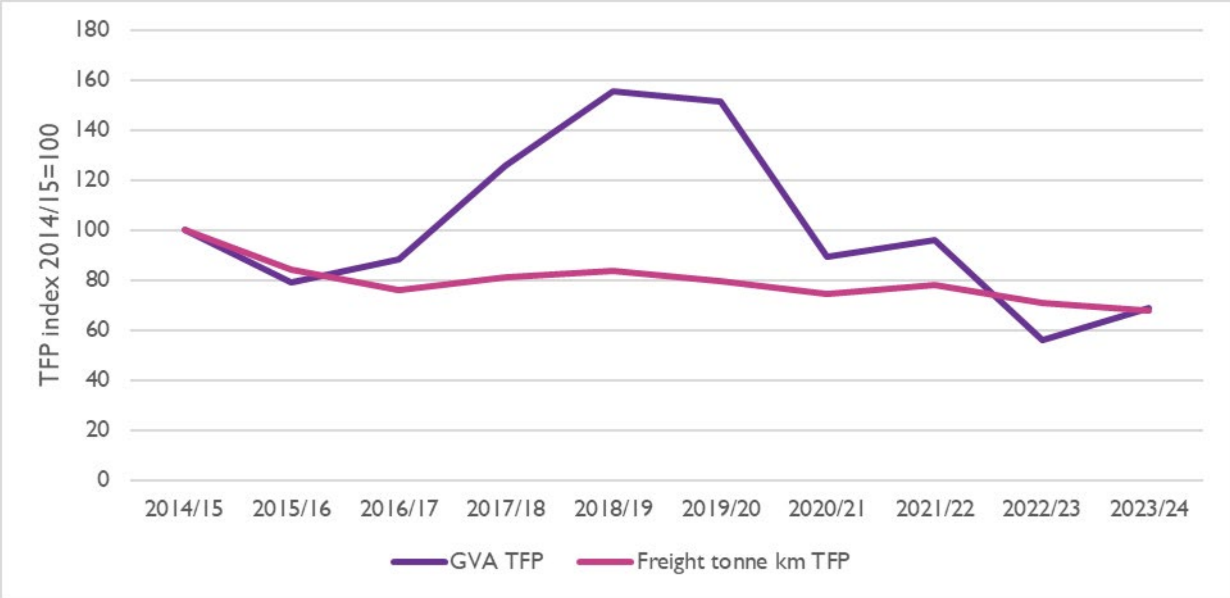
Table 3.13: FOC annual GVA TFP growth (%)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
TFP growth	-21.1	11.7	42.8	23.7	-2.7	-40.9	7.4	-41.5	22.6

Source: Europe Economics calculations

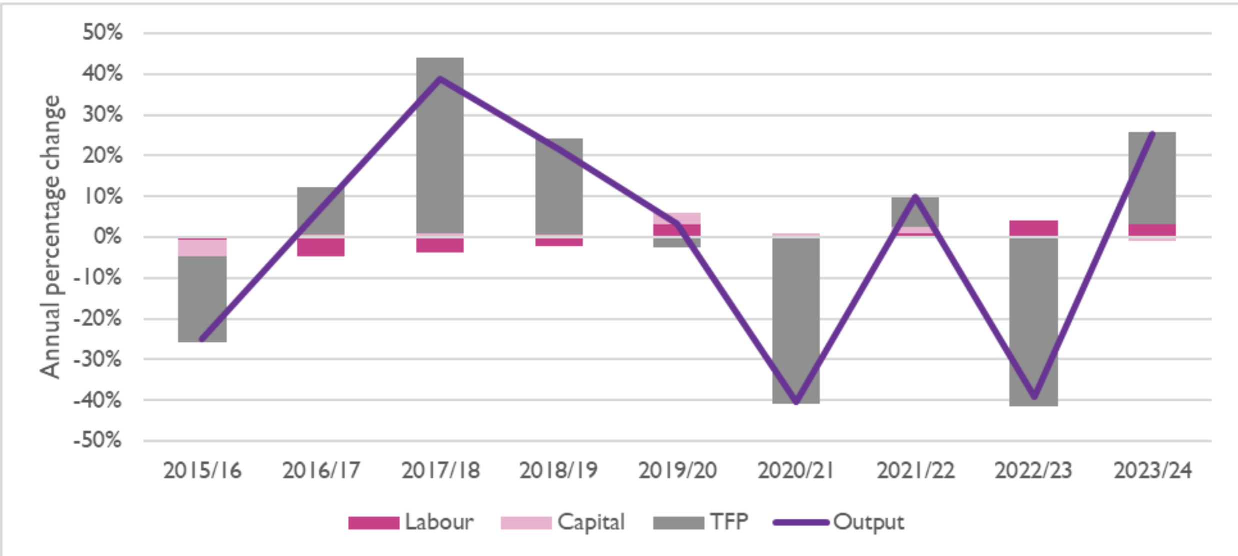
The GVA TFP results are very different from the GO TFP results There is a pronounced upswing in GVA TFP through 2016/17–2018/19, including a rise of over 40 per cent in 2017/18. followed by a modest decline in 2019/20, a sharp contraction in 2020/21, only a partial rebound in 2021/22, a renewed fall in 2022/23 and then a major upturn in 2023/24, ultimately leaving the index well below its pre-pandemic peak. The decomposition indicates that labour and capital contributions are relatively small and stable; the large movements in FOC GVA are captured in the TFP residual. A discussion of the differences between GO and GVA results is set out in Chapter 4.

Figure 3.52: FOC GVA TFP index, 2014/15=100



Source: Europe Economics calculations

Figure 3.53: Decomposition of FOC output growth (GVA)



Source: Europe Economics calculations

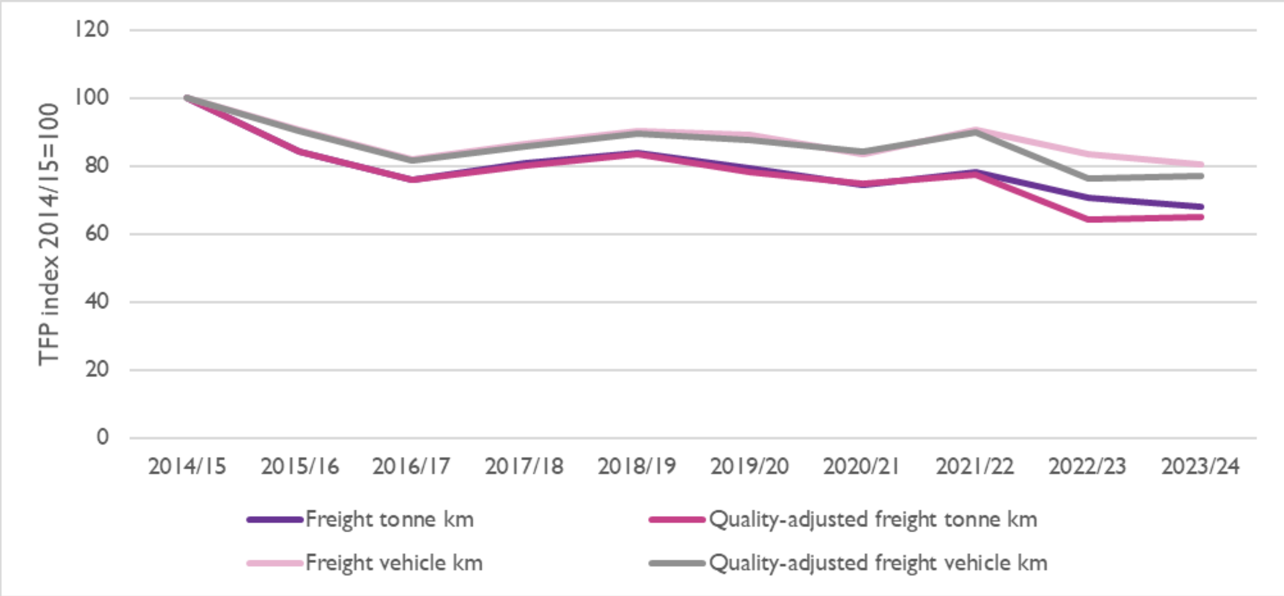
3.4.4 Sensitivities

We apply the same sensitivity tests for FOC TFP as for TOC TFP, with the exception of the capacity utilisation adjustment given FOC output did not suffer significantly during Covid-19.

Alternative GO measures

As shown in Figure 3.54, TFP growth is less negative when freight-vehicle km are used (either with or without quality adjustment).

Figure 3.54: TFP indices for alternative GO measures

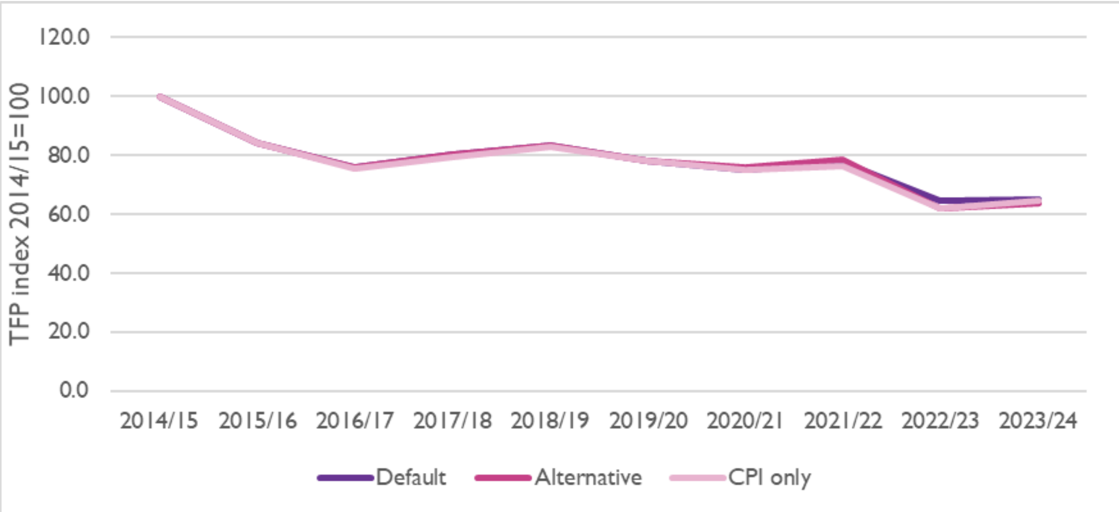


Source: Europe Economics calculations

Alternative deflators

Varying the asset price indices, or using only CPI, only has very minor impacts on the FOC TFP results.

Figure 3.55: Quality-adjusted GO TFP index with alternative asset price indices for FOCs

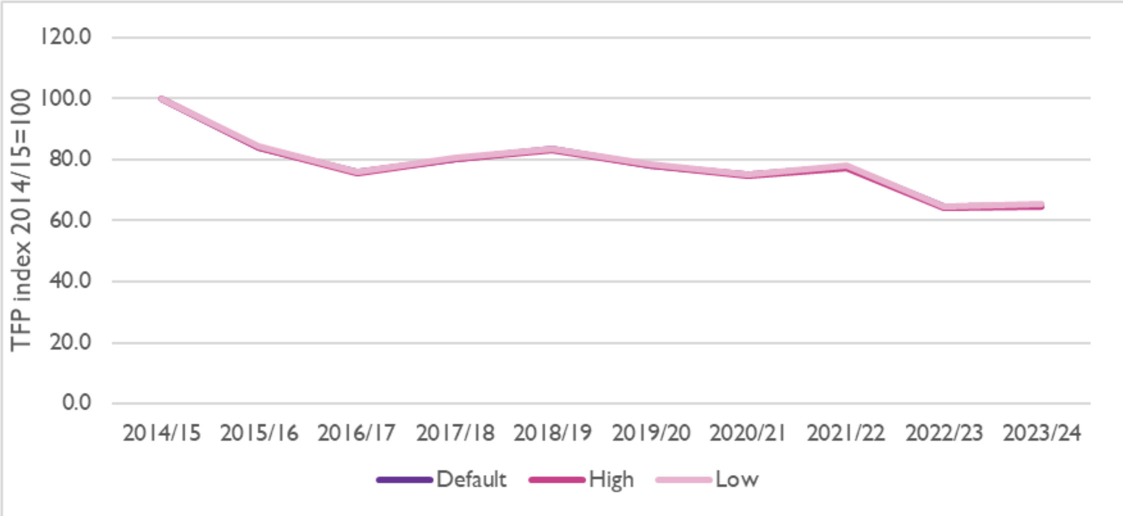


Source: Europe Economics calculations

Alternative depreciation assumptions

As with TOCs, the FOC TFP results are stable to changes in the depreciation assumptions.

Figure 3.56: Quality-adjusted GO TFP index with alternative depreciation assumptions for FOCs

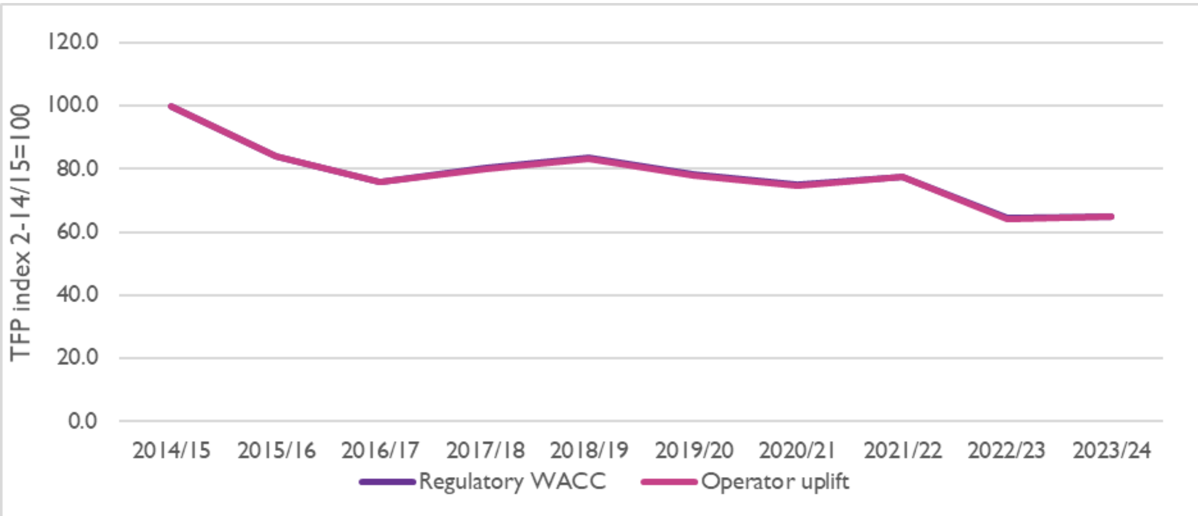


Source: Europe Economics calculations

Alternative rate of return

In this sensitivity, a 2 per cent uplift is applied to the regulatory WACC for FOCs. To be clear, this is not an estimate of what the appropriate WACC is for FOCs. The uplift is purely intended to test the sensitivity of the results to movements in the assumed rate of return. As with TOCs, the FOC TFP results are stable to changes in the assumed rate of return.

Figure 3.57: Quality-adjusted GO TFP index with alternative rate of return assumptions for FOCs

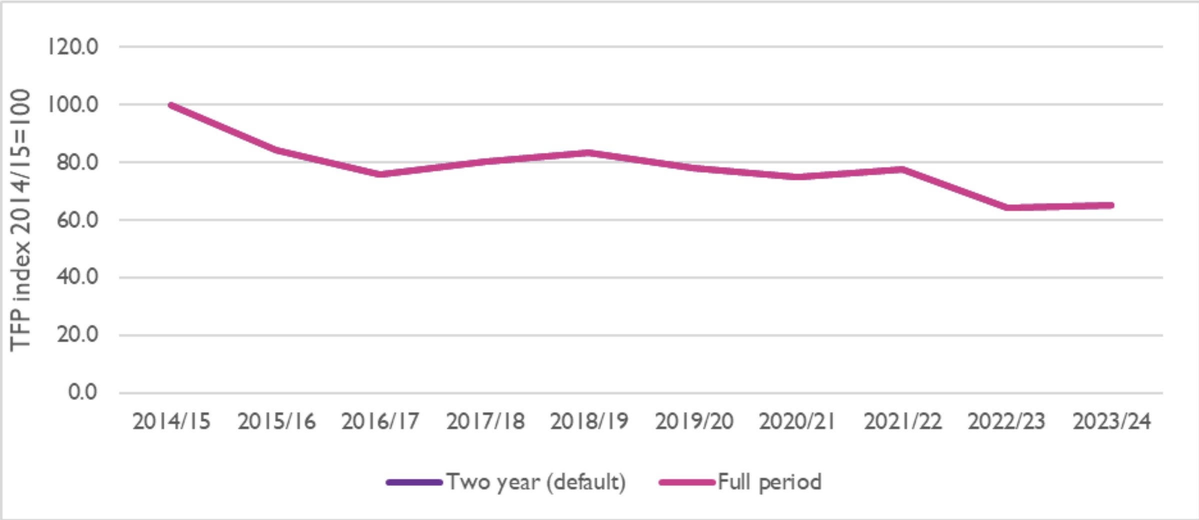


Source: Europe Economics calculations

Alternative Törnqvist weights

As input cost shares for FOCs are relatively stable across time, the impact of the Törnqvist averaging period sensitivity test is limited for FOC TFP, such that there is no material change from the core results.

Figure 3.58: Quality-adjusted GO TFP index with alternative Törnqvist averaging for TOCs



Source: Europe Economics calculations

4 Discussion

In this section we discuss the findings of our rail sector TFP calculations. We also set out our advice on the future use of TFP analysis in the sector.

4.1 Key findings

Here we outline the main trends in our TFP results by segment, and then discuss what might be driving the results.

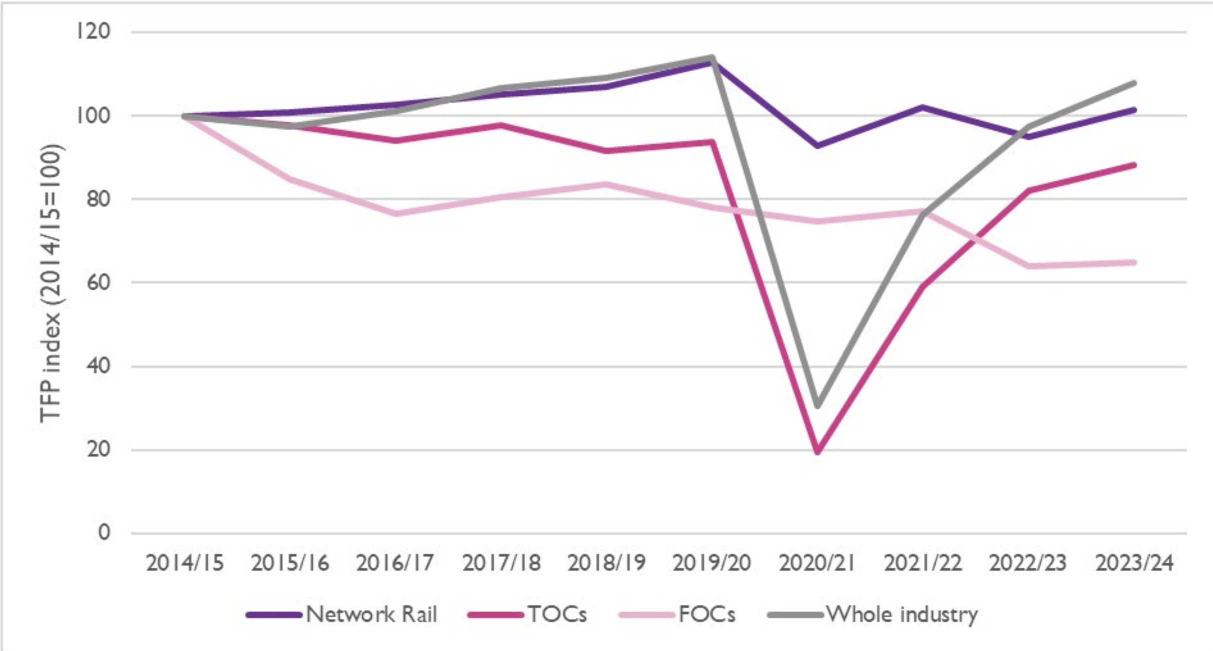
4.1.1 Trends in TFP

There is a divergence in non-quality adjusted GO TFP trends for Network Rail and for operators. Network Rail's TFP rises steadily in the pre-pandemic period, with trend growth of around 2.5 per cent. Network Rail experiences negative TFP growth in the first year of the pandemic, and in 2022/23. By 2023/24 Network Rail's GO TFP is around 1.5 per cent above its 2014/15 level. The whole-industry index follows a similar pattern, reflecting the dominant weight of Network Rail in inputs (particularly capital), though it has a much sharper drop in 2020/21 due to the collapse of passenger km, and it has a lower pre-pandemic trend of 0.7 per cent due to a fall in GO TFP in 2019/20.

TOC and FOC TFP follow a very different trajectory. For TOCs, there is a downward trend in TFP before the pandemic, followed by a very sharp fall in 2020/21 and a strong but incomplete recovery thereafter; by 2023/24 TOC TFP remains far below its 2014/15 level. For FOCs, TFP declines through most of the period, with relatively small movements around the pandemic years, and ends substantially below its starting point. These patterns suggest that, over the period as a whole, productivity gains at the whole-industry level are driven largely by increases in TFP on the infrastructure side, while operator-level TFP has been negative.

Adjusting GO for quality does not significantly change the trends in GO TFP. For TOCs and the whole industry, quality adjustment raises TFP growth in most years, and particularly in 2019/20 (driven by improvements in the quality of rolling stock). For FOCs, quality-adjusted GO TFP has a slightly lower trend than unadjusted GO TFP because timeliness has declined year on year for FOCs, outside of 2020/21 and 2021/22. For Network Rail, the overall trend in GO TFP is not significantly affected by using quality-adjusted GO, although year-to-year TFP growth rates do differ. The figure below shows the quality-adjusted GO TFP trends for all segments.

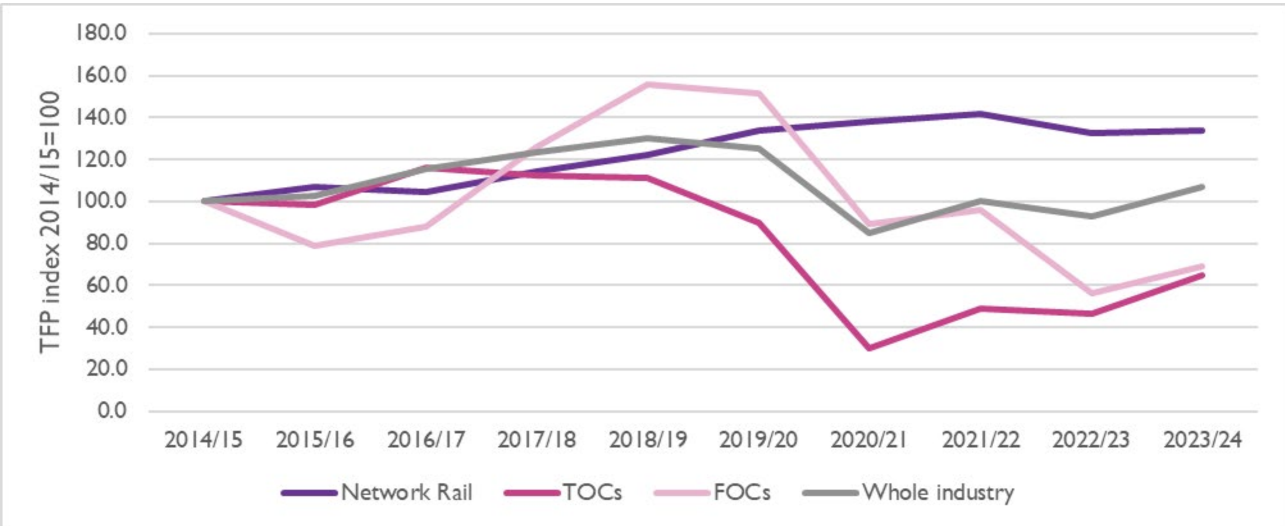
Figure 4.1: Comparison of quality-adjusted GO TFP indices



Source: Europe Economics calculations

GVA TFP results are quite different from GO TFP. For TOCs and FOCs, GVA TFP is much more volatile than GO TFP. FOC GVA TFP increases by over 40 per cent in 2017/18 and over 20 per cent the following year, but then falls by a similar amount in 2020/21 and 2022/23. TOC GVA TFP rises significantly in 2016/17, but then declines for the next three years. This is followed by a steep pandemic-related drop and only a partial subsequent recovery. By 2023/24, TOC GVA TFP is far below its 2014/15 starting point. Network Rail's GVA TFP is less volatile, and increases in every year of the period (including the pandemic) other than 2022/23. Whole industry GVA TFP mostly follows the same trends as Network Rail GVA TFP, but with a significant pandemic drop, and by 2023/24 it lies between Network Rail and TOC GVA TFP in cumulative growth terms, being around 7 per cent above its 2014/15 starting point.

Figure 4.2: Comparison of GVA TFP indices



Source: Europe Economics calculations

4.1.2 Potential drivers of observed TFP

Taken together, our TFP results suggest slightly increasing productivity for the rail industry as a whole over 2014/15–2023/24. However, the picture is mixed across segments, with operators experiencing declining productivity while Network Rail's TFP has slightly increased.

The behaviour of GO and GVA TFP varies, particularly for operators. This section explores the main factors that help to explain the observed patterns, including the differences between GO and GVA TFP, differences across the industry and the extent to which our findings are sensitive to key modelling choices.

Differences between GO and GVA TFP

A key driver of the differences in our estimated GO TFP and GVA TFP is the distinction between the output measures themselves, GO and GVA. GO TFP compares the growth of GO with the cost-weighted growth of labour, capital and intermediate inputs. In our work, GO is measured using physical indicators of activity – train-km for Network Rail, passenger-km for TOCs and freight tonne-km for FOCs – and so the GO TFP measures are anchored in the technical relationship between physical inputs and the volume of rail services. By contrast, GVA TFP compares growth in GVA with the cost-weighted growth of labour and capital only, netting out intermediate consumption. As explained in Section 3.1.3, for the operators, GVA comes from the ONS Annual Business Survey (ABS), where it is derived from financial data on turnover, other operating income and intermediate costs rather than from physical volumes. This means that operators' GVA TFP is influenced not only by changes in the volume of services delivered and the quantity of primary inputs, but also by revenue effects that do not appear in the GO measures, such as ticket-mix. These effects can generate swings in operator GVA that are only loosely related to changes in passenger-km or freight tonne-km, and hence to the underlying technical efficiency of converting inputs into train services. This helps to explain why TOC and FOC GVA TFP is much more volatile than the corresponding GO TFP series.

For Network Rail, GVA is not taken from ONS but is instead constructed directly from cost data as the sum of staff costs and depreciation. This approach is pragmatic given data constraints, and is the standard statistical approach taken for general government activities.[11] Nonetheless, it is a relatively stylised representation of value added. In effect, it is using a cost-side measure of the remuneration of labour and capital depreciation as a proxy for the value that Network Rail adds, rather than deriving GVA as GO minus intermediate consumption. The depreciation component is calculated on the RAB, whereas our measure of capital input is derived from a DRC-based estimate of the capital stock. Over the period, the RAB-based depreciation term included in our GVA proxy is relatively stable, while DRC-based capital services decline because estimated economic depreciation exceeds new investment. When we compare growth in the cost-side GVA measure (staff costs plus RAB-based depreciation) with growth in labour and DRC-based capital services, GVA rises faster than measured inputs and this shows up as strong positive GVA TFP. The Network Rail GVA TFP results therefore need to be interpreted with care, as they reflect movements in labour costs and the regulatory depreciation charge per unit of measured inputs, rather than necessarily demonstrating improvements in the efficiency with which physical inputs are transformed into train services. As Network Rail GVA feeds into the whole industry GVA, some caution also needs to applied to interpreting whole industry GVA TFP.

Overall, the divergence between GO and GVA TFP reflects differences in what each measure captures and in how the underlying data are constructed. GO TFP provides a clearer picture of how efficiently operators and Network Rail convert inputs into physical rail services, while GVA TFP for operators is more sensitive to pricing, revenue and accounting effects embodied in ONS GVA data.

[11] The same approach was used in Oxford Economics 2018 report for the Rail Industry Association "The Economic Contribution of UK Rail" when measuring Network Rail's GVA [online]

Differences across segments

The TFP paths differ across Network Rail, TOCs and FOCs in ways that are closely linked to their output trends and the way changes in inputs show up in the decompositions. For Network Rail, the GO decompositions show relatively modest movements in GO (train-km) over most of the period, alongside a downward trend in capital services as depreciation of the DRC-based capital stock exceeds new investment. Intermediates make a more volatile but generally smaller contribution. Labour inputs are broadly flat or slightly declining, while intermediates are more volatile but generally make a smaller contribution. Because output is broadly stable or rising while capital services fall, TFP is positive in most pre-pandemic years and again in 2021/22 and 2023/24. The main exception is 2020/21, when train-km fall and inputs do not adjust fully, producing a negative TFP contribution. Overall, the upward trend in Network Rail's GO TFP largely reflects a gradual reduction in measured capital services relative to a fairly stable volume of train services, rather than rapid growth in train-km. In other words, Network Rail is maintaining a consistent level of output despite a reducing amount of inputs, which implies an increase in productivity.

For TOCs, the picture is different. The GO decompositions indicate that the contributions of labour, capital and intermediates to output growth are relatively stable over time, while the TFP residual accounts for most of the volatility, especially around the pandemic. This reflects the fact that passenger-km move much more sharply than inputs: when demand changes sharply, staffing, rolling stock leases and many purchased services adjust only slowly, so capacity utilisation changes are largely captured in TFP. The very large negative TFP contribution in 2020/21, and the equally striking positive contributions in 2021/22 and 2022/23, are therefore best interpreted as utilisation effects layered on top of an underlying pre-Covid trend in which TOC inputs were already growing faster than passenger volumes. The whole-industry GO decompositions show that the changes in GO TFP 2020/21 and 2021/22 are driven mainly by the TOC output component, though the general positive trend in whole industry TFP is due to the same reduction in capital inputs that drives Network Rail's productivity growth.

Prior to the pandemic, increases in capital and/or intermediate inputs that outweigh increases in output drives the negative TFP results for TOCs. A key contributor to rising capital services costs is changes in rolling stock lease payments, which account for the largest proportion of TOC capital services. There a significant increases in lease payments for rolling stock from 2015/16 to 2019/20, which are not fully offset by the quality adjustment for new rolling stock. Increases in intermediates costs over the same period may reflect increased maintenance cost associated with the higher rolling stock costs, but we cannot confirm this with the data available.

The trends in FOCs' output sit somewhere between the TOC and Network Rail cases. The GO decompositions show that freight-tonne km is less volatile than passenger-km, and that the contributions of labour and capital to output growth are generally small and stable. Intermediate inputs show somewhat more year-to-year variation and tend to move in line with freight output (though not always). The TFP residual for FOCs is therefore less dominated by large utilisation shocks and instead reflects a combination of output movements and intermediate fluctuations. This helps to explain why FOC GO TFP exhibits a smaller Covid-related dip and a somewhat flatter overall profile than TOC GO TFP, even though the longer-run trend remains negative.

In summary, differences in TFP across segments is explained by the decomposition of output growth. Network Rail's positive trend mainly reflects a gradual reduction in measured capital services against fairly stable train-km. The decline in Network Rail's capital services also drives positive results for the whole industry, outside of pandemic years. For TOCs, TFP is dominated by swings in passenger demand and capacity utilisation against a largely fixed input base. Freight output is less volatile, so the TFP path for FOCs is flatter but still declining over time.

Effect of key modelling choices and robustness

The sensitivity tests indicate that some of the modelling choices have a material impact on the profile of TFP, particularly for TOCs and, by extension, the whole industry.

The valuation of Network Rail's initial capital stock matters because Network Rail accounts for the vast bulk of industry capital services. As has already been discussed, our preferred specification anchors the 2014/15 capital stock to the DfT's DRC valuation of the network. We test several alternative calibrations. One sensitivity uses the 2014/15 RAB. Since the RAB is materially lower than the DRC valuation, starting with the RAB implies faster subsequent growth in capital services for any given path of investment, and this higher capital input growth implies lower (or negative) TFP growth. The RAB-based TFP series therefore show a gradual deterioration in productivity over the period, in contrast to the upward trend estimated under the DRC-based specification. We view the DRC valuation as the more appropriate measure of economic capital input, as it is designed to reflect the replacement cost of the physical assets employed. The RAB is a regulatory construct and does not map cleanly onto the economic concept of productive capital. For this reason, we base our core results on the DRC-anchored series and treat the RAB-based estimates as an informative but non-preferred sensitivity.

We also test an alternative DRC anchor using the more recent 2023/24 DfT valuation, rolled back to 2014/15 using the same PIM approach. This yields a materially higher implied opening stock than the 2015/16 DRC anchor and therefore implies slower growth in capital services and higher measured TFP. We treat this as a useful robustness check, but do not adopt it as our central specification because it requires rolling the valuation back over a substantially longer horizon. This increases reliance on the cumulative effect of modelling assumptions (including depreciation and the treatment of renewals and enhancements) and therefore increases the scope for back-casting distortions. By contrast, anchoring on the earliest available DRC valuation (2015/16) minimises the required back-casting and reduces the risk that the initial stock is being driven by compounding measurement error rather than the underlying asset base.

Third, we test sensitivity to the *coverage* of assets included in the network valuation. In our central specification we exclude land from the DRC valuation when constructing capital services, consistent with standard productivity measurement practice in which land is treated as a non-produced asset and is typically excluded from capital services. Including land raises the opening stock and therefore modestly increases measured TFP over most of the period. We also test a more restrictive variant that excludes civils and earthworks in addition to land. This substantially lowers the opening stock and therefore increases measured capital services growth, resulting in materially lower measured TFP. While this sensitivity is informative about the importance of asset coverage, we do not view there as a clear conceptual basis for excluding civils and earthworks from productive capital, since these assets form part of the infrastructure that enables rail services to be delivered.

Overall, we view the DRC-based calibration (anchored on the earliest available DfT valuation) and the exclusion of land as the most appropriate basis for our core results. The DRC is designed to reflect the replacement cost of the physical assets employed in production, which maps more closely to the economic concept of productive capital than the RAB, which is a regulatory construct. The earlier DRC anchor also requires less extrapolation to reach the start of our period.

The choice of gross-output measure is one of the most important modelling choices in the case of operators. When TOC and industry GO are proxied by train-km or vehicle-km rather than passenger-km, output grows more strongly and the TFP indices are higher in most years, with a far less pronounced pre-Covid decline. The same effect occurs for FOCs when switching from freight-tonne km to freight train km. However, even on these alternatives, TOC GO TFP still falls in the run-up to the pandemic, exhibits a sharp Covid-related dip and a strong but incomplete recovery, and remains below its 2014/15 level in 2023/24, though to a significantly lesser extent than in our core results. Similarly, FOC GO TFP still declines over time when using freight train km, albeit to a lesser extent than the core results.

Passenger-km and freight-tonne km better reflects the service actually consumed and thus the productivity of the system in delivering transport to users. Train-km, by contrast, captures capacity provided. The capacity-utilisation adjustment applied to TOC capital services materially reduces the size of the Covid-era TFP fall and subsequent rebound. However, the decline in GO TFP in 2020/21 is still very large, and by 2023/24 the adjusted and unadjusted indices are very similar, and both remain below their 2014/15 starting points. In practice, using train-km as GO is at least as effective in dampening the Covid swings as the utilisation adjustment, but it does so by changing the definition of output rather than by isolating utilisation effects. Our view is that passenger-km-based, quality-adjusted GO remains the most appropriate primary specification for operator output, with the train-km and utilisation-adjusted variants used as cross-checks when interpreting Covid-period movements.

Another consequential choice for TOC GO TFP is the quality-adjustment approach. Using a timeliness-only adjustment rather than timeliness plus rolling-stock quality lowers TFP growth for TOCs and the industry in every year and particularly in 2019/20, when new rolling stock enters service. The rolling stock quality adjustment is a blunt instrument – it abstracts from differences in specification between fleets and assumes a common relationship between age and quality – but it is one way to capture quality changes given the data currently available. Not adjusting for rolling-stock quality would imply that all additional capital services associated with new fleets represent pure inefficiency unless they translate one-for-one into higher passenger-km, which is unlikely to be the case.

Most other modelling choices have only limited effects on the results, across all segments. Using alternative capital and intermediate deflators (including a CPI-only variant), varying depreciation rates within a plausible range, applying a higher rate of return in the user cost of capital, or moving from two-year to full-period Törnqvist weights all produce only small changes in TFP growth rates.

Overall, we place most weight on the quality-adjusted GO TFP estimates for each segment and for the industry, as these are anchored in physical measures of activity and explicitly account for changes in service quality. Given the inherent limitations of TFP as a residual measure and the data constraints discussed above, we view the estimates as providing a robust indication of broad trends and differences across segments, rather than as precise point estimates of "true" productivity. In interpreting the results, greater emphasis should therefore be placed on the direction and relative magnitude of TFP changes over time and between segments than on exact annual growth rates.

4.2 Advice on future use

Our advice on the future use of TFP analysis in the GB rail sector is divided into 4 sections:

- Future updates of TFP
- Using TFP figures for benchmarking
- Using TFP for Periodic Reviews
- TFP and rail reform

4.2.1 Future updates of TFP

We recommend that TFP analysis is maintained as a recurring element of ORR's analytical toolkit, with a focused core suite of measures. In our view, future work should centre on the quality-adjusted GO TFP indices for Network Rail, TOCs, FOCs and the industry as a whole. These measures are rooted in physical activity data, explicitly reflect changes in service quality, and are less affected by the volatility and measurement challenges that arise in the operator GVA series. GVA-based TFP remains useful as a supplementary perspective but we would be cautious about using operator GVA TFP as a headline indicator.

For future updates, methodological continuity is important. We suggest that ORR treats the approach developed in this study as a baseline and, as far as possible, extends the existing indices forward using the same definitions of output, inputs and quality adjustments. Where substantial improvements in underlying data become available – for example, a cleaner split between rolling-stock lease payments and embedded maintenance costs, or richer quality metrics – it may be appropriate to refine the methodology. In those cases, we would advise implementing any changes in a way that preserves comparability over time, for instance by re-estimating the series on a consistent basis and providing a clear bridge between the old and new indices.

Given the data requirements and the lag on some inputs, we do not think that a full bottom-up TFP update is necessary every year. A more proportionate approach would be to undertake a substantive update on a three- to five-year cycle, potentially aligned with key regulatory milestones, and to rely on simpler partial productivity indicators (such as distance per employee or per pound of expenditure) in intervening years. This would allow ORR to track medium-term trends in productivity and differences across segments, while keeping the burden of data collection and model maintenance manageable.

Looking ahead, the main priorities for improving future TFP updates lie in data rather than in changing the underlying framework. In particular, a better separation of leasing and maintenance costs for rolling stock would strengthen the TOC capital-services estimates; any enhancement to the way Network Rail's GVA is measured would make its GVA TFP series more informative; and, if consistent time series become available, richer measures of service quality (for example, broader punctuality metrics or measures of cancellations and crowding) could be incorporated more systematically. With these incremental improvements, TFP analysis can continue to provide a robust view of how productivity in the GB rail sector evolves over time. Interpretation should focus on multi-year movements and cross-segment comparisons rather than on judging performance on the basis of any single year's TFP outturn.

4.2.2 Using TFP figures for benchmarking

TFP is most naturally used for benchmarking within GB Rail – i.e. comparing segments and tracking how productivity has evolved over time. The quality-adjusted GO TFP indices provide a consistent way to compare Network Rail, TOCs, FOCs and the whole industry in terms of how efficiently they convert labour, capital and intermediates into rail services. In that sense, they are useful for identifying where productivity has deteriorated most, where it has been more resilient or positive, and where closer investigation might be warranted.

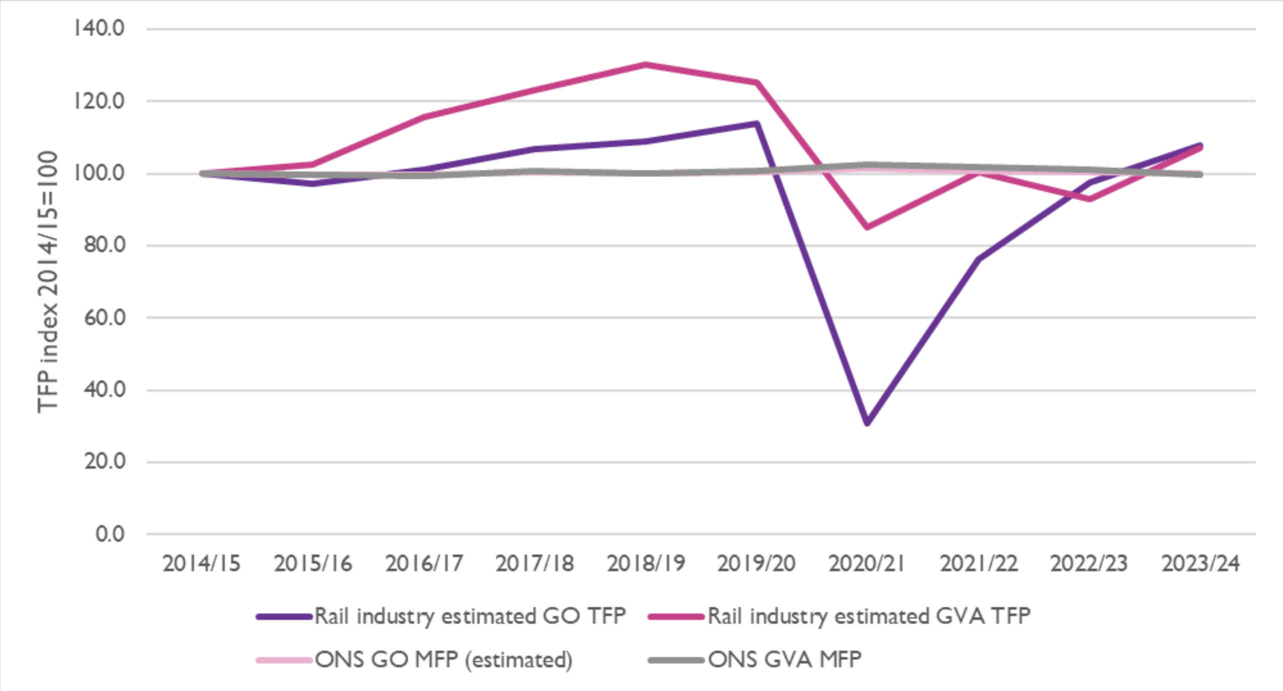
There is also a role for using these results to place GB rail in a wider productivity context, including comparison with EU KLEMS and ONS TFP estimates. We can compare average TFP growth for the GB rail industry (or for Network Rail) over a given period with whole-economy TFP growth for the UK. This can provide a broad indication of whether rail productivity has evolved better or worse than the economy as a whole. Similarly, the rail TFP estimates could be compared with TFP in selected comparator sectors (for example, other network industries or transport-related sectors) from ONS or EU KLEMS.

We have compared our findings to ONS MFP for the UK economy as a whole. ONS MFP uses GVA-based TFP, which can be compared with our GVA TFP estimates for the rail sector. We have also estimated GO-based MFP for the whole economy by adjusting GVA-based MFP growth figures for the ratio between GVA and GO in each year of the estimation period.[12] This is in line with the approach often taken by regulators using EU KLEMS TFP data to set frontier shift targets, as EU KLEMS TFP estimates are also GVA-based, and can be converted to GO based using the GVA/GO ratio. We use ONS MFP for our comparison because more recent years of data are available.

[12] The ratio is calculated using basic price GVA at current prices from the Quarterly National Accounts and domestic output at basic prices from the ONS Supply–Use tables.

Figure 4.3 compares our estimated rail-industry TFP indices with ONS multi-factor productivity (MFP) indices for the UK whole economy (rebased to 2014/15 = 100). The rail sector GO index is quality-adjusted. As can be seen in the figure, the ONS whole-economy series are broadly flat over the period and track each other closely. The rail industry series are far more volatile than the whole-economy benchmark. Prior to 2020/21, rail industry productivity growth was generally stronger than whole economy productivity growth. The sector then experienced a much sharper decline in TFP in Covid than the whole economy, particularly the GO TFP measure, followed by a rebound.

Figure 4.3: Comparison of rail industry TFP indices with ONS MFP for the UK economy



Source: ONS MFP data and national accounts data, Europe Economics calculations

The most obvious takeaway from the chart is that rail productivity has experienced larger swings than the economy as a whole. More detailed comparisons need to be interpreted cautiously. Rail productivity is likely to be more exposed than the wider economy to large demand shocks, such as Covid-19, because a substantial share of labour and capital inputs cannot adjust quickly in the short run. There are also differences in measurement (e.g. physical output volumes) and methodology (endogenous versus exogenous rate of return) that mean the comparison is best interpreted at a high level. The estimates indicate that measured whole-economy MFP was broadly flat over the decade, whereas rail productivity was more cyclical and more heavily affected by the Covid shock (particularly when focusing on the GO-based measure), consistent with the sector's limited short-run flexibility in the use of labour and capital inputs.

A benchmarking framework could also be extended to benchmark individual TOCs (and FOCs) against each other. All of the key building blocks – operator-level outputs, labour, capital and intermediates – have already been assembled for this study, so producing operator-specific quality-adjusted GO TFP indices would mainly require re-running the existing methodology at a finer level of disaggregation. Multi-year TFP comparisons across operators could help to identify where productivity has been persistently weak relative to peers. Such analysis could be valuable for policy and contractual oversight by DfT and, in due course, Great British Railways.

4.2.3 Using TFP for Periodic Reviews

For Periodic Reviews, with the primary focus being on Network Rail, TFP evidence can provide a structured view of historical productivity performance that complements other strands of analysis. The quality-adjusted GO TFP series for Network Rail summarises how, over time, train-km have evolved relative to labour, capital and intermediate inputs, after allowing for changes in punctuality.

The results from this study indicate that Network Rail's TFP has generally increased marginally over 2014/15–2023/24. The decompositions show that the increasing TFP is driven mainly by a gradual decline in measured capital services while train-km are broadly stable or rising, rather than by rapid growth in train-km. On our DRC-based capital measure, depreciation has exceeded new investment over much of the period. Interpreted in economic terms, this pattern is consistent with Network Rail delivering a similar level of train services from a progressively smaller capital stock – in effect, running the network harder relative to its replacement cost. This delivers an improvement in TFP, but if sustained it could also be read as a sign of network deterioration, with potential implications for future asset condition, reliability and the scale of renewals expenditure that will be required. For Periodic Reviews, this underlines the importance of viewing TFP evidence alongside engineering assessments of asset health, resilience and maintenance backlogs, rather than treating higher TFP as unambiguously positive.

Given that TFP trends could be different over future decades, it is also worth considering how ORR might interpret other possible patterns of TFP growth that may be observed in the future. For example, a sustained decline in TFP would imply that, for a given level of output and quality, Network Rail is now using more inputs than it did in the past. In other words, it would suggest that it has moved further away from what has been demonstrated to be achievable on its own network. This would provide evidence that there is scope – subject to changes in operating conditions, safety standards and policy requirements – to move back towards earlier levels of efficiency over time. In such a scenario, TFP could therefore help to estimate a catch-up efficiency challenge to be applied at a Periodic Review.

Overall, however, we do not think TFP should be used mechanically in Periodic Reviews. The indices are backward-looking, and they inevitably reflect data and modelling choices (for example, the treatment of capital and the construction of GVA). Network Rail's GVA-based TFP in particular is best seen as a cross-check, given it is derived from staff costs and depreciation rather than from an independent measure of value added.

4.2.4 TFP and rail reform

Rail reform – including the planned creation of Great British Railways (GBR) and associated changes to the way passenger services are specified and funded – is intended to address long-standing issues around fragmentation, misaligned incentives and complexity in the current model. These changes have the potential to affect productivity through several channels: by altering how risks and responsibilities are allocated between infrastructure and operations, by changing the contractual incentives faced by passenger operators, and by enabling more integrated planning of capacity, timetables, investment and fares. At the same time, reform is likely to involve transitional costs and organisational disruption, which may depress measured productivity in the short term even if longer-term gains are achievable.

In that context, TFP analysis provides a useful framework for monitoring the impact of rail reform on productivity at a system level. If reform is successful in improving alignment between track and train and enables more efficient use of capacity, we would expect to see this reflected in stronger TFP performance relative to the pre-reform period, after allowing for exogenous factors such as demand conditions and wider cost shocks.

To use TFP effectively in this way, we would recommend continuing to produce TFP indices for: (i) infrastructure activities, (ii) passenger operations and (iii) freight, alongside a whole-industry measure, even if functions currently undertaken by Network Rail and TOCs are reorganised within GBR or other entities.

The approach developed in this study can serve as a baseline, with post-reform indices constructed on the same conceptual basis and, where possible, back-cast if reporting structures change. Establishing a clear "pre-reform" baseline and then updating TFP on a three- to five-year cycle would allow ORR and government to assess whether the sector's productivity trajectory is improving, flat or deteriorating under the new arrangements.

If TFP analysis is to play a role in assessing the impact of rail reform, it will be important that data and reporting under GBR are designed with productivity analysis in mind. This includes maintaining consistent time series on physical outputs, labour, capital and intermediates for the main parts of the system; improving the treatment of key items such as rolling-stock leases and embedded maintenance; and ensuring that quality metrics (including punctuality, cancellations and, where possible, crowding) are available on a consistent basis over time.

Appendix 1: Brief literature review

In this literature review we cover three key publications relating to TFP estimation:

- EU KLEMS Growth and Productivity Accounts Methodology[13]
- ONS methodological notes on multi-factor productivity (MFP) measurement in the UK[14,15]
- OECD Manual: Measuring Productivity[16]

EU KLEMS Growth and Productivity Accounts Methodology

EU KLEMS is a cross-country, industry-level database that provides information on output, inputs and productivity for European economies. It reports both gross output and value added, together with hours worked, labour composition indices and capital services by asset type. The TFP measures are VA TFP, though GO TFP can be constructed straightforwardly by users based using the GO and GVA data.

Output definition

EU KLEMS relies on the underlying national accounts for much of its output data. It provides current-price, price-index and volume-index series for gross output, intermediate inputs and value added. In practice, the quality of the resulting real-output measures depends heavily on how well the national statistical office deflators adjust for quality change (for example in services and ICT). Differences in national accounting practice, even with guidance such as Eurostat's Handbook on Price and Volume Measures, mean that cross-country comparisons can be affected by deflator choices as much as by "true" productivity differences.

Measuring inputs

Labour: EU KLEMS measures labour input as labour services rather than headcount. Hours worked are cross-classified by worker characteristics (education, age and gender) and aggregated using compensation shares as weights, so shifts towards higher-paid or more experienced workers raise the labour-services index faster than total hours. This means that part of what might otherwise appear as TFP growth is instead recorded as labour "quality" growth.

Capital: Capital is measured as capital services by asset and industry, using the perpetual inventory method with geometric depreciation to construct productive capital stocks, and user-cost (rental-price) weights to aggregate across assets. EU KLEMS distinguishes seven asset types (three ICT: computing, communications, software, and four non-ICT: transport equipment, other machinery/equipment, residential, non-residential structures); ICT assets are quality-adjusted via appropriate investment deflators. EU KLEMS uses an endogenous rate of return that is consistent with national-accounts capital compensation (for example, gross operating surplus), so that the user costs aggregate back to observed capital income. ICT assets (such as computers, communications equipment and software) receive relatively high weights because they depreciate quickly and/or experience rapid price declines. Depreciation rates vary significantly by asset type (e.g., 0.315 for computers versus 0.011 for residential structures).

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[13] Koszerek, D., Havik, K., Mc Morrow, K., Röger, W., & Schönborn, F. (2007). An overview of the EU KLEMS growth and productivity accounts. *European Economy-Economic Papers 2008-2015*, (290).[online]
[14] ONS (2025) "Multi-factor productivity (MFP) QMI" [online]
[15] ONS (2018) "A simple guide to multi-factor productivity" [online]
[16] OECD Manual (2001) "Measuring Productivity: Measurement Of Aggregate And Industry-Level Productivity Growth" [online]

Intermediates: EU KLEMS provides separate series for intermediate inputs; energy, materials and services. For value-added-based analysis, intermediate inputs are netted out by construction. EU KLEMS notes that gross output at industry level can overstate "sectoral" output when there are large intra-industry deliveries, and that a sectoral-output concept net of such intra-industry flows may be preferred for aggregation.

Conceptual considerations for calculating TFP

EU KLEMS follows the Jorgenson-Griliches tradition: under competitive factor markets, full input utilisation, and constant returns to scale, the growth of output equals the share-weighted growth of inputs (capital services, labour services, and, under GO, intermediates), plus the TFP residual. In other words, TFP is the portion of output growth not explained by measured input growth under these assumptions. In practice, measured TFP is a residual that can absorb allocative and technical efficiency changes, mark-ups/returns-to-scale effects, shifts in utilisation, unmeasured inputs/outputs and measurement error, so interpretation requires caution. For VA-based decompositions, the input weights are the capital and labour shares in VA (which sum to one in the model), yielding contributions from labour services, capital services and TFP to VA growth.

Embodied technical change and implications for interpreting TFP

Capital-services measurement and quality-adjusted deflators are intended to ensure that embodied technical change (for example, newer vintages of ICT) is captured in capital deepening rather than in TFP, but EU KLEMS recognises that some embodied improvements may still leak into the residual due to measurement gaps.

ONS methodological notes on multi-factor productivity measurement in the UK

Output definition

ONS compiles MFP for the UK using a growth-accounting framework with gross value added (GVA) as the output measure. The published MFP series cover the UK market sector only and explicitly remove imputed rental from the output concept, so general government and non-profit institutions serving households are excluded. GVA is taken from the national accounts as a chained-volume series; intermediate inputs are netted out by construction, so the published MFP measures do not show separate contributions from energy, materials and services.

Quality adjustment of outputs

ONS does not quality-adjust output directly within the MFP system; instead they take the national-accounts GVA volume series as given and focus on quality adjustments to the inputs (labour and capital). Where service quality improves, this would only affect measured MFP if it is reflected in prices/deflators and hence GVA volumes; otherwise it appears in the MFP residual. The ONS Quality, Methodology and Information report (QMI) notes that some drivers of productivity (for example, natural or social capital, or intangibles outside the asset boundary) are not captured explicitly, so measured MFP will inevitably absorb some unmeasured "quality" change.

Measuring inputs

Labour:

Labour input is measured as Compositionally Adjusted Labour Input (CALI). This starts from hours worked by industry and breaks them down by worker characteristics; changes in hours in each group are weighted by that group's share of the wage bill, giving a quality-adjusted labour index that rises faster than total hours when the workforce shifts towards higher-paid groups. CALI is constructed mainly from the Labour Force Survey with pay data benchmarked to ASHE, and the series used in MFP are seasonally adjusted. ONS stresses that CALI captures both volume (hours) and composition (quality) changes; any movement in GVA not explained by share-weighted CALI and capital services is attributed to MFP.

Capital: Capital input in the ONS MFP framework is the Volume Index of Capital Services (VICS). Conceptually this measures the flow of services from different asset types (for example buildings, machinery, software), modelled from capital-stock data using assumptions on asset lives, age-efficiency profiles and returns. Asset categories are aligned with National Account classifications, and asset lives and age-efficiency/depreciation schedules differ by asset category. As with EU KLEMS, asset-specific user-cost weights are used to aggregate across assets. Using capital services with rental-price weights is designed to capture embodied technical change as capital deepening rather than MFP. However, ONS note the limits of coverage (for example, assets outside the National Accounts boundary, some intangibles, or natural/social capital).

Intermediates: Because published ONS MFP is GVA-based, intermediate inputs are netted out rather than appearing as separate contributors (unlike a gross-output EU KLEMS decomposition). The guide's GVA section is explicit about deducting the cost of sales (materials, energy, bought-in services) to arrive at value added. This means that improvements in service quality or the introduction of new products will only affect measured MFP if they are reflected in prices and hence in price deflators; otherwise they appear in the residual.

Conceptual considerations for calculating TFP

ONS present MFP as the residual in a share-weighted growth decomposition of GVA: changes in (quality-adjusted) labour and capital services are multiplied by their average cost shares and subtracted from GVA growth; the remainder is MFP. ONS notes that MFP reflects factors such as technological progress, organisational change, economies of scale and measurement error.

OECD Manual: Measuring Productivity

Output definition

The OECD manual sets out two standard representations of multi-factor productivity:

- a gross-output approach, relating gross output to primary inputs (labour and capital) and intermediate inputs
- a value-added approach, relating value added to primary inputs only

Gross output is defined as sales plus changes in inventories before deducting intermediate inputs; value added is gross output minus intermediate consumption, both including consumption of fixed capital. For aggregating industry-level productivity, the manual introduces "sectoral output" – gross output net of intra-industry deliveries – so that industry-level gross-output MFP can be combined without double-counting. At the whole-economy level, sectoral output converges towards value added apart from the role of imported intermediates.

A key message in the manual is the separation of price and quantity, particularly for services and fast-changing products. The manual stresses that output indices should be constructed independently of input indices to avoid mechanical bias (for example, extrapolating real value-added using input-based indicators). It notes that single-deflating value added – i.e. using only an output deflator – is generally inferior to **double deflation**, where outputs and intermediate inputs are deflated separately and real value added is obtained as the difference between the corresponding volume measures.

Measuring inputs

Labour: the preferred quantity is hours actually worked, not headcount or jobs, because hours track services supplied more closely and accommodate changes in part-time work, vacations, and multiple job-holding. The manual further encourages quality-adjusted labour input (LQI), weighting hours for different worker types by their compensation shares. This shifts part of output growth from the productivity residual into labour's contribution and makes compositional change in the workforce an explicit source of growth.

Capital: OECD adopts capital services as the appropriate input concept: flows of services from assets, aggregated across asset types with user-cost weights reflecting the marginal productivity of each asset. This distinguishes between wealth measures (capital stocks) and service flows (capital services). Separating capital by asset type is not optional: service flows differ by asset, and aggregation requires asset-specific user-cost weights; the manual sets out that capital input should be built from productive stocks by asset and industry, then combined with user costs to form a capital-services index.

Intermediates: The OECD recommends separate quantity indices for energy, materials and services, weighted by cost shares. Input-output tables are noted as useful for consistently identifying and valuing these flows, and the manual recommends valuing outputs at basic prices and inputs at purchasers' prices to align with producers' decisions.

Conceptual approach to TFP calculation

The OECD frames TFP in a growth-accounting setting: growth of output equals a cost-share-weighted sum of the growth of labour, capital and (for gross-output measures) intermediate inputs, with the residual term labelled MFP/TFP.

A key interpretive distinction is between embodied technical change (improvements embodied in new vintages of capital or intermediates, which should be captured in the measured values of those inputs if they are properly differentiated and quality-adjusted) and disembodied technical change (organisational improvements, spillovers, etc.), which is more likely to appear in TFP. If capital, labour and intermediates are not fully differentiated or quality-adjusted, some embodied changes will be mis-classified into the TFP residual.

Appendix 2: Full results from sensitivity tests

In this appendix we set out the full results from our TFP sensitivity tests, by segment. As explained in Chapter 3, the sensitivities use GO TFP with quality adjustments, unless specified otherwise.

Whole industry

Table 4.1: Whole industry annual GO TFP growth for different quality adjustments (%)

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Timeliness and rolling stock age	-2.7%	3.9%	5.6%	2.1%	4.6%	-73.1%	148.8%	27.8%	10.6%
Timeliness only	1.1%	0.2%	2.9%	0.1%	-3.5%	-73.3%	147.3%	27.0%	10.1%

Table 4.2: Whole industry GO TFP index for different quality adjustments

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Timeliness and rolling stock age	100.0	97.3	101.1	106.7	108.9	113.9	30.7	76.3	97.5	107.8
Timeliness only	100.0	101.1	101.3	104.3	104.3	100.7	26.9	66.5	84.5	93.0

Table 4.3: Whole industry annual GO TFP growth – Alternative initial capital stock for Network Rail

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
DfT valuation 2015/16	-2.7%	3.9%	5.6%	2.1%	4.6%	-73.1%	148.8%	27.8%	10.6%
RAB valuation	-6.9%	-0.8%	3.6%	-1.3%	1.2%	-73.7%	146.5%	27.3%	8.5%
DfT valuation 2023/24	-1.1%	5.7%	6.4%	3.7%	6.4%	-72.8%	150.1%	28.2%	11.8%

Table 4.4: Whole industry GO TFP index – Alternative initial capital stock for Network Rail

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
DfT valuation 2015/16	100.0	97.3	101.1	106.7	108.9	113.9	30.7	76.3	97.5	107.8
RAB valuation	100.0	93.1	92.3	95.6	94.4	95.5	25.2	62.0	78.9	85.6
DfT valuation 2023/24	100.0	98.9	104.6	111.3	115.4	122.8	33.4	83.7	107.2	119.9

Table 4.5: Whole industry annual GO TFP growth – Alternative asset coverage for initial capital stock for Network Rail, using 2015/16 DfT valuation

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default (exclude land)	-2.7%	3.9%	5.6%	2.1%	4.6%	-73.1%	148.8%	27.8%	10.6%
Include Land	-1.6%	4.7%	6.1%	2.6%	5.0%	-73.0%	149.1%	27.9%	10.8%
Exclude Land, Civils and Earthworks	-5.2%	1.0%	4.7%	-0.4%	2.0%	-73.5%	147.9%	27.9%	9.2%

Table 4.6: Whole industry GO TFP index – Alternative asset coverage for initial capital stock for Network Rail, using 2015/16 DfT valuation

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default (exclude land)	100.0	97.3	101.1	106.7	108.9	113.9	30.7	76.3	97.5	107.8
Include Land	100.0	98.4	103.0	109.3	112.1	117.7	31.8	79.1	101.2	112.1
Exclude Land, Civils and Earthworks	100.0	94.8	95.8	100.2	99.8	101.8	27.0	67.0	85.6	93.5

Table 4.7: Whole industry annual GO TFP growth – Alternative price indices

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	-2.7%	3.9%	5.6%	2.1%	4.6%	-73.1%	148.8%	27.8%	10.6%
Alternative	-2.9%	3.5%	5.6%	1.7%	5.0%	-72.9%	148.5%	25.4%	11.6%
CPI Only	-2.8%	3.7%	5.5%	2.1%	5.4%	-73.0%	147.4%	27.3%	12.2%

Table 4.8: Whole industry GO TFP index – Alternative price indices

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	100.0	97.3	101.1	106.7	108.9	113.9	30.7	76.3	97.5	107.8
Alternative	100.0	97.1	100.5	106.1	107.9	113.3	30.6	76.2	95.5	106.6
CPI Only	100.0	97.2	100.8	106.3	108.5	114.4	30.9	76.5	97.3	109.2

Table 4.9: Whole industry annual GO TFP growth – Alternative depreciation assumptions

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	-2.7%	3.9%	5.6%	2.1%	4.6%	-73.1%	148.8%	27.8%	10.6%
High	-2.1%	4.4%	5.9%	2.3%	4.9%	-73.0%	149.1%	28.0%	10.8%
Low	-3.1%	3.5%	5.3%	1.9%	4.3%	-73.1%	148.5%	27.7%	10.5%

Table 4.10: Whole industry GO TFP index – Alternative depreciation assumptions

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	100.0	97.3	101.1	106.7	108.9	113.9	30.7	76.3	97.5	107.8
High	100.0	97.9	102.2	108.2	110.7	116.1	31.3	77.9	99.8	110.5
Low	100.0	96.9	100.2	105.5	107.5	112.1	30.1	74.9	95.6	105.6

Table 4.11: Whole industry annual GO TFP growth – Alternative cost of capital

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Regulatory WACC	-2.7%	3.9%	5.6%	2.1%	4.6%	-73.1%	148.8%	27.8%	10.6%
Operator uplift	-2.7%	3.9%	5.6%	2.1%	4.5%	-73.1%	148.7%	27.8%	10.6%

Table 4.12: Whole industry GO TFP index – Alternative cost of capital

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Regulatory WACC	100.0	97.3	101.1	106.7	108.9	113.9	30.7	76.3	97.5	107.8
Operator uplift	100.0	97.3	101.1	106.7	108.9	113.9	30.6	76.2	97.4	107.7

Table 4.13: Whole industry annual GO TFP growth – Capacity utilisation adjustment

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
No adjustment	-2.7%	3.9%	5.6%	2.1%	4.6%	-73.1%	148.8%	27.8%	10.6%
Adjustment	-2.7%	3.9%	5.6%	2.1%	4.6%	-69.3%	129.6%	25.7%	8.6%

Table 4.14: Whole industry GO TFP index – Capacity utilisation adjustment

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
No adjustment	100.0	97.3	101.1	106.7	108.9	113.9	30.7	76.3	97.5	107.8
Adjustment	100.0	97.3	101.1	106.7	108.9	113.9	34.9	80.2	100.8	109.4

Table 4.15: Whole industry annual GO TFP growth – Alternative Tornqvist weights

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Two year (default)	-2.7%	3.9%	5.6%	2.1%	4.6%	-73.1%	148.8%	27.8%	10.6%
Full period	-3.2%	3.4%	5.8%	2.0%	5.1%	-72.9%	148.6%	27.7%	10.9%

Table 4.16: Whole industry GO TFP index – Alternative Tornqvist weights

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Two year (default)	100.0	97.3	101.1	106.7	108.9	113.9	30.7	76.3	97.5	107.8
Full period	100.0	96.8	100.2	106.0	108.1	113.7	30.8	76.5	97.7	108.4

Table 4.17: Whole industry annual GO TFP growth – Alternative enhancements split

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Two year (default)	-2.7%	3.9%	5.6%	2.1%	4.6%	-73.1%	148.8%	27.8%	10.6%
Full period	-2.7%	3.8%	5.6%	2.0%	4.6%	-73.1%	148.9%	27.9%	10.6%

Table 4.18: Whole industry GO TFP index – Alternative enhancements split

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Two year (default)	100.0	97.3	101.1	106.7	108.9	113.9	30.7	76.3	97.5	107.8
Full period	100.0	97.3	101.0	106.7	108.8	113.9	30.7	76.3	97.6	107.9

Network Rail

Table 4.19: Network Rail annual GO TFP growth – Alternative initial capital stock for Network Rail

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
DfT 2015/16 valuation	0.9%	1.6%	2.5%	1.7%	5.4%	-17.7%	9.9%	-6.8%	6.7%
RAB valuation	-6.5%	-2.3%	-1.1%	-3.4%	1.0%	-21.8%	8.4%	-8.9%	4.0%
DfT 2023/24 valuation	2.7%	2.7%	3.5%	3.3%	7.0%	-16.0%	10.5%	-5.9%	7.9%

Table 4.20: Network Rail GO TFP index – Alternative initial capital stock for Network Rail

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
DfT 2015/16 valuation	100.0	100.9	102.5	105.1	106.9	112.6	92.7	101.9	95.0	101.4
RAB valuation	100.0	93.5	91.4	90.4	87.3	88.2	69.0	74.8	68.1	70.8
DfT 2023/24 valuation	100.0	102.7	105.4	109.1	112.8	120.6	101.3	112.0	105.3	113.6

Table 4.21: Network Rail annual GO TFP growth – Alternative asset coverage for initial capital stock for Network Rail, using 2015/16 DfT valuation

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default (exclude land)	0.9%	1.6%	2.5%	1.7%	5.4%	-17.7%	9.9%	-6.8%	6.7%
Include Land	2.3%	2.6%	3.2%	2.4%	5.9%	-17.3%	10.1%	-6.6%	6.9%
Exclude Land, Civils and Earthworks	-2.9%	0.2%	1.0%	-1.6%	2.4%	-20.3%	9.6%	-7.8%	5.1%

Table 4.22: Network Rail GO TFP index – Alternative asset coverage for initial capital stock for Network Rail, using 2015/16 DfT valuation

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default (exclude land)	100.0	100.9	102.5	105.1	106.9	112.6	92.7	101.9	95.0	101.4
Include Land	100.0	102.3	104.9	108.2	110.8	117.3	97.0	106.8	99.8	106.7
Exclude Land, Civils and Earthworks	100.0	97.1	97.3	98.2	96.7	99.1	79.0	86.6	79.8	83.9

Table 4.23: Network Rail annual GO TFP growth – Alternative price indices

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	0.9%	1.6%	2.5%	1.7%	5.4%	-17.7%	9.9%	-6.8%	6.7%
Alternative	0.4%	1.4%	2.5%	1.4%	5.3%	-17.6%	9.9%	-7.3%	6.9%
CPI Only	0.6%	1.6%	2.7%	1.5%	5.6%	-17.3%	9.5%	-7.0%	7.2%

Table 4.24: Network Rail GO TFP index – Alternative price indices

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	100.0	100.9	102.5	105.1	106.9	112.6	92.7	101.9	95.0	101.4
Alternative	100.0	100.4	101.8	104.3	105.7	111.3	91.7	100.8	93.5	99.9
CPI Only	100.0	100.6	102.2	104.9	106.5	112.4	93.0	101.8	94.7	101.4

Table 4.25: Network Rail annual GO TFP growth – Alternative depreciation assumptions

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	0.9%	1.6%	2.5%	1.7%	5.4%	-17.7%	9.9%	-6.8%	6.7%
High depreciation	1.7%	2.2%	2.9%	2.0%	5.8%	-17.4%	10.1%	-6.6%	7.0%
Low depreciation	0.2%	1.2%	2.2%	1.4%	5.0%	-17.9%	9.7%	-7.0%	6.5%

Table 4.26: Network Rail GO TFP index – Alternative depreciation assumptions

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	100.0	100.9	102.5	105.1	106.9	112.6	92.7	101.9	95.0	101.4
High depreciation	100.0	101.7	103.9	107.0	109.1	115.4	95.3	104.9	98.0	104.8
Low depreciation	100.0	100.2	101.4	103.6	105.0	110.3	90.6	99.3	92.4	98.5

Table 4.27: Network Rail annual GO TFP growth – Alternative Tornqvist weights

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Two year weights	0.9%	1.6%	2.5%	1.7%	5.4%	-17.7%	9.9%	-6.8%	6.7%
Full period weights	0.0%	2.4%	2.9%	0.8%	5.5%	-16.5%	9.6%	-6.5%	7.4%

Table 4.28: Network Rail GO TFP index – Alternative Tornqvist weights

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Two year weights	100.0	100.9	102.5	105.1	106.9	112.6	92.7	101.9	95.0	101.4
Full period weights	100.0	100.0	102.4	105.3	106.2	112.1	93.5	102.5	95.9	102.9

Table 4.29: Network Rail annual GO TFP growth – Alternative enhancements split

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	0.9%	1.6%	2.5%	1.7%	5.4%	-17.7%	9.9%	-6.8%	6.7%
IT and Telecoms sensitivity	0.8%	1.6%	2.5%	1.6%	5.5%	-17.6%	9.9%	-6.7%	6.7%

Table 4.30: Network Rail GO TFP index – Alternative enhancements split

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	100.0	100.9	102.5	105.1	106.9	112.6	92.7	101.9	95.0	101.4
IT and Telecoms sensitivity	100.0	100.8	102.4	105.0	106.7	112.6	92.8	102.0	95.1	101.5

TOCs

Table 4.31: Annual TOC GO TFP growth for different quality adjustments

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Timeliness and rolling stock age	-2.4%	-3.5%	3.9%	-6.3%	2.2%	-79.3%	204.4%	38.9%	7.5%
Timeliness only	1.8%	-7.2%	1.1%	-8.3%	-6.3%	-79.5%	202.0%	37.9%	6.9%

Table 4.32: TOC GO TFP index for different quality adjustments

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Timeliness and rolling stock age	100.0	97.6	94.2	97.9	91.7	93.7	19.4	59.1	82.1	88.3
Timeliness only	100.0	101.8	94.4	95.4	87.5	82.0	16.9	50.9	70.2	75.1

Table 4.33: TOC annual GO TFP growth – Alternative price indices

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	-2.4%	-3.5%	3.9%	-6.3%	2.2%	-79.3%	204.4%	38.9%	7.5%
Alternative	-1.8%	-3.2%	3.7%	-7.0%	2.5%	-79.0%	203.8%	31.7%	9.7%
CPI Only	-2.0%	-3.8%	3.1%	-5.9%	2.8%	-79.1%	199.6%	36.7%	11.7%

Table 4.34: TOC GO TFP index – Alternative price indices

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	100.0	97.6	94.2	97.9	91.7	93.7	19.4	59.1	82.1	88.3
Alternative	100.0	98.2	95.0	98.5	91.6	93.9	19.8	60.0	79.1	86.7
CPI Only	100.0	98.0	94.2	97.2	91.4	94.0	19.6	58.7	80.3	89.6

Table 4.35: TOC annual GO TFP growth – Alternative depreciation assumptions

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	-2.4%	-3.5%	3.9%	-6.3%	2.2%	-79.3%	204.4%	38.9%	7.5%
High	-2.4%	-3.5%	3.9%	-6.3%	2.2%	-79.3%	204.4%	38.9%	7.5%
Low	-2.4%	-3.5%	3.9%	-6.3%	2.2%	-79.3%	204.4%	38.9%	7.5%

Table 4.36: TOC GO TFP index – Alternative depreciation assumptions

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	100.0	97.6	94.2	97.9	91.7	93.7	19.4	59.1	82.1	88.3
High	100.0	97.6	94.2	97.9	91.7	93.7	19.4	59.1	82.2	88.3
Low	100.0	97.6	94.2	97.8	91.7	93.7	19.4	59.1	82.1	88.3

Table 4.37: TOC annual GO TFP growth – Alternative cost of capital

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Regulatory WACC	-2.4%	-3.5%	3.9%	-6.3%	2.2%	-79.3%	204.4%	38.9%	7.5%
Operator uplift	-2.4%	-3.5%	3.9%	-6.3%	2.2%	-79.3%	204.3%	38.9%	7.5%

Table 4.38: TOC GO TFP index – Alternative cost of capital

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Regulatory WACC	100.0	97.6	94.2	97.9	91.7	93.7	19.4	59.1	82.1	88.3
Operator uplift	100.0	97.6	94.2	97.8	91.6	93.6	19.4	59.1	82.0	88.2

Table 4.39: TOC annual GO TFP growth – Capacity utilisation adjustment

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
No adjustment	-2.4%	-3.5%	3.9%	-6.3%	2.2%	-79.3%	204.4%	38.9%	7.5%
Adjustment	-2.4%	-3.5%	3.9%	-6.3%	2.2%	-72.7%	151.5%	33.3%	2.8%

Table 4.40: TOC GO TFP index – Capacity utilisation adjustment

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
No adjustment	100.0	97.6	94.2	97.9	91.7	93.7	19.4	59.1	82.1	88.3
Adjustment	100.0	97.6	94.2	97.9	91.7	93.7	25.6	64.3	85.7	88.1

Table 4.41: TOC annual GO TFP growth – Alternative Tornqvist weights

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Two year	-2.4%	-3.5%	3.9%	-6.3%	2.2%	-79.3%	204.4%	38.9%	7.5%
Full period	-2.3%	-3.9%	3.8%	-6.4%	2.2%	-79.3%	204.4%	39.1%	7.4%

Table 4.42: TOC GO TFP index – Alternative Tornqvist weights

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Two year	100.0	97.6	94.2	97.9	91.7	93.7	19.4	59.1	82.1	88.3
Full period	100.0	97.7	93.9	97.4	91.2	93.3	19.3	58.9	81.9	88.0

Table 4.43: TOC annual GO TFP growth – Alternative Rolling stock maintenance adjustment

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	-2.4%	-3.5%	3.9%	-6.3%	2.2%	-79.3%	204.4%	38.9%	7.5%
No adjustment	-3.3%	-4.4%	3.3%	-6.8%	1.7%	-79.3%	203.7%	38.1%	7.6%

Table 4.44: TOC GO TFP index – Alternative Rolling stock maintenance adjustment

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	100.0	97.6	94.2	97.9	91.7	93.7	19.4	59.1	82.1	88.3
No adjustment	100.0	96.7	92.4	95.5	89.0	90.5	18.7	56.8	78.5	84.4

FOCs

Table 4.45: FOC annual GO TFP growth – Alternative price indices

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	-15.9%	-9.9%	5.9%	4.0%	-6.2%	-4.1%	3.5%	-17.0%	1.0%
Alternative	-15.7%	-9.9%	5.9%	3.4%	-6.0%	-3.0%	3.3%	-20.7%	2.6%
CPI Only	-15.8%	-10.3%	5.1%	4.4%	-5.9%	-3.7%	1.7%	-18.6%	4.3%

Table 4.46: FOC GO TFP index – Alternative price indices

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	100.0	84.1	75.8	80.3	83.5	78.3	75.0	77.6	64.4	65.1
Alternative	100.0	84.3	76.0	80.5	83.2	78.2	75.9	78.4	62.2	63.8
CPI Only	100.0	84.2	75.5	79.4	82.8	78.0	75.1	76.3	62.1	64.8

Table 4.47: FOC annual GO TFP growth – Alternative depreciation assumptions

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	-15.9%	-9.9%	5.9%	4.0%	-6.2%	-4.1%	3.5%	-17.0%	1.0%
High	-16.0%	-10.0%	5.8%	4.0%	-6.2%	-4.1%	3.4%	-17.0%	1.0%
Low	-15.7%	-9.8%	6.0%	4.0%	-6.2%	-4.1%	3.5%	-17.0%	1.0%

Table 4.48: FOC GO TFP index – Alternative depreciation assumptions

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Default	100.0	84.1	75.8	80.3	83.5	78.3	75.0	77.6	64.4	65.1
High	100.0	84.0	75.6	80.0	83.2	78.0	74.7	77.3	64.2	64.8
Low	100.0	84.3	76.0	80.5	83.7	78.5	75.3	77.9	64.7	65.4

Table 4.49: FOC annual GO TFP growth – Alternative cost of capital

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Regulatory WACC	-15.9%	-9.9%	5.9%	4.0%	-6.2%	-4.1%	3.5%	-17.0%	1.0%
Operator uplift	-15.9%	-9.9%	5.8%	3.9%	-6.3%	-4.2%	3.5%	-17.0%	1.0%

Table 4.50: FOC GO TFP index – Alternative cost of capital

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Regulatory WACC	100.0	84.1	75.8	80.3	83.5	78.3	75.0	77.6	64.4	65.1
Operator uplift	100.0	84.1	75.7	80.1	83.2	78.0	74.7	77.3	64.2	64.9

Table 4.51: FOC annual GO TFP growth – Alternative Tornqvist indices

	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Two year (default)	-15.9%	-9.9%	5.9%	4.0%	-6.2%	-4.1%	3.5%	-17.0%	1.0%
Full period	-15.7%	-9.7%	5.7%	4.0%	-6.3%	-4.1%	3.3%	-17.1%	1.0%

Table 4.52: FOC GO TFP index – Alternative Tornqvist indices

	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24
Two year (default)	100.0	84.1	75.8	80.3	83.5	78.3	75.0	77.6	64.4	65.1
Full period	100.0	84.3	76.1	80.4	83.6	78.3	75.1	77.6	64.4	65.0

Appendix 3: Descriptive data for operator capital inputs

In this appendix we present charts of the data collected from TOC and FOC accounts for capital inputs, broken down into our four asset categories:

- Intangible assets (software)
- Property (including leasehold improvements)
- Other equipment and vehicles
- Rolling stock

For each tangible asset category, we present annual totals (in nominal £000s) for TOCs and FOCs, separating:

- New investment based on additions and transfers reported; and
- Lease payments representing the annual cost of using leased / ROU assets.

Intangible Assets

For intangible assets, only new investment was reported by operators.

Figure 4.4: New Investment – Intangibles (TOCs)

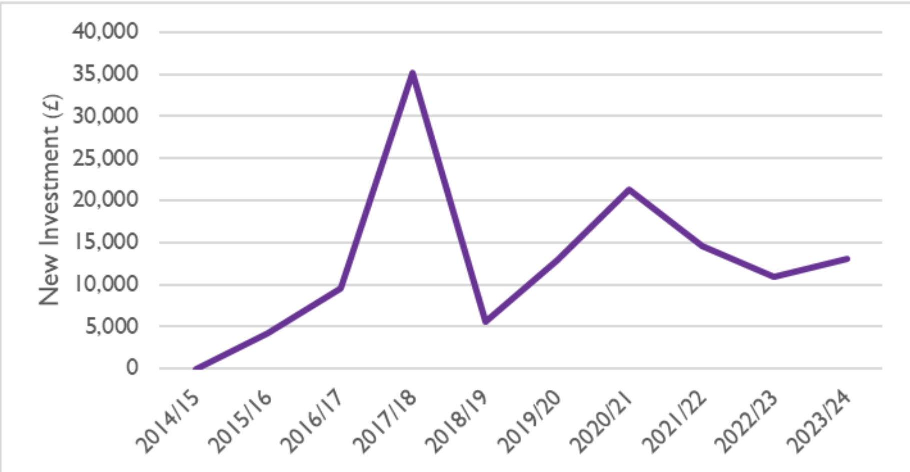
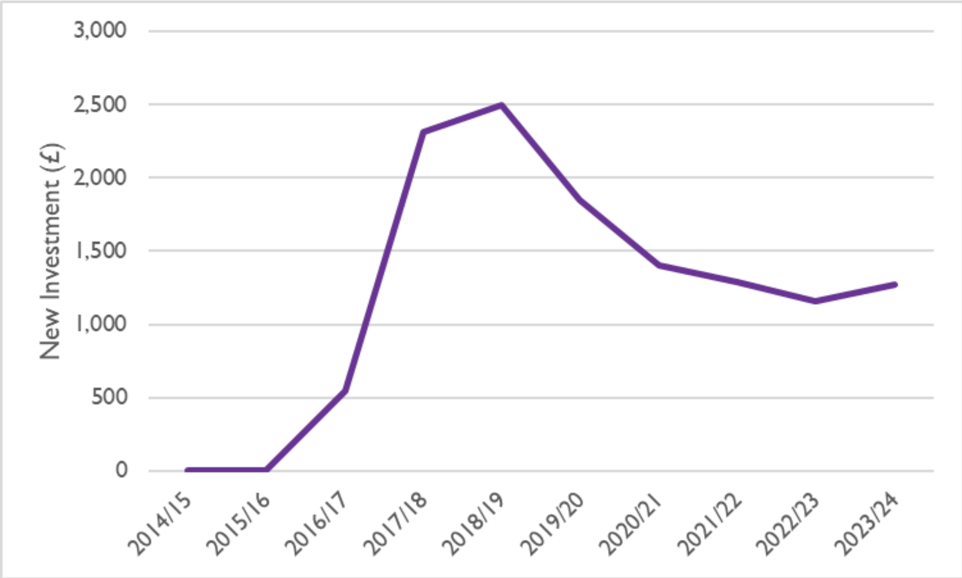


Figure 4.5: New Investment – Intangibles (FOCs)



Property

The property category includes both owned and leased assets classified as land and buildings.

Before the adoption of IFRS 16 (i.e. up to 2018/19 or 2019/20 depending on reporting), lease-related costs were taken from the 'rentals payable under operating leases – property' line in the operating-cost tables. After IFRS 16 was adopted (from 2020/21 onwards), lease payments were replaced by the depreciation of right-of-use (ROU) assets associated with property, plus a proportional share of the interest payable on lease liabilities. This proportional allocation was based on the share of property-related depreciation in total ROU depreciation. For example, if depreciation on property ROU assets accounted for one-third of total ROU depreciation, then one-third of the total lease-related interest expense was attributed to property.

Figure 4.6: New Investment – Property (TOCs)

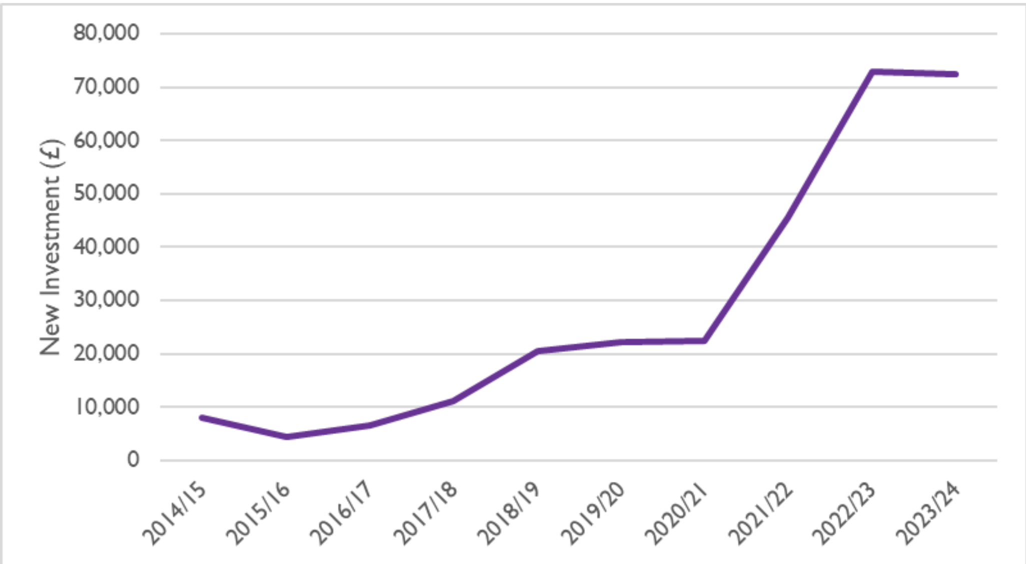


Figure 4.7: New Investment – Property (FOCs)

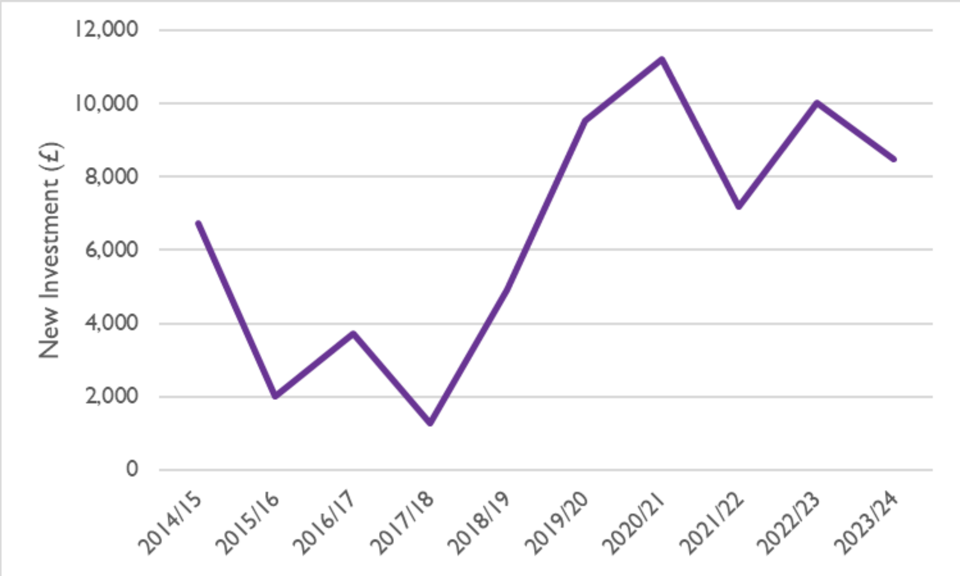


Figure 4.8: Lease Payments – Property (TOCs)

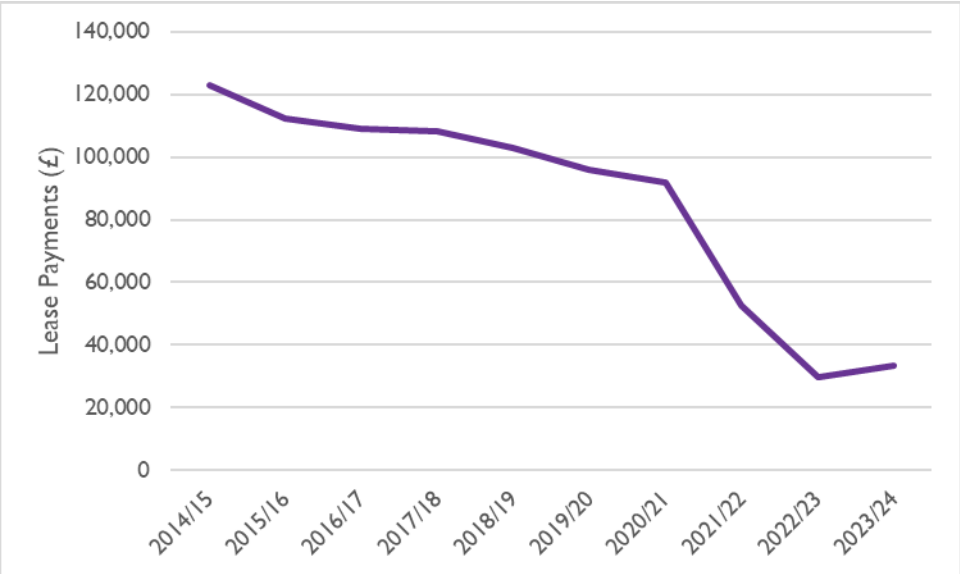
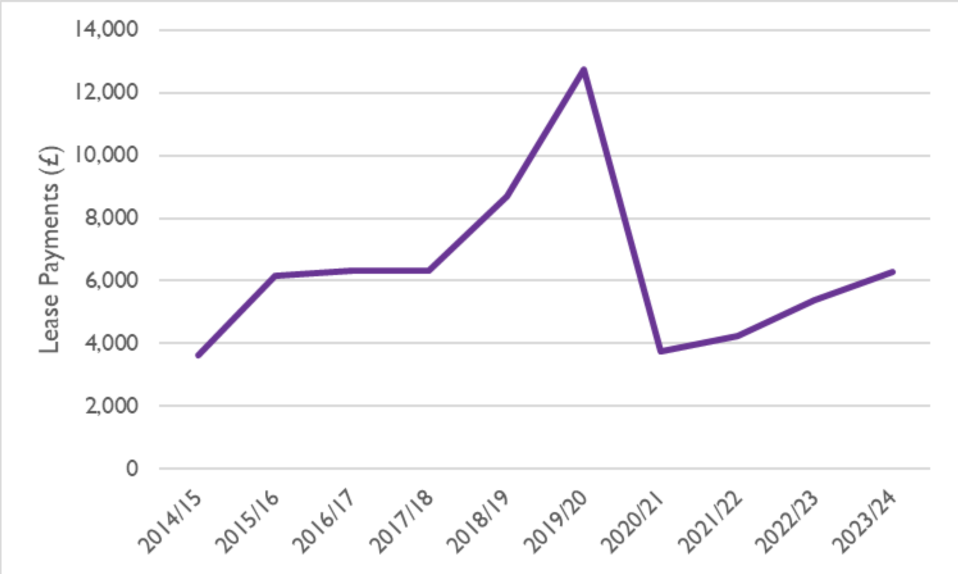


Figure 4.9: Lease Payments – Property (FOCs)



Other Plant and Machinery

This category covers investment and leases for other tangible assets such as plant, equipment, machinery, and road vehicles. The same approaches were used to estimate new investment and lease payments as for property.

Figure 4.10: New Investment – Other Plant and Machinery (TOCs)

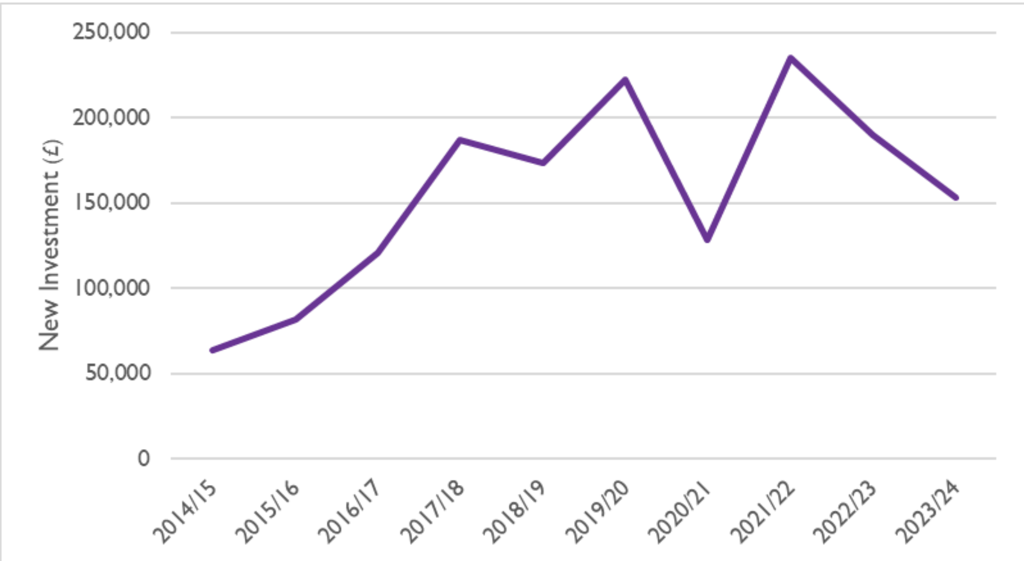


Figure 4.11: New Investment – Other Plant and Machinery (FOCs)

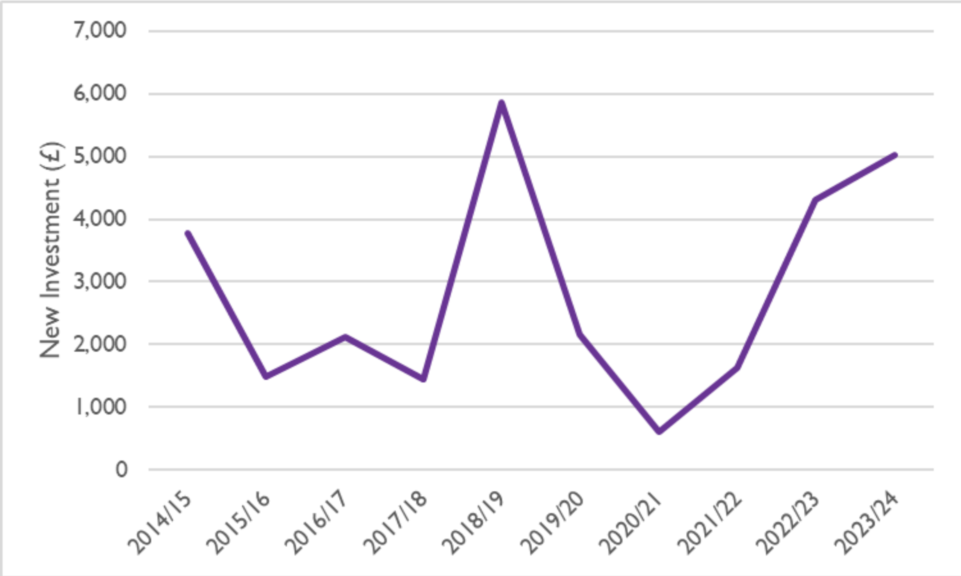


Figure 4.12: Lease Payments – Other Plant and Machinery (FOCs)

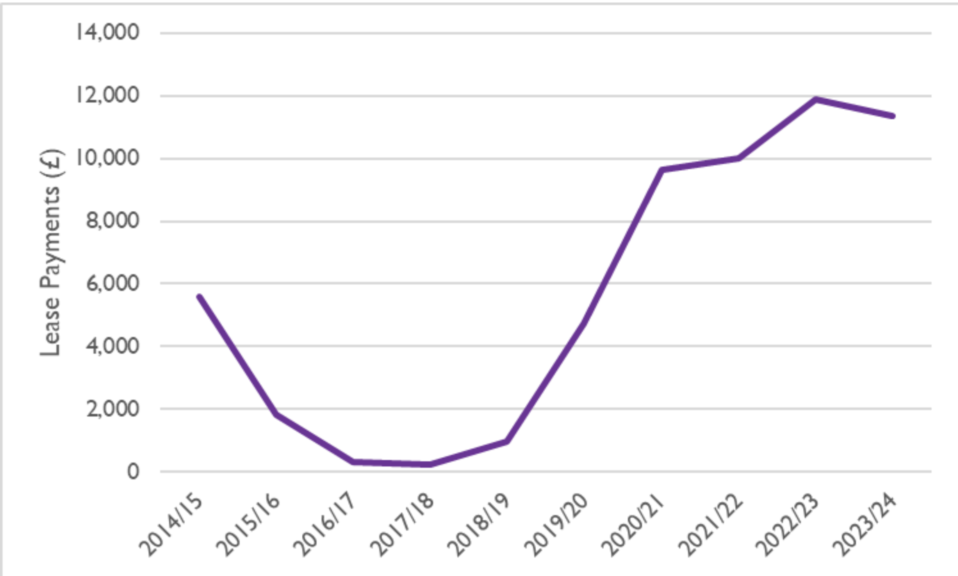
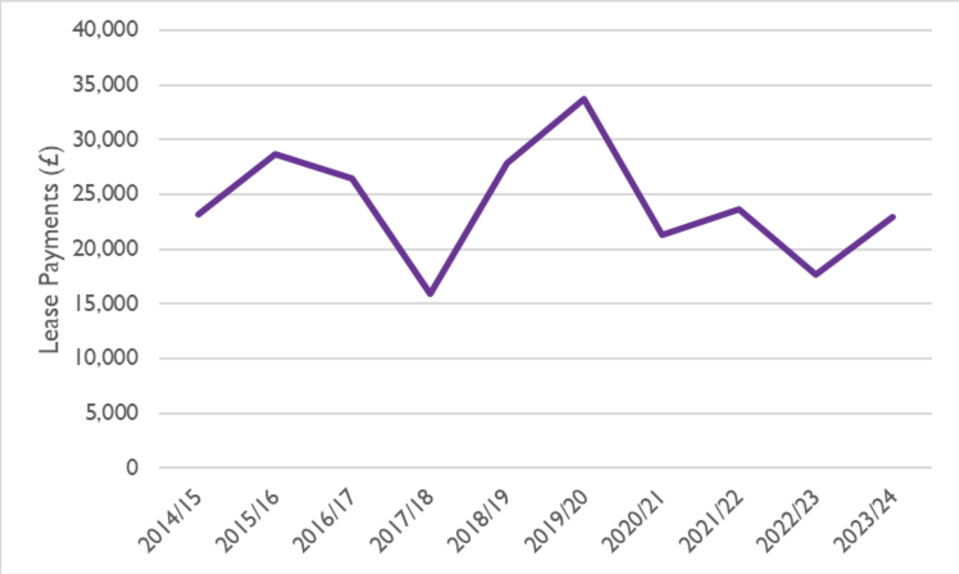


Figure 4.13: Lease Payments – Other Plant and Machinery (TOCs)



Rolling Stock

Rolling stock represents the most significant category of capital input, typically accounting for around 90 per cent of capital inputs for operators. As discussed in the main report, we have tested two sources of data on rolling stock leases – Rail Finance and operators' statutory accounts. The data in the charts below use Rail Finance data (in nominal terms) for franchise TOCs in all years except 2014/15, which is not covered in that dataset. 2014/15 franchise TOC data and all non-franchise TOC data is based on statutory accounts.

Figure 4.14: New Investment – Rolling Stock (TOCs)

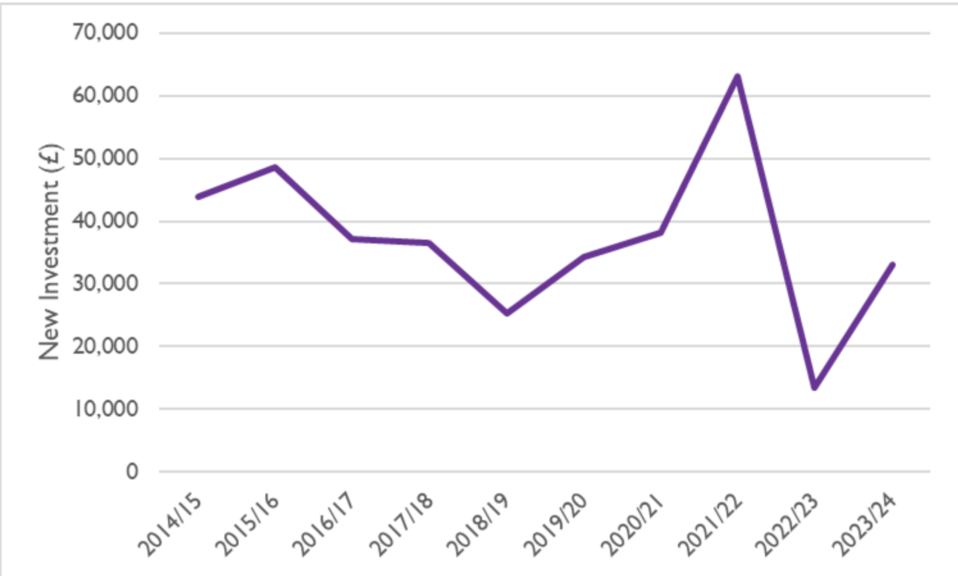


Figure 4.15: New Investment – Rolling Stock (FOCs)

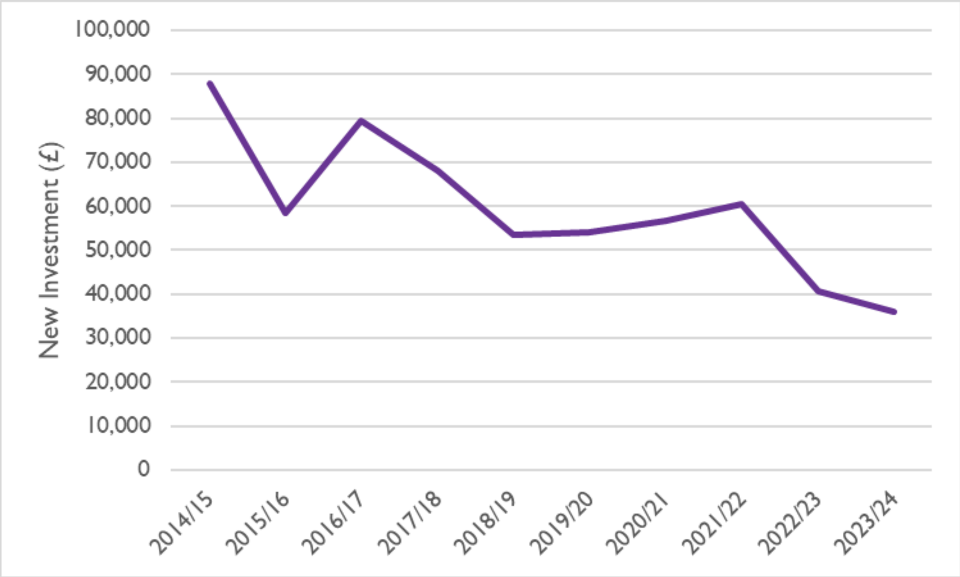


Figure 4.16: Lease Payments – Rolling Stock (TOCs)

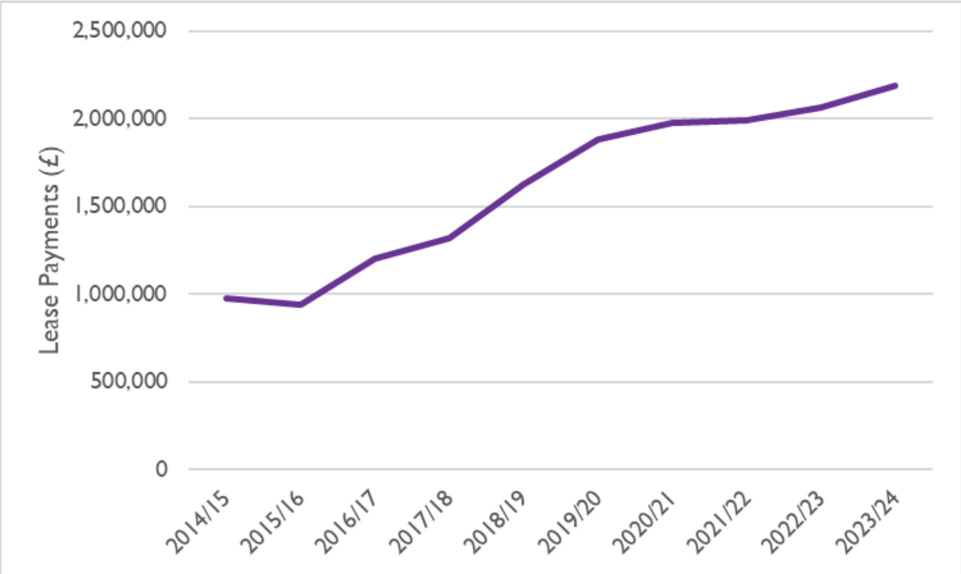


Figure 4.17: Lease Payments – Rolling Stock (FOCs)