

Review of PwC analysis conducted for the Airports Commission.

A Report for Gatwick Airport Ltd.

16 October 2015

This report has been prepared on the basis of the limitations set out in the engagement letter and the matters noted in the Important Notice From Deloitte on page 1.

Deloitte refers to one or more of Deloitte Touche Tohmatsu Limited (“DTTL”), a UK private company limited by guarantee, and its network of member firms, each of which is a legally separate and independent entity. Please see www.deloitte.co.uk/about for a detailed description of the legal structure of DTTL and its member firms. Deloitte LLP is a limited liability partnership registered in England and Wales with registered number OC303675 and its registered office at 2 New Street Square, London, EC4A 3BZ, United Kingdom. Deloitte LLP is the United Kingdom member firm of DTTL.

Contents

- Important Notice from Deloitte 3
- Executive summary 4
- 1 Introduction..... 10
- 2 Airports Commission: Wider Economy Impacts analysis..... 13
- 3 Overview of the PwC Methodology 17
- 4 Airports Commission Traffic forecasts 21
 - 4.1 Aggregate traffic 22
 - 4.2 Connectivity..... 22
 - 4.3 Rate of traffic growth 24
- 5 Review of PwC analysis 26
 - 5.1 Passenger flows 28
 - 5.2 Productivity..... 33
- 6 Implications 37
- Appendix A: Airports Commission traffic forecasts 39
- Appendix B: Methodological approach 44
 - S-CGE Methodology 45
 - Passenger flows..... 48
 - Productivity impact..... 53
 - Frequency benefits 59
 - Transport Economic Efficiency Impact..... 60

Important Notice from Deloitte

This final report (the "Final Report") has been prepared by Deloitte LLP ("Deloitte") for Gatwick Airport Ltd in accordance with the contract with them dated 16th September 2015 ("the Contract") and on the basis of the scope and limitations set out below.

The Final Report has been prepared solely for the purpose of reviewing the economic impact analysis conducted by PricewaterhouseCoopers in connection to the Airports Commission's consultation on expanding airport capacity in the UK, as set out in the Contract. It should not be used for any other purpose or in any other context, and Deloitte accepts no responsibility for its use in either regard.

The Final Report is provided exclusively for Gatwick Airport's use under the terms of the Contract. No party other than Gatwick Airport Ltd is entitled to rely on the Final Report for any purpose whatsoever and Deloitte accepts no responsibility or liability or duty of care to any party other than Gatwick Airport Ltd in respect of the Final Report or any of its contents.

As set out in the Contract, the scope of our work has been limited by the information and explanations made available to us. The information contained in the Final Report has been obtained from Gatwick Airport Ltd and third party sources that are clearly referenced in the appropriate sections of the Final Report. Deloitte has neither sought to corroborate this information nor to review its overall reasonableness. Further, any results from the analysis contained in the Final Report are reliant on the information available at the time of writing the Final Report and should not be relied upon in subsequent periods.

All copyright and other proprietary rights in the Final Report remain the property of Deloitte LLP and any rights not expressly granted in these terms or in the Contract are reserved.

Any decision to invest, conduct business, enter or exit the markets considered in the Final Report should be made solely on independent advice and no information in the Final Report should be relied upon in any way by any third party. This Final Report and its contents do not constitute financial or other professional advice, and specific advice should be sought about your specific circumstances. In particular, the Final Report does not constitute a recommendation or endorsement by Deloitte to invest or participate in, exit, or otherwise use any of the markets or companies referred to in it. To the fullest extent possible, both Deloitte and Gatwick Airport Ltd disclaim any liability arising out of the use (or non-use) of the Final Report and its contents, including any action or decision taken as a result of such use (or non-use).

Executive summary

In July 2015 the Airports Commission published its final report into the options for expansion of airport capacity in the UK. In this report, the Commission recommended expansion at Heathrow through the construction of a North West Runway (Heathrow NWR). In making this recommendation, the Airports Commission highlighted economic analysis that indicated that Heathrow expansion could generate an increase in GDP over the next 60 years of up to £147 billion in net present value, compared to £89 billion at Gatwick.¹ Given the weight that the Airports Commission has accorded to these figures relative to the weight given to other considerations such as costs, delivery risk, noise and air pollution, the objective of this report is to review the robustness of the analysis supporting these numbers.

This estimated GDP impact of up to £147 billion comes from a study into the wider effects of airport expansion conducted by PricewaterhouseCoopers (PwC). This study has already faced some scrutiny, not least from the Airports Commission's own expert advisors, who:

“counsel caution in attaching significant weight either to the absolute or relative results of the GDP/GVA S-CGE approach (PwC report) within the Economic Case.”²

In response to these comments, the Airports Commission has removed the PwC estimates from the economic case presented in the final report; instead, these figures are included as part of the strategic case. The final report notes the concerns raised by the expert advisors and acknowledges that the approach used by PwC in their analysis is “highly innovative.”³ Nonetheless, this has not prevented the estimates from being given considerable prominence in the executive summary of the report, alongside the Airports Commission's own economic analysis. Furthermore, despite the concerns of its own independent advisors of “exaggeration by media,” the results of the PwC work are highlighted by the Airports Commission in the press release accompanying the final report; the Commission's own economic analysis was not quoted.⁴

The significant difference in impacts between Heathrow NWR and Gatwick found in the PwC analysis is inconsistent with that found in other evidence:

- The Airports Commission's own economic analysis of the net present value (NPV) of each scheme suggests they offer similar net benefits.
- The Airports Commission's traffic forecasts indicate that the two schemes are expected to generate a similar volume and mix of UK origin-destination (O-D) traffic in both 2030 and 2050. They would therefore be expected to deliver similar economic benefits.

While there is likely to be value in attempting to assess the wider GDP impacts of airport expansion and the core methodology used by PwC is well-established in other contexts, the discrepancy between the PwC results and other evidence raises significant questions about the weight that should be placed on these results. A review of the PwC assumptions and methodology suggests that there are two key issues with the analysis that adversely affect the reliability of their results:

¹ Airports Commission (2015), “Airports Commission: Final Report”, p. 24.

² A Note from Expert Advisors, Prof. Peter Mackie and Mr Brian Pearce, on key issues considering the Airports Commission Economic Case, May 2015, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/438981/economy-expert-panelist-wider-economic-impacts-review.pdf

³ Airports Commission (2015), “Airports Commission: Final Report”, p. 113.

⁴ Press release, 1st July 2015, <https://www.gov.uk/government/news/airports-commission-releases-final-report>

- The majority (£35bn) of the estimated £58bn difference in economic impacts is due to a traffic mix assumption made by PwC that is contradicted by the Airports Commission's own traffic forecasts.
- PwC estimate the productivity impact using an untested approach that leads to estimates of the relationship between passenger numbers and productivity that are over ten times larger than those found by other studies, and between two and five times as high for Heathrow as for Gatwick. This is the aspect of the model that has drawn most criticism from the Commission's own advisors.

It is recognised that this is a complex topic; however, these two issues, which together account for over 90% of the estimated difference between the schemes, raise concerns and suggest that the PwC analysis has significantly overstated any difference in the GDP impacts. The magnitude of the estimated difference, and the prominence it has been accorded by the Commission, has also tended to obscure other issues that should inform the Airports Commission's recommendations, including: the difference in costs between the schemes; the additional risks of planning or construction delay associated with the scale of the Heathrow scheme; and the environmental and noise impacts of the schemes.

Airports Commission analysis

The Airports Commission's own analysis of the economic impacts of expansion at Heathrow or Gatwick indicates that the two schemes are more finely balanced than the PwC analysis suggests⁵.

The Airports Commission's analysis estimates that Heathrow expansion can deliver up to £55bn in consumer benefits, compared to £47bn at Gatwick; however, the figures quoted include benefits that accrue to overseas passengers who do not enter the UK and therefore do not generate value for the UK economy. When the benefits accruing to such international transfer passengers are excluded from these figures (in accordance with DfT guidance) the difference in consumer benefits falls to just £3bn.⁶

With the costs of each scheme taken into account, the Airports Commission's analysis shows the two schemes are even more finely balanced. The Heathrow NWR expansion is estimated to cost over £10bn more than expansion at Gatwick, in NPV terms⁷. As a result, with costs included, the NPV of expansion at Gatwick and Heathrow NWR is estimated to be £10.8 billion and £11.8 billion respectively.⁸ When the benefits accruing to international transfer passengers are excluded, these figures fall and Gatwick expansion comes out ahead, generating an economic NPV of £9.1 billion compared to £5.3 billion from Heathrow expansion.

Moreover, these figures do not reflect the additional risks associated with the schemes. These are expected to be greater for Heathrow expansion since the scale and complexity of the project raises the likelihood of construction delays while the potential for breaching air quality legislation may also add to costs and delays. The Heathrow expansion scheme may also face a greater risk of delays in planning consent. Neither the traffic forecasts nor the economic impact assessment has included any sensitivity testing around these risks, as would be normal practice.

Airports Commission Traffic Forecasts

The PwC estimates also appear incongruous when compared to the Airports Commission's own traffic forecasts. Focussing on UK-wide traffic and connectivity, and thereby accounting for displacement of traffic from other UK airports, Airports Commission forecasts based on the DfT model show little difference in O-D traffic between the two schemes.

It is the difference in O-D traffic for the UK as a whole that should drive the economic impacts of expansion, rather than changes in the market share of individual airports or the volumes of transfer passengers handled. While the Airports Commission report argues that expansion at Heathrow generates significantly more traffic and connectivity than expansion at Gatwick⁹, this does not account for displacement from other UK airports; that is, much of the growth in O-D passenger traffic at Heathrow in 2030 is achieved by taking market share from other UK airports and therefore is not matched by an equivalent increase in UK-wide O-D passengers. To the extent that Heathrow expansion generates more traffic for the UK as a whole, this is largely because it is expected to attract more transfer passengers. As PwC recognise, these passengers may increase the profitability of certain routes and as a result facilitate higher levels of O-D traffic but they have no direct impact on the UK economy.

Consequently, the key generator of economic impact under PwC's methodology is O-D passengers who are either resident in or visiting the UK, across all UK airports. Figure 1 shows that the two

⁵ The analysis undertaken by the Airports Commission is not directly comparable to that done by PwC, since it focuses on the direct welfare benefits of airport expansion, rather than aiming to estimate the wider GDP impacts (including the effects of additional employment and investment caused by airport expansion).

⁶ Based on figures reports in Airports Commission (2015) "Transport Economic Efficiency Benefits"

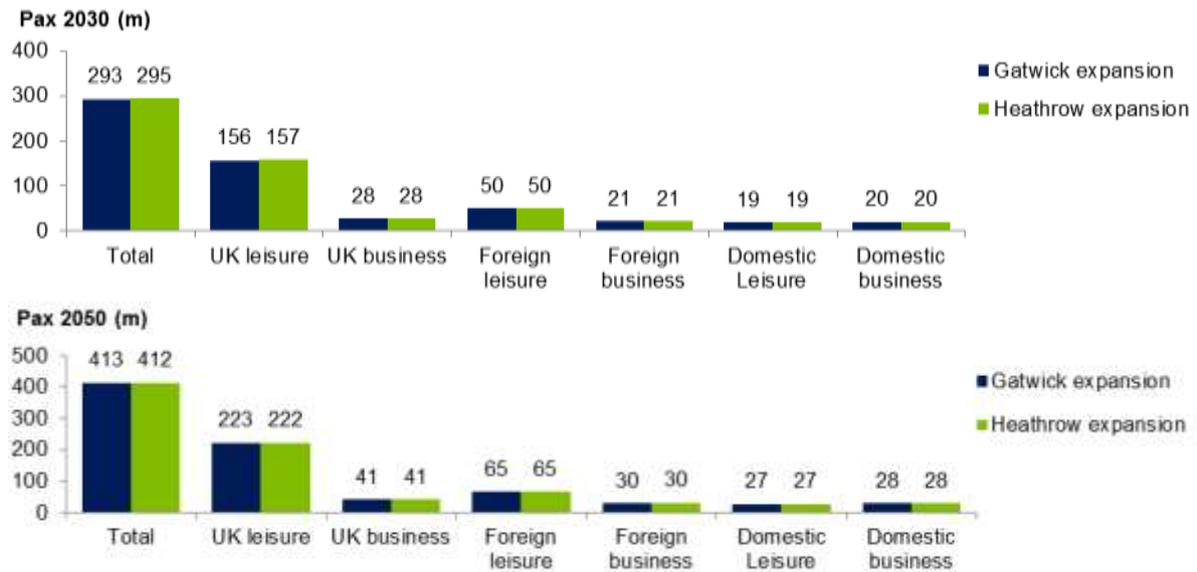
⁷ The net present value also includes other dis-benefits, including decreases in operators' profits and environmental costs.

⁸ Based on Table 7.1, Airports Commission (2015), "Airports Commission: Final Report."

⁹ See, for example, Figure ES.2, Table 6.1, Airports Commission (2015), "Airports Commission: Final Report"

schemes have broadly the same impact on UK-wide O-D passenger numbers, according to Airports Commission forecasts.

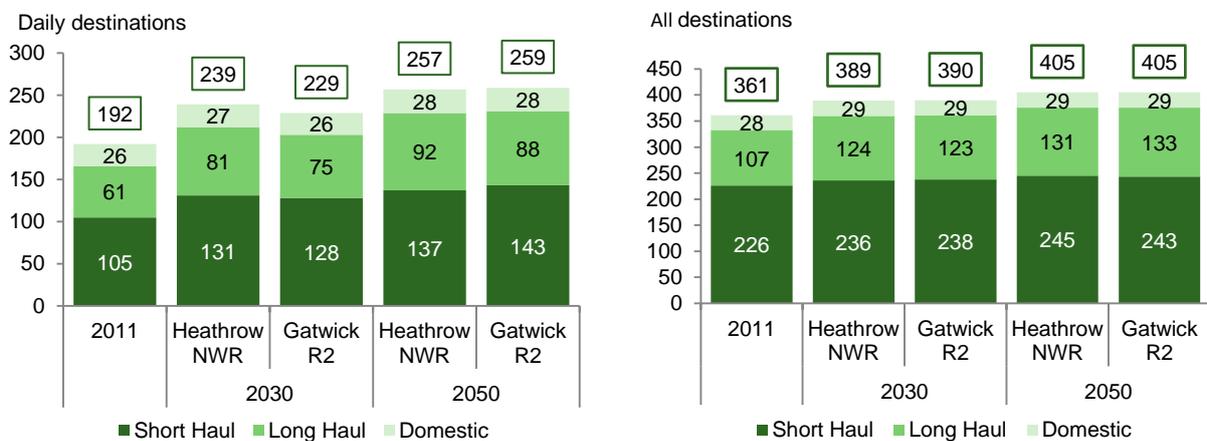
Figure 1: UK mix of O-D traffic in 2030 and 2050



Source: Airports Commission (2015) "Strategic Fit: Forecasts"

In addition to delivering a similar level and mix of additional O-D passengers as Gatwick expansion, by 2050 Heathrow NWR expansion supports only two additional direct long-haul routes for the UK as a whole and four additional daily long-haul routes. As figure 2 shows, the two schemes deliver a similar level of connectivity overall.

Figure 2: AC assessment of destinations served from the UK



Source: Airports Commission (2015) "Strategic Fit: Forecasts."

PwC analysis

To supplement the analysis undertaken by the Airports Commission, PwC were commissioned to estimate the wider impacts of airport expansion on GDP. PwC did this by developing a complex model of the UK macroeconomy, intended to fully account for the direct and indirect impacts of airport expansion. These indirect impacts include facilitating investment, creating employment and delivering increases in visitor numbers and trade. While the use of such models is well-established in connection to fiscal policy, their use in the context of investment in transport infrastructure is less well tested.

Given the relatively untested approach used, it is particularly important that the results of the PwC analysis are given proper scrutiny.

The discrepancy between the key inputs - namely the traffic forecasts, which show little difference for the UK between the schemes – and the outputs of the PwC model raises questions. To address this, a detailed review of the PwC methodology has been undertaken. Although there are areas where a lack of detail or transparency in the PwC report makes it challenging to identify the precise approach used, there are also aspects of the analysis that are clear and of considerable significance.

There is nothing inherent in the PwC economic model itself that would generate a difference between expansion at Heathrow and expansion at Gatwick for equivalent inputs. While the model incorporates some breakdown across UK regions, the two proposed sites both fall into the same region. Therefore the results of the PwC model cannot be accounted for by any location-specific impacts, for example spillover effects on local businesses. Similarly, the model itself does not account for potential impacts on competition; effects on prices and profits are treated as an input based on Airports Commission forecasts.

The table below shows the impacts that PwC consider in their report and the assumptions driving each of these impacts. Since the PwC economic model itself cannot structurally capture the differences between the schemes the economic impacts are driven by differences in the inputs; the robustness of the results is therefore wholly dependent on the inputs used.

Table 1: Impacts included in the PwC analysis

Economic Impact	Effect being considered	Key driver	PwC estimates (PV of Real GDP, £bn) ¹⁰		
			LGW 2R	LHR NWR	Difference
Passenger Flows	UK travellers spending overseas Foreign travellers spending in the UK	O-D passenger flows and mix of inbound/outbound passengers	(2.3)	32.8	35.1
Productivity	GDP growth through UK productivity	O-D passenger flows (through their impact on trade)	52.1	70.9	18.8
Frequency Benefits	Reduction in travel times	Additional business passengers	3.6	6.5	2.9
Transport Economic Efficiency	Reducing constraints on UK airport capacity leading to a redistribution of benefits from airlines and airport operators to consumers	Consumer and producer surplus (from the AC's own analysis; this is not an output of the PwC model)	20.0	21.6	1.6
Total			73.3	131.8	58.5

Source: PwC, "Airports Commission: Strategic Fit: GDP/GVA Impacts"

A review of the PwC model methodology indicates that the differential between Gatwick and Heathrow NWR is driven by three main factors:

- **Assumptions on passenger mix:** The majority of the gap between Heathrow NWR and Gatwick derives from the passenger flows impact. The difference between the schemes is driven by the PwC assumption ("agreed in conjunction with the AC"¹¹) that the UK will experience a lower share of inbound traffic following Gatwick expansion than it would with Heathrow expansion. This assumption is inconsistent with the Airports Commission's own forecasts that show an almost identical level and mix of inbound-outbound traffic at the UK level under each scheme (see Figure 1).

¹⁰ PwC report their results as an NPV over the period 2016-2064; in contrast the Airports Commission report results over a 60-year period. This explains the difference between these figures and the totals quoted in the Airports Commission final report.

¹¹ PwC, "Airports Commission: Strategic Fit: GDP/GVA Impacts," page 87

PwC's own sensitivity analysis reveals that their results are highly dependent on this assumption: assuming the same mix of additional passengers under either scheme eliminates entirely the difference in passenger flow impacts.

- **Treatment of productivity in the PwC model:** As the Airports Commission's advisors, Professor Peter Mackie and Brian Pearce argue, "while the content of the model itself has been well-tested, the same cannot be said of the front end, where an increase in capacity is converted into an increase in trip-making, trade, tourism and finally productivity."

This is most apparent in the way in which productivity, which is essentially treated as an input to the model, is reverse-engineered to yield the trade impact that PwC separately estimate would result from the increase in traffic. This approach generates estimates of the productivity input following Heathrow expansion that are almost twice those of Gatwick, relative to the volume of traffic. PwC do not provide any explanation for this divergence. Moreover, these inputs seem inconsistent with the wider academic literature; as noted by Laird and Stroombergen in their peer review of the analysis, the implied relationship between passenger flows and productivity is over ten times that found by other studies.¹²

- **The economic impacts of Heathrow expansion appear to be strongly front-loaded:** The PwC analysis suggests that Heathrow expansion is expected to generate a significant economic impact prior to 2030, despite there being only a small increase in UK-wide O-D traffic by this time. It is not clear what is behind this effect, but it may be driven by passenger flow and productivity inputs that also appear to be front-loaded compared to traffic forecasts. This would also suggest that the economic impacts calculated may be highly sensitive to any delays in the construction or operation of the third runway at Heathrow. This risk of delay has been acknowledged by the Airports Commission, but it is argued that this would not cause a concern since it would be unlikely to prevent delivery prior to 2030.¹³ While that may be the case, it would nonetheless affect the net present value of the economic impacts, something that has not been tested.

These issues appear to benefit the Heathrow schemes over Gatwick in the analysis. For example, using an assumption on passenger mix which is closer to Airports Commission forecasts eliminates about two-thirds of the difference between Gatwick and Heathrow NWR. In the case of the productivity impact, the estimates for both schemes may be significantly overstated. This would reduce the magnitude of the impact of both schemes as well as the absolute value of the difference between them. Given the higher costs associated with Heathrow expansion, this could have a significant impact on the net value and return associated with the scheme.

Given the potential limitations of the PwC analysis, it is a matter of concern that the results have been given such prominence in the Airports Commission's final report and have been used in the media without proper caveats or scrutiny. This review of the PwC methodology suggests that both the absolute impacts estimated by PwC and the difference between the two schemes are likely to be overstated. In contrast to the PwC analysis, neither the UK-level O-D traffic forecasts nor the Airports Commission's own economic analysis of the net present values of expansion suggest that the schemes differ significantly in their impacts. Moreover, the suggested magnitude of the difference in estimated economic impacts has tended to obscure other factors, including the fact that the Heathrow NWR scheme comes at a much higher cost than Gatwick expansion and with greater risks.

¹² Laird and Stroombergen, "Airports Commission. 2. Economy: Wider Impacts Assessment – Peer Review."

¹³ Sir Howard Davies letter to the Secretary of State, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/463769/howard-davies-to-patrick-mcloughlin-070915.pdf

1 Introduction

The Airports Commission was established in order to examine the UK's need for additional airport capacity and to make recommendations to the Government as to how these capacity needs can be addressed in the short, medium and long term. After an initial period of research and consultation, the Airports Commission identified three options for the expansion of UK airport capacity:

- Addition of a second runway at Gatwick (LGW 2R);
- Addition of a third runway at Heathrow by extending the Northern runway (LHR ENR); and
- Addition of a third runway at Heathrow through the construction of a Northwest runway (LHR NWR).

Having identified these three options, the Airports Commission undertook a further analysis of the viability and potential impacts of the three schemes. The areas of impact considered include:

- Economic impacts;
- Strategic fit, intended to address the impact on traffic flows, connectivity and competition;
- Costs of the schemes;
- Environmental impacts.

To support this impact analysis, the Airports Commission both undertook their own research into the wider economic impacts, in accordance with DfT WebTAG guidance, and commissioned PricewaterhouseCoopers (PwC) to conduct additional analysis into the GDP impacts.

The Airports Commission published its Final Report in July 2015, which recommended expansion at Heathrow through the North West Runway scheme. In making this recommendation, the Airports Commission have cited PwC analysis that estimates that expansion at Heathrow may generate up to £147bn in GDP impacts over a 60 year period.

*A new northwest runway at Heathrow will not increase noise above current levels, will generate up to £147 billion in GDP impacts over 60 years and over 70,000 new jobs by 2050, and will add regular daily services from the airport to around 40 new destinations, including 10-12 new long-haul routes.*¹⁴

Airports Commission Press Release

*Providing new capacity at Heathrow would support trade and enhance productivity, strengthen the business clusters around the airport and provide a stimulus to economic growth throughout the UK. The overall effect could be to increase GDP by 0.65-0.75% by 2050, amounting with carbon emissions traded to £131-147 billion in present value terms over the 60 years following expansion. This compares to £89 billion in GDP impacts from expansion at Gatwick.*¹⁵

Executive Summary, Airports Commission Final Report

¹⁴ Airports Commission Press Release 1st July 2015; <https://www.gov.uk/government/news/airports-commission-releases-final-report>

¹⁵ Airports Commission (2015), "Final Report".

The Airports Commission's own expert advisors, Professor David Mackie and Mr Brian Pearce, counselled caution in placing reliance on these estimates:

*"While the content of the model itself has been well-tested, the same cannot be said of the front end, where an increase in capacity is converted into an increase in trip-making, trade, tourism and finally productivity. Furthermore the interpretation of the result---what exactly do they mean and is their basis transparent--- is an issue. Overall, therefore, we counsel caution in attaching significant weight either to the absolute or relative results of the GDP/GVA S-CGE approach (PwC report) within the Economic Case. We would accept that there is some useful indicative material for the Strategic Case but care is required in assessing its robustness and reliability."*¹⁶

Their review of the methodology highlights the fact that some of the results rest on overly optimistic economic assumptions and that there is a risk of double-counting some of the impacts considered in the PwC model. Similar concerns have been expressed by Dr James Laird and Dr Adolf Stroombergen in their peer review of the analysis, which argues that the PwC model may have been "shocked" in an inappropriate way, leading to GDP impacts that are much greater than the welfare impacts estimated by the Airports Commission.

These concerns are partially acknowledged by the Airports Commission later on in the report, where the methodology used is described as "highly innovative" and the sensitivity of some of the results to the input assumptions is also noted. Nonetheless, this has not prevented the £147bn figure from being given considerable weight by the Airports Commission. It was highlighted without any caveats in the executive summary of the Airports Commission report and in the accompanying press release, contributing to its gaining considerable traction in the media. The prominence that these figures have gained is a matter of concern, given the reservations expressed by the Airports Commission's own advisors and their warning against "exaggeration by media".¹⁷

The PwC estimates suggest a much greater difference in the impacts of the schemes than other evidence included in the Airports Commission report, including the Airports Commission's own estimates of the economic impact, which find a much smaller overall impact, and only a minimal difference in the NPV generated by each scheme. The PwC results also appear inconsistent with traffic forecasts that show a very similar mix in UK-wide O-D traffic between the schemes.

Given the attention that the PwC estimates have received, the objective of this report is to review the assumptions, methodology and findings of the PwC analysis in order to better understand the robustness of these results. It should be noted that this review is based on the details of the data, assumptions and methodology provided by PwC in their report. The review is therefore constrained by the fact that there are some areas in which the details of the approach are not made clear by the Airports Commission or by PwC.

This report is structured as follows:

- Section 2 provides an overview of the analysis conducted by the Airports Commission into the economic impacts of airport expansion.
- Section 3 describes the methodology used by PwC in their analysis and the key drivers of their results.
- Section 4 introduces the Airports Commission traffic forecasts that underpin both the Airports Commission analysis and the PwC study.
- Section 5 discusses the potential limitations of the PwC study.

¹⁶ A Note from Expert Advisors, Prof. Peter Mackie and Mr Brian Pearce, on key issues considering the Airports Commission Economic Case, May 2015, page 6

¹⁷ Ibid.

- Section 6 concludes by discussing what implications the findings of this report may have for the estimates of the economic impact and for the reliance that may be placed upon them.

2 Airports Commission: Wider Economy Impacts analysis

The Airports Commission's own economic impact analysis, based on guidance from the Department of Transport, suggests that the two schemes are finely balanced in terms of their economic impacts:

- *Taking into account the capital costs of the schemes, the net present value of expansion at Heathrow is estimated to be £11.8bn, compared to £10.8bn from expansion at Gatwick.*
- *Gatwick expansion comes at a lower cost than Heathrow expansion. Using customary benefit-cost ratios, Gatwick expansion is estimated to generate a return of 2.8 times investment, representing "high value for money;" Heathrow expansion delivers a return of 1.7, only "medium value for money."¹⁸*
- *However, these Commission figures include benefits for international transit passengers, which would not accrue to the UK economy. If these impacts are excluded – in accordance with DfT guidance – the net present values fall to £5.3bn from Heathrow and £9.1bn from Gatwick, reversing the relative value of the schemes and indicating that Gatwick outperforms Heathrow.*
- *Focussing just on the wider economic benefits included in the Airports Commission assessment, the difference between the two schemes is estimated to be only about £3 billion.*

As part of their own assessment of the three schemes under consideration, the Airports Commission conducted their own analysis of the wider economic impacts of airport expansion. This analysis is based on WebTAG Transport Analysis Guidance from the Department for Transport.¹⁹

The objective of the analysis was to understand the direct benefits (or dis-benefits) accruing to passengers, airlines and the government; the indirect impacts on the wider economy through gains from trade, agglomeration and clustering effects and competition; and potential externalities including effects on noise, air quality and the environment. This analysis is narrower in scope than the PwC study, which seeks to estimate the wider effects that expansion can have on the economy by facilitating additional investment and supply chain spending and through spending on construction. These second- and third-round impacts are not reflected in WebTAG analyses such as that prepared by the Airports Commission.

The table below summarises the results of the Airports Commission's own analysis under the carbon-traded Assessment of Need scenario. The results are presented as a NPV over a 60 year period from the start of operations.

¹⁸ Department for Transport Guidance: Transport Business Case, Value for Money Assessments https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/255126/value-for-money-external.pdf

¹⁹ Transport Analysis Guidance: WebTAG, <https://www.gov.uk/guidance/transport-analysis-guidance-webtag>

Table 2: Airports Commission estimates of the net present value of airport expansion, £bn (Carbon-traded, Assessment of Need)

	LGW R2	LHR NWR
Consumer surplus	47.1	54.8
Government revenues	2.5	1.8
Delays	2.4	1.0
Wider Economic benefits	8.1	11.5
Total benefits	60.1	69.1
Producer surplus	-41.8	-38.4
Other costs	-1.6	-2.7
Total dis-benefits	-43.3	-41.1
Net social benefit	16.8	28.0
Present value of construction and surface access costs	-6.0	-16.1
NPV	10.8	11.8

Source: Airports Commission Final Report

As can be seen from the table, when the capital costs of the schemes are taken into account, the Airports Commission's own analysis indicates that there is little difference in the NPV of the two schemes. The Airports Commission forecasts also suggest a relatively small difference in the overall benefits generated by the schemes, with Gatwick expected to generate £60.1bn in benefits compared to £69.1bn from the Heathrow Northwest Runway. However, the Gatwick scheme is estimated to result in a larger reduction in producer surplus. This surplus represents the profits accruing to both UK and foreign airlines and to airport operators, which may fall as the London airport system becomes less capacity constrained. This fall in producer surplus is consistent with a greater increase in competition following Gatwick expansion than Heathrow expansion.

In addition to considering the results in NPV terms, they may also be represented through a benefit-cost ratio. The Airports Commission have argued against this approach – which is generally used when evaluating public investment projects – on the grounds that the costs associated with each of the schemes will be borne by the private sector. However, these costs will be passed on to users through increases in airport charges, and are accordingly relevant to this analysis.

Moreover, while the direct construction costs associated with the projects will be privately financed, the costs associated with surface access and public transportation may be publicly funded, in part or in whole. For the Heathrow NWR scheme, surface access costs are estimated to represent £5.0bn of the total costs; for Gatwick, surface costs contribute £0.8bn.²⁰ This is also an area that would merit further scrutiny: the Airports Commission report does not include a full assessment of these costs or of the extent to which they will be met through public funding. Treasury guidelines suggest that the cost-benefit ratios associated with this public expenditure should be assessed.

If these impacts are presented in terms of the customary benefit-cost ratio then Gatwick expansion is estimated to generate a return of 2.8 times investment, representing “high value for money” based on government guidance; in contrast, Heathrow expansion leads to a return of 1.7, “medium value for money.”²¹

²⁰ “Airports Commission Final Report – Areas of Concern”

http://www.gatwickairport.com/globalassets/publicationfiles/business_and_community/all_public_publications/second_runway/airports_commission/airports-commission-final-report-areas-of-concern.pdf

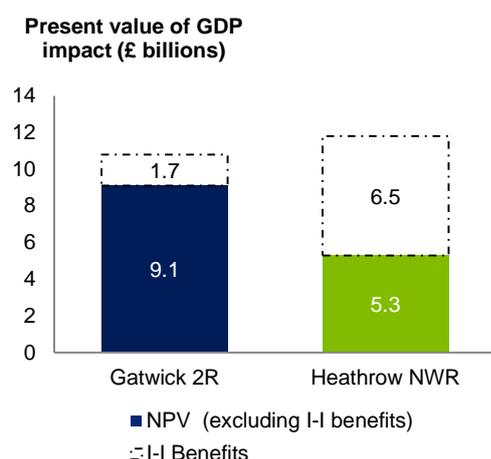
²¹ Department for Transport Guidance: Transport Business Case, Value for Money Assessments

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/255126/value-for-money-external.pdf

The consumer surplus figures in table 2 are inclusive of benefits accruing to international transfer passengers (that is, to international passengers who make a stop-over at a UK airport but do not actually enter the country). WebTAG guidance is that benefits to such passengers be excluded from the welfare analysis²² since they do not represent benefits to the UK. In this case, the Airports Commission has included this effect on the grounds that these passengers would be expected to bear a share of the capital costs through increased transfer charges. However this approach is not wholly consistent with other statements made by the Airports Commission, where they suggest that the costs of the schemes are generally of less relevance given that they will be predominantly privately funded.²³ Given that some of the costs will be borne by users and UK residents (either through public expenditure or through higher airport charges) there is clearly merit separately assessing and presenting the costs and benefits for the UK.

The figure below shows the net present value associated with each of the options, excluding the benefits associated with international transfer passengers. As the figure shows, while Heathrow expansion is estimated to generate a marginally higher net present value than Gatwick expansion with benefits accruing to transfer passengers included, the results are reversed when the analysis focusses on benefits for passengers entering the UK and contributing to the UK economy. In this case, Gatwick expansion is estimated to generate £9.1bn in NPV and Heathrow expansion £5.3bn.

Figure 3: Net present value of airport expansion, Airports Commission analysis



Source: Airports Commission Final Report, 2015²⁴

The chart above shows the impact on the net present value excluding the benefits accruing to international transfer passengers, based on the Airports Commission's own estimates of these benefits. These benefits represent 36% of the net direct benefits²⁵ associated with the Heathrow NWR scheme, compared to 21% of the benefits of the Gatwick Second Runway.²⁶ While the Airports Commission has not provided any estimates of the share of the costs borne by international transfer passengers these may be estimated based on the forecast increase in passenger numbers and the charges to be levied on these passengers following expansion. If the contribution to costs of international transfer passengers are adjusted on this basis the net present value of Heathrow expansion is estimated to be £7.6 billion, with Gatwick generating £9.2 billion.

²² "An exception is made for international to international interliners who simply change planes at a UK airport. Cost and time savings to these passengers are not counted as benefits to the UK." Department for Transport, TAG UNIT A5.2 Aviation Appraisal, page 5.

²³ Airports Commission (2015), Final Report, page 148

²⁴ The contribution of transfer passengers to consumer benefits comes from the Airports Commission "Economy: Transport Economy Efficiency Impacts" report; their contribution to costs is estimated based on traffic forecasts and charges paid by transfer passengers.

²⁵ The net direct benefits capture the benefits to producers (airlines and airport operators), consumers and the government (through greater revenues). See Airports Commission (2015), Economy: Transport Economic Efficiency Impacts.

²⁶ Airports Commission (2015), Economy: Transport Economic Efficiency Impacts.

Turning specifically to the wider economic impacts included in its analysis, the Airports Commission's findings suggest that the Heathrow Northwest Runway has the potential to generate about £3.4bn (NPV) in additional benefits compared to the Gatwick Second Runway. The breakdown of the impacts is shown in the table below. The majority of this gap is driven by the agglomeration impacts and by the associated change in the tax take due to higher labour productivity. Essentially, expansion at Heathrow is argued to bring greater spillover effects for businesses in the surrounding area due to an increase in connectivity and business density. The regional breakdown included in the PwC model does not include sufficient detail to capture these location-specific effects. However, the Airports Commission results show that these local effects are not estimated to be very substantial.

Table 3: Airports Commission estimates of the wider economic impacts of airport expansion (£bn)

	LGW R2	LHR NWR
Imports	1.1	1.3
Exports	5.2	6.0
Net agglomeration	0.6	1.7
Tax wedge	0.1	1.1
Business output benefits	1.1	1.4
Total	8.1	11.5

Source: Airports Commission "Economy: Wider Economic Impacts Assessment."

In summary, the difference in benefits between the two schemes, as calculated by the Airports Commission, is found to be similar in magnitude to the difference in capital costs, meaning that the two schemes deliver similar net value overall. Moreover, when the benefits to international transfer passengers are excluded Gatwick outperforms Heathrow under the Airports Commission's own methodology. The difference in wider economic impacts is also not estimated to be very large. While the different methodologies mean that these figures are not directly comparable to the PwC results, this raises questions regarding the factors driving the large difference calculated by PwC, especially since the PwC model is not able to capture the location-specific factors that partially explain the Airports Commission's estimates.

3 Overview of the PwC Methodology

In addition to the economic analysis done by the Airports Commission, PwC have undertaken a wider economic impact analysis. The objective of this analysis was to understand the wider impacts on airport expansion on GDP through increased visitor spending and increases in trade and productivity, which can in turn enable greater investment, employment and output across the economy. This analysis was originally intended to form part of the Economic Case; however, based on the concerns expressed by the Airports Commission's expert advisors it was instead presented as part of the "Strategic Fit" section of the final report. However, it is not clear that the PwC approach is well-suited to address strategic concerns.

At the core of the PwC analysis is a general equilibrium model of the UK macroeconomy. Such models are complex, and while their use in connection to fiscal policy is well-established and well-tested, their use in connection to transport infrastructure projects is less common. Therefore, while the technical approach used in the underlying model is relatively well-established, it is important to understand the specific channels through which the impacts of airport expansion are introduced into the model.

However, it must be recognised that the PwC model itself cannot discern any differences between the schemes. Such differences in economic impacts are instead driven by the input assumptions. This means that to the extent the traffic forecasts underlying the model are the same, the outputs of the model should also be the same.

The Airports Commission's own economic analysis is supplemented by additional analysis conducted by PwC and summarised in the report "Strategic Fit: GDP/GVA Impacts." The objective of this additional analysis is to understand the impact of expanding airport capacity on the UK's economy by taking into account how changes in one sector or region may affect other areas of the economy. These effects are then represented in terms of an aggregate GDP impact.

The PwC analysis is based on the use of a Spatial Computable General Equilibrium (S-CGE) Model of the UK economy. Such models aim to capture the functioning of the macroeconomy by specifying the behaviour of all agents in the economy - households, workers, firms, investors and the government – and the linkages between sectors. The advantage of this modelling approach is that it can potentially account for the aggregate response of the economy as a whole to the direct changes brought about by airport capacity expansion. This allows the model to account for impacts across sectors and can capture second- and third-order impacts in addition to first-order effects. For example, whereas the Airports Commission analysis only takes into account the direct effects of airport expansion on the productivity of local firms, the PwC analysis seeks to also reflect the possibility of increases in productivity further stimulating follow-on investment throughout the economy, in turn generating further effects on output and employment.

The features of this approach that enable this broader analysis also increase its complexity. In particular, such models require detailed data on the underlying relationships between different segments of the economy; this data is available for the UK as a whole, but further estimation is required to use this technique on a regional basis, as PwC have done. Given that the regional analysis is insufficiently detailed to distinguish between Heathrow and Gatwick (since both are in the same region) it is not clear how much value is added by this approach. Moreover, the results of the

analysis may be sensitive to the precise method by which a policy change is incorporated into the model.

While the use of CGE models to estimate the impact of fiscal policy is well-established, their use in connection to aviation and transport policy is less common. Both PwC and the Airports Commission acknowledge that the use of a CGE model in this context is “highly innovative.”²⁷ The way in which the CGE model is used is also a cause of concern for the Commission’s own expert advisors, who argue that “The most serious issue is not with the model itself but with how to estimate the shock which new runway capacity will administer to the economy.”²⁸ They further state that “while the content of the model itself has been well-tested, the same cannot be said of the front end, where an increase in capacity is converted into an increase in trip-making, trade, tourism and finally productivity.”²⁹

Before turning to the specific channels through which the increase in capacity enters the PwC model, it should be noted that there is nothing in the CGE model itself that distinguishes between expansion at Gatwick and expansion at Heathrow. While the model does contain a spatial element, it is limited to considering three regions: the South and East of England, the remainder of England, and the rest of the UK. With both Gatwick and Heathrow being in the same region the model is unable to capture differential spatial or agglomeration effects, such as spillover effects onto the specific sectors in the local area. Any difference in impacts across the schemes is therefore driven solely by differences in the underlying input assumptions. Specifically, if two schemes are forecast to generate an identical volume and mix of UK-wide traffic, the design of the PwC model is such that they should have the same economic impact.

The PwC analysis examines four channels through which the expansion in airport capacity may impact the wider economy. The most important of these channels are discussed in more detail in section 5 of the report.

- **Passenger flows:** The first impact of expanded airport capacity analysed by PwC is the effect in changing flows of passenger spending. This includes additional spending in the UK by inbound passengers and international spending by UK passengers travelling overseas, which may divert spending from the UK economy. International transfer passengers are not assumed by PwC to have any impact. The model then accounts for the wider impact that this spending may have on the economy, taking into account supply chain effects and the potential impacts on employment and wages in associated sectors.
- **Productivity:** The PwC model allows for increased volumes of UK O-D traffic to increase productivity by stimulating trade. This is modelled in two stages. First, PwC estimate the relationship between passenger flows and trade between the UK and other markets. Second, this effect is incorporated into the model through a productivity parameter, which is set so as to yield the desired trade impact. This impact is driven by passengers residing in or visiting the UK, with international transfer passengers being excluded from PwC’s analysis of the relationship between passenger numbers and trade.
- **Transport Economic Efficiency (TEE):** This channel is used to account for the wider economic impacts of changes in consumer and producer benefits. This is based on analysis from the Airports Commission that shows that reducing the capacity constraints facing the London airport system can promote competition, leading to lower prices or other benefits to consumers (for example better facilities, less congestion or more convenient flights). However airport owners and airlines may experience a reduction in profits. The effects of this reallocation of benefits will in turn affect the

²⁷ Airports Commission (2015), “Airports Commission: Final Report”, p. 113.

²⁸ A Note from Expert Advisors, Prof. Peter Mackie and Mr Brian Pearce, on key issues considering the Airports Commission Economic Case, May 2015, page 5

²⁹ Ibid, page 7

wider economy by changing overall patterns of spending and investment. This is captured in the model through a change in the productivity of different sectors.

- **Frequency benefits:** Lastly, the PwC model accounts for the potential benefits of increased flight frequency, which can allow business passengers to travel at more convenient times and reduce effective travel times. As with the productivity benefits and the TEE effects, this is also accounted for in the model through an increase in economy-wide productivity.

In addition to these impacts arising from operations following airport expansion, PwC also estimate the wider economic impacts generated during the construction phase; however these impacts are not included in the totals reported by the Airports Commission.

The table below shows the relevant drivers of each of the impacts analysed in the PwC model.

Table 4: Drivers and assumptions in the PwC analysis

Channel	Drivers/assumptions	Source
Construction	Cost of runway/airports construction	Analysis by Leigh Fisher
	Cost of surface access	
Passenger flows	Number of additional UK-wide O-D passengers	Airports Commission forecasts
	Split of inbound/outbound passengers	PwC assumption (agreed with Airports Commission)
	Mix of business, leisure and other passengers	Airports Commission forecasts
	Origin/destination of passengers	Airports Commission forecasts
Productivity	Number of additional UK-wide O-D passengers	Airports Commission forecasts
TEE	Estimated change in consumer surplus	Airports Commission "Transport Economic Efficiency Impacts"
	Estimated change in producer surplus	
Frequency benefits	Additional business traffic	Airports Commission forecasts

Source: based on PwC "Airports Commission: Strategic Fit: GDP/GVA Impacts"

As can be seen from the table, it is the underlying estimates for passenger volumes and mix that drive the results of the PwC analysis, whether directly or indirectly (as in the case of the TEE impacts)³⁰. Accordingly, the outputs of the model would be expected to be broadly consistent with traffic forecasts.

In order to account for potential diversion of traffic from other UK airports and to be in keeping with the Airports Commission's remit to "maintain a UK-wide perspective," the relevant traffic forecasts must be considered at a UK level. PwC's own statements in connection to the methodology also make this point: "In addition to the total UK passenger numbers, the characteristics of these passengers and their associated spending patterns are important in determining the impact on real GDP."³¹

Moreover, it is UK O-D passengers that drive the majority of these impacts, either through spending in the UK economy or by facilitating trade linkages and contributing to knowledge and technology spillovers. In contrast, international transfer passengers that pass through UK airports are not expected to have a direct effect on the UK economy, although they may have an indirect effect by increasing the profitability of certain routes and, by facilitating connectivity, support additional O-D

³⁰ Forecasts of each of the key variables have been developed by the Airports Commission and published in their report "Strategic Fit: Forecasts."

³¹ PwC, "Airports Commission: Strategic Fit: GDP/GVA impacts" page 87

traffic. As PwC state in their report: “to the extent that transfer passengers enable more flights, the impacts will be reflected in the domestic leisure and business passenger flow inputs provided by the AC, and in frequency benefits and TEE effects.”³²

There is nothing in the PwC model itself that can generate a difference in economic impacts between the two schemes, meaning that the results of the PwC analysis are driven by the inputs used. The key inputs to this model are volume and mix of passengers entering and departing the UK, regardless of the specific airport used. Therefore, to the extent that the two schemes generate the same volume and mix of UK O-D traffic, they would be expected to generate the same economic impact.

³² Ibid. page 51.

4 Airports Commission Traffic forecasts

As would be expected, and as PwC's explanation of the methodology makes clear, it is changes in UK-wide traffic flows that drive the impacts on the wider UK economy. The Airports Commission traffic forecasts show that:

- Heathrow expansion and Gatwick expansion are forecast to generate similar volumes of O-D traffic for the UK as a whole.*
- The mix of business/leisure passengers and inbound/outbound O-D passengers is approximately the same under both schemes.*
- There is almost no difference in the number of destinations served from the UK, long-haul or short-haul.*
- Heathrow expansion is forecast to generate more international transfer passengers. However, as PwC recognise, these passengers do not directly benefit the economy, nor the two key channels of economic impact assessed by PwC.*

Therefore, to the extent that these forecasts suggest the two schemes generate similar UK-level traffic a similar impact on the economy and GDP would be expected.

As discussed in Section 3, the design of the PwC model is such that identical UK-wide traffic volumes and mix should generate an identical economic impact. Given the model's dependency on the input assumptions, it is important to understand the traffic forecasts that underpin the analysis. These forecasts are supplied by the Airports Commission, based on a model developed by the Department for Transport.³³ For the purposes of this report, these forecasts are accepted at face-value; the objective of this review is to understand the relationship between these forecasts and the economic impacts estimated by PwC.

Of particular importance for the analysis are the volume and mix of UK-wide O-D traffic:

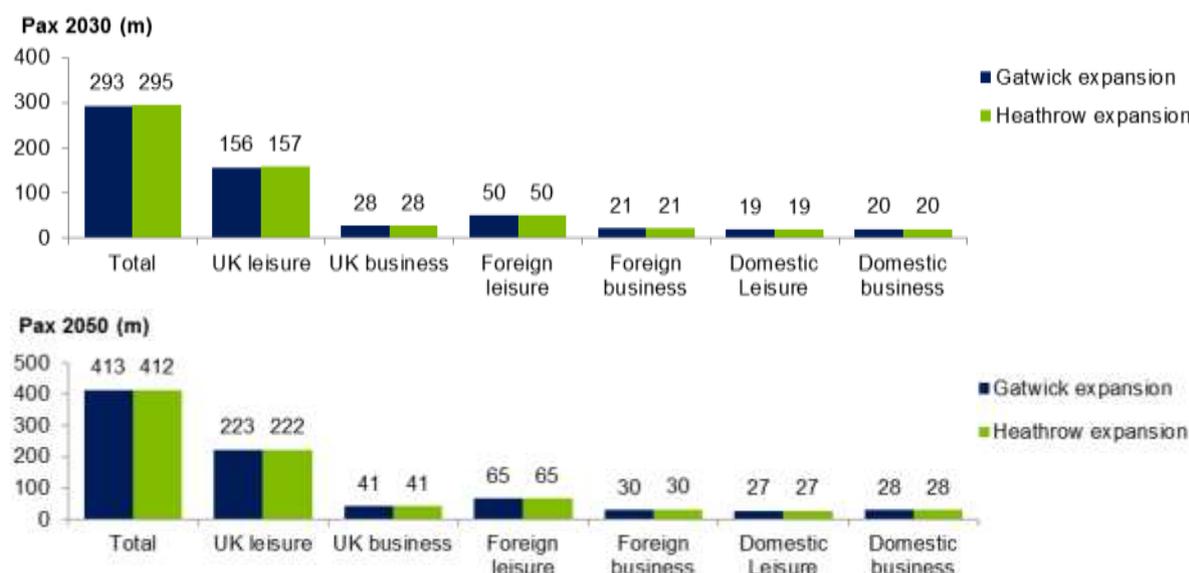
- The traffic forecasts need to be considered at the UK level in order to account for the aggregate impact on UK connectivity, passenger numbers and frequency benefits, accounting for any redirection of traffic from other airports to the expanded airport.
- The economic impacts are driven by O-D traffic, that is, by passengers who either begin or terminate their journey in the UK. While transfer passengers can have an indirect effect by enabling greater overall connectivity or increasing frequency on certain routes, thus supporting additional O-D traffic, they do not directly impact the UK economy.

³³ The full details of the traffic forecasts and scenarios considered in the model are provided in the Airports Commission report "Strategic Fit: Forecasts"

4.1 Aggregate traffic

As shown in figure 4 below, the Airports Commission forecasts suggest that expansion at Heathrow and Gatwick will generate similar volumes of UK O-D traffic in both 2030 and 2050. This is based on the carbon-traded “Assessment of Need” scenario, which is the core scenario for traffic growth considered by the Airports Commission. As discussed in Section 3, it is the passengers residing in or visiting the UK who generate positive benefits for the UK economy.

Figure 4: UK mix of O-D traffic in 2030 and 2050



Source: Airports Commission (2015) “Strategic Fit: Forecasts”

The figure also shows that there is little difference in the mix of traffic generated by the two options. This includes the mix of business and leisure traffic, which affects the frequency benefits and passenger expenditure, and the mix of foreign and UK traffic, which underpins the passenger flow impact.

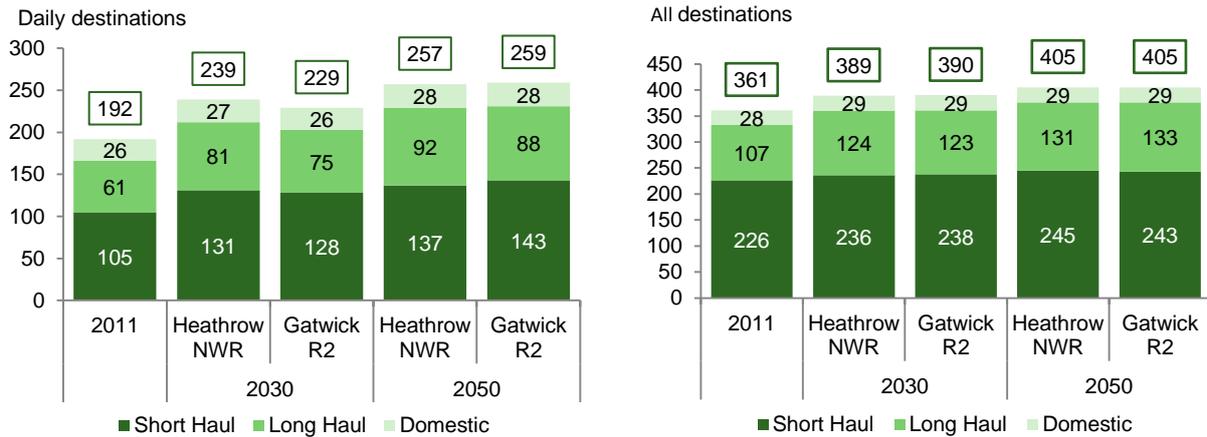
4.2 Connectivity

Turning to the mix of destinations served, the Airports Commission report states that “...increasing capacity at Heathrow would drive significant connectivity benefits, delivering a much stronger long haul network than would be seen at an expanded Gatwick”.³⁴ This is what the Commission’s forecasts indicate if the airports are considered in isolation, without accounting for changes across the UK system as a whole: expansion at Heathrow enables that airport to serve 160 destinations daily by 2050, whereas Gatwick would serve 142 destinations daily following expansion. However at a London or UK level the two schemes have an almost identical effect on the total number of destinations served from the UK, daily or otherwise.

Figure 5 shows the number of short haul, long haul and domestic routes served in 2011 compared with the routes predicted to be served by 2030 and 2050 under each scheme. This shows that, at the UK level, Heathrow expansion enables the UK to connect directly to only two additional long-haul destinations compared to Gatwick; overall, however, Gatwick expansion delivers slightly more daily destinations and the same number of total destinations. These differences between individual airport performance and aggregate traffic serve to highlight the fact that the two schemes deliver broadly the same outcome for London and the UK. However, under Gatwick expansion the market is served by multiple airports, whereas under Heathrow expansion, Heathrow airport would dominate.

³⁴ Airports Commission (2015) Final Report, Page 20

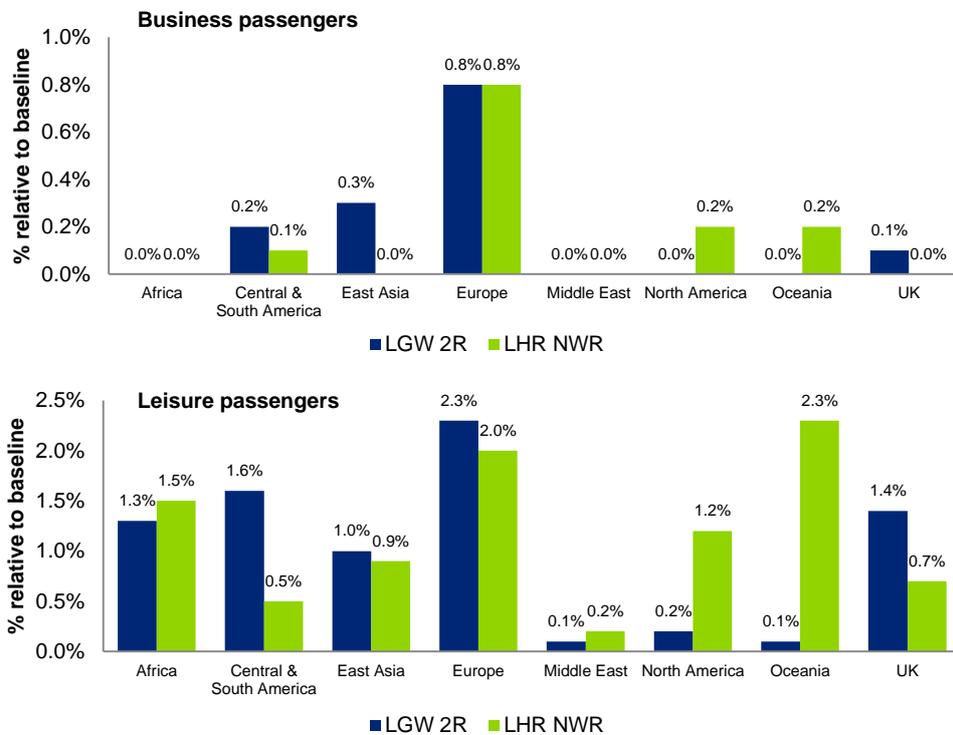
Figure 5: Airports Commission assessment of destinations served from the UK



Source: Airports Commission (2015) "Strategic Fit: Forecasts."

While the Airports Commission has not published the full details of the breakdown in destinations served in terms of passenger numbers, the PwC report includes some details of how airport expansion may affect the regions served. The Airports Commission forecasts indicates that there are some differences between the two schemes – for example Heathrow expansion has the potential to generate more traffic from Oceania and North America, while Gatwick expansion can generate more traffic from the Far East and Central and South America. However, these forecasts do not suggest that Heathrow expansion has significant advantages in terms of long-haul passengers or connectivity.

Figure 6: UK Business and Leisure growth by region relative to baseline in 2050

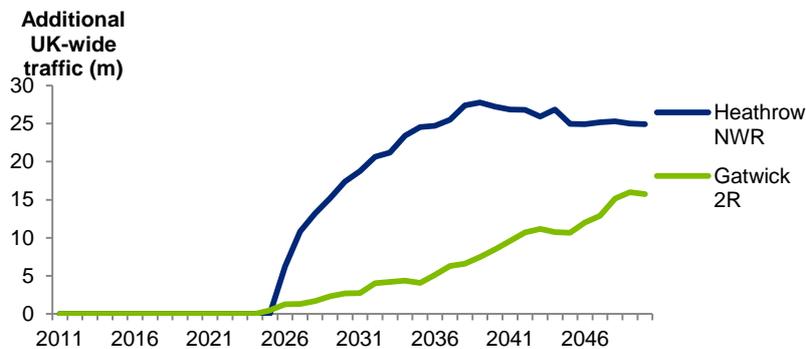


Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts based on Airports Commission forecasts

4.3 Rate of traffic growth

Where the Airports Commission forecasts do exhibit any significant differences between Heathrow and Gatwick in terms of their impact on aggregate O-D traffic, this lies in differences in the rates of traffic build-up following the increase in capacity. As figure 7 shows, growth is assumed to be more rapid following Heathrow expansion.

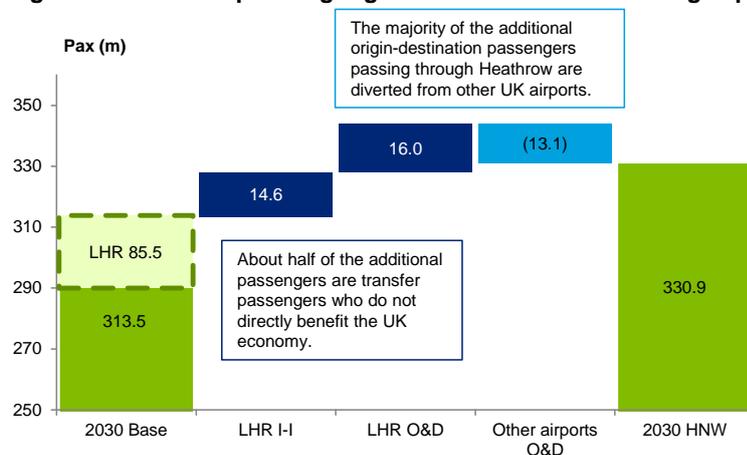
Figure 7: Build-up of additional UK-wide traffic under the Assessment of Need scenario (including I-I passengers)



Source: Airports Commission

However, these figures include the contribution of international transfer passengers, who make up about 80% of additional UK traffic in 2030 following Heathrow expansion. The figure below provides a breakdown of the factors contributing to the rapid expansion of traffic at Heathrow: while Heathrow itself may see an additional 30.6 million passengers by 2030, this only amounts to an additional 2.6 million O-D passengers for the UK as a whole. In comparison, Gatwick expansion is estimated to lead to 1.4 million additional passengers at the UK level by 2030.

Figure 8: Drivers of passenger growth at Heathrow following expansion



Source: Airports Commission

As figure 8 shows, the majority of the rapid growth in traffic at Heathrow following expansion is due to displacement from other UK airports or to international transfer passengers. The contribution of international transfer passengers may also explain the fact that Heathrow expansion is forecast to lead to more rapid growth in UK-wide traffic in the first decade after expansion. It is not clear whether the build-up of origin-destination traffic exhibits a similar pattern, with Heathrow generating much faster growth in traffic in the decade immediately following expansion. If so, this may partially account for some of the differences in the net present value of the schemes, although it would not explain the difference in the long-run impact. The Airports Commission has not made detailed forecasts of the

rate of O-D passenger growth publicly available, so it is not possible to assess the precise extent to which differences in the rate of traffic growth may affect the results.

While there may be some differences in the rate of traffic build-up following expansion, the similarity in the UK-wide O-D passenger numbers in 2030 and 2050 indicates that the two schemes generally have the same potential to increase UK traffic. Based on the PwC methodology, this would suggest that the two schemes should deliver similar benefits to the UK economy.

5 Review of PwC analysis

Although the underlying modelling approach used by PwC is well-established in the context of fiscal policy, the way in the model is shocked in order to estimate the impacts of airport expansion is not well-tested. The inconsistency between the stated drivers of the economic impacts – namely the traffic forecasts – and the results therefore raises concerns about the specific inputs used in the PwC model.

A review of the PwC assumptions and methodology suggests that there are two key issues with the analysis that may affect the reliability of their results:

- The majority (£35bn) of the estimated £58bn difference in economic impacts is due to a traffic mix assumption made by PwC that is contradicted by the Airports Commission's own forecasts.*
- PwC estimate the productivity impact using an untested approach that leads to estimates of the relationship between connectivity and productivity that are over ten times larger than those found by other studies, and almost twice as high for Heathrow as for Gatwick, despite comparable traffic forecasts.*

Addressing these issues is likely to eliminate the majority of the estimated difference in impacts between the two schemes.

This section of the report reviews the details of the PwC methodology, assumptions and results in order to better understand their robustness and what may drive the apparent inconsistencies between the PwC figures and other estimates. There are areas where a lack of detail or transparency in the PwC report makes it challenging to fully understand the specifics of the approach and the extent to which it is appropriate. A full review of potential limitations and areas for clarification is included in the technical appendix to this report.

In contrast to the other analysis summarised earlier in this report, the PwC estimates of the economic impacts suggest a much greater advantage to Heathrow expansion, with the North West runway scheme estimated to generate £147bn in benefits over a 60 year period, compared to £89bn generated by Gatwick expansion. Over the 48-year period analysed by PwC (from 2016-2064), the impacts are estimated at £132 billion and £73 billion respectively³⁵. In the long-run, PwC estimates that Heathrow expansion can increase GDP by 0.75% per year; the long-run GDP impact with Gatwick is estimated to be 0.6%.³⁶

As discussed in section 3, there is nothing in the design of the S-CGE model itself that would drive such a disparity in impacts, since the model is unable to address strategic impacts such as local agglomeration or competition effects. Nor should the disparity be driven by differences in the underlying traffic forecasts, which show that by 2050 the two schemes generate a similar level and mix of O-D traffic, with the forecasts also being comparable in 2030. Although there is a difference in

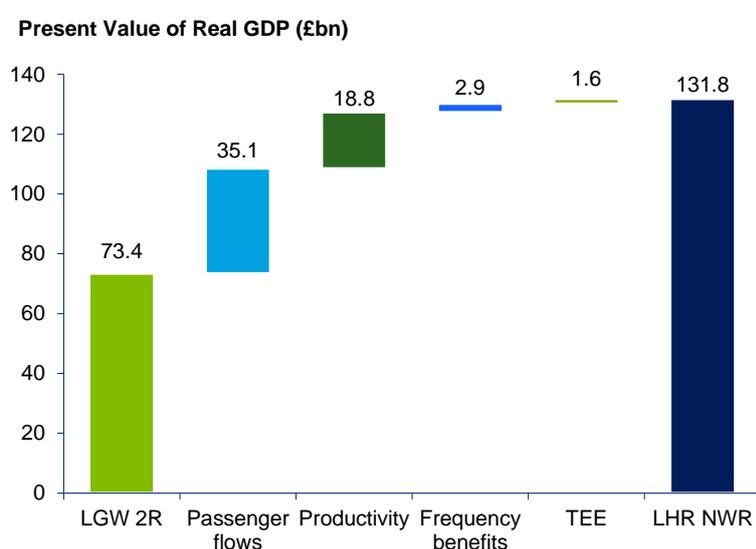
³⁵ For the purposes of this section of the report, we focus on the time-period covered by PwC, since their report does not provide a detailed breakdown of the impacts over the 60-year appraisal period considered by the Airports Commission. The extrapolation is based on the assumption that traffic remains constant after 2050, since DfT forecasts do not extend beyond this point. The effect of this assumption is to perpetuate any differences between the impacts of the scheme estimated by PwC.

³⁶ PwC (2015), *Airports Commission 1. Strategic Fit: GDP/GVA Impacts*

international transfer passenger numbers, PwC state that this is reflected through the underlying passenger forecasts and in the TEE and frequency impacts; this therefore cannot explain the difference in passenger flows or productivity impacts. Moreover, the absence of any meaningful difference in the O-D traffic under each scheme and PwC's own estimates of the TEE and frequency impacts indicate that the contribution of international transfer passengers is negligible. While part of the difference in net present values may be explained by differences in the rate of traffic growth, it is not clear from Airports Commission forecasts whether this difference exists for O-D traffic and this would still not explain the difference in long-run impacts.

Given these apparent inconsistencies, it is important to understand the drivers of the suggested GDP differential and the robustness of the results and assumptions. The figure below shows the estimated impact of the two schemes, through each of the four channels discussed in section 3. As shown in the figure, the majority of the difference between Heathrow and Gatwick is driven by the difference in the passenger flows impact and the productivity impact.

Figure 9: Drivers of the estimated difference in impacts between Heathrow and Gatwick (£bn, 2014 prices)



Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts

This review has found that there are two key issues which may lead to an overstatement of the difference in economic impacts between Heathrow and Gatwick:

- **Assumptions on passenger mix:** PwC's assumptions regarding the mix of inbound and outbound passengers are inconsistent with the Airports Commission's own forecasts. PwC's sensitivity analysis reveals that the results are highly dependent on this assumption.
- **Treatment of productivity in the model:** The treatment of productivity in the PwC model raises a number of issues. First, there is a risk of overestimating the impacts, either through double-counting of certain impacts or by overstating the strength of the causal relationship between passenger flows and productivity. This is noted by Laird and Stroombergen in their peer review of the analysis: the implied relationship between passenger flows and productivity is over ten times that found by other studies.³⁷ Second, the productivity inputs used in the model appear inconsistent, with Heathrow having about twice the productivity impact per passenger as Gatwick despite a similar mix of traffic.

³⁷ Laird and Stroombergen, "Airports Commission. 2. Economy: Wider Impacts Assessment."

5.1 Passenger flows

5.1.1 Overview of PwC's approach

As shown in Figure 9, the majority of the estimated difference in economic impacts between the two schemes comes from the passenger flow impacts. This reflects the wider economic impacts of changes in inbound and outbound passenger expenditure. The figure below shows the effects considered in the PwC model.

Additional traffic	Additional expenditure	GDP impact
Additional outbound passengers	£ spent overseas £667 per passenger per trip via LGW currently £694 per passenger per trip via LHR currently	GDP negative
Additional inbound passengers	£ spent in the UK £931 per passenger per trip via LGW currently £811 per passenger per trip via LHR currently ¹	GDP positive
Additional transfer passengers	nil spent in the UK	GDP neutral

The additional spending has knock-on effects to the UK economy, leading to a multiplier effect on GDP.

Hence, the split between inbound and outbound passengers applied to the forecast of additional O-D traffic will drive the size of the economic impact under each scheme. For example, an additional 10m of O-D passengers, of which 70% (7m) are inbound and 30% (3m) are outbound, will have a significantly greater impact on GDP than if the same overall increase was derived from 50:50 (5m:5m) split of inbound to outbound passengers. International transfer passengers are not included by PwC in this analysis, since their spending in the UK is assumed to be negligible.

5.1.2 PwC's assumptions and potential issues

Given this approach, the passenger flow impacts hinge on the assumptions made about the mix of inbound and outbound traffic. PwC assume that the additional O-D passengers brought by an expansion will be allocated to inbound/outbound passengers based on the current splits that exist at Heathrow and Gatwick. Currently, Gatwick has a bigger share of outbound passengers (c. 73%) than Heathrow (c. 51%).³⁸ The explanation given for this assumption is that:

"The AC did not provide forecasts of the split between inbound and outbound passengers in the future. For the purpose of this analysis we have agreed in conjunction with the AC to assume that the balance of inbound and outbound passengers and their associated spending patterns remain at their existing levels in the event of airport expansion."³⁹

However, the Airports Commission forecasts discussed in Section 4 explicitly include the split between foreign passengers and UK passengers. These forecasts show that the mix of additional passengers is broadly similar with either scheme. This is as would be expected, given that the forecasts are based on estimates of underlying global demand for air travel. It is not clear why PwC should have stated that this information is not available or why it was necessary to make additional assumptions here.

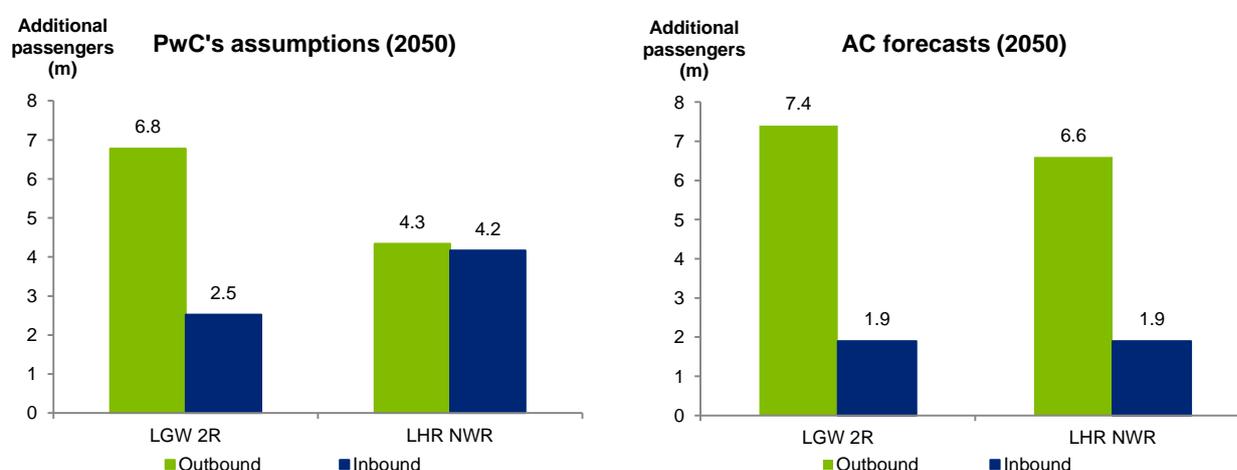
³⁸ PwC (2015) "Airports Commission: Strategic Fit: GDP/GVA Impacts"

³⁹ PwC (2015) "Airports Commission: Strategic Fit: GDP/GVA Impacts" page 51

Figure 10 below compares the passenger numbers used by PwC to those in the Airports Commission forecasts. The Airports Commission predicts that at the UK level expansion under either scheme would result in approximately 9m additional O-D passengers by 2050, relative to a baseline scenario in which there is no increase in UK airport capacity.⁴⁰ PwC's assumption that the split of additional passengers under each scheme matches the current split of inbound and outbound passengers at each airport translates into about 6.8m additional outbound passengers and 2.5 million inbound passengers following Gatwick expansion; the equivalent figures following Heathrow expansion are assumed to be 4.3 million and 4.2 million respectively.

However, the Airports Commission forecasts predict that the mix of the additional passengers is much more similar under both schemes, with about 7 million additional outbound passengers and 2 million additional inbound passengers, as illustrated in Figure 10. The similar mix of additional passengers under each scheme suggests that there should be a similar impact on GDP if the Airports Commission's estimates were used instead of the assumption adopted by PwC.

Figure 10: Implied additional UK-wide O-D passengers relative to the baseline



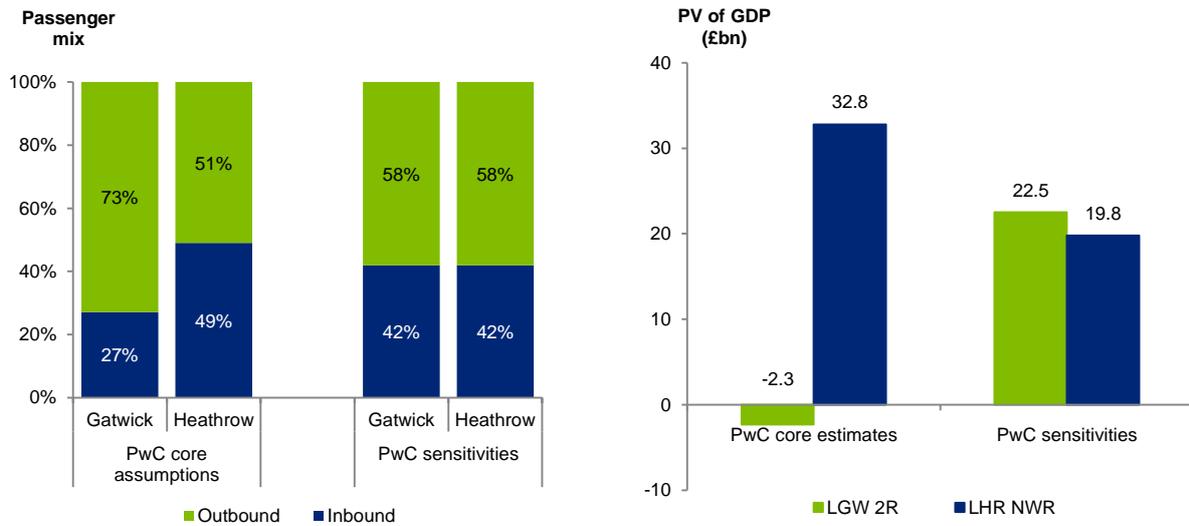
Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts and Airports Commission (2015) "Strategic Fit: Forecasts"

PwC's own analysis shows that their results are very sensitive to the passenger mix assumption used. Moreover, when the same inbound/outbound split is used for Gatwick and Heathrow, the impact of passenger flows is indeed similar under both schemes. Figure 11 illustrates that when the overall London passenger mix is applied to the additional O-D traffic under both schemes, Gatwick outperforms Heathrow on the passenger flow impact; Gatwick's NPV of the passenger flow impact is £22.5bn versus £19.8bn for Heathrow.⁴¹

⁴⁰ Airports Commission (2015) "Strategic Fit: Forecasts"

⁴¹ In their passenger flow sensitivity analysis, PwC use different assumptions of passenger mix but also alter their assumptions on passenger spending. However, they show that most of the resulting impact can be attributed to the difference in passenger mix assumptions.

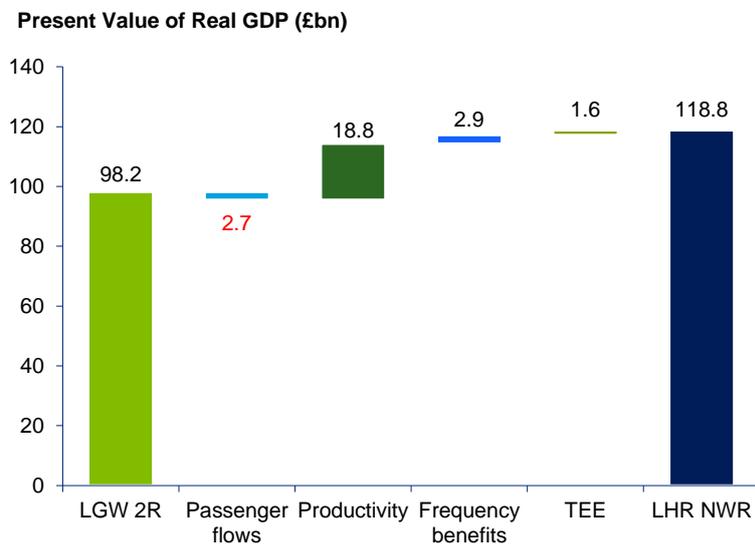
Figure 11: PwC’s assumptions and results under the core scenario and the passenger mix sensitivity scenario



Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts

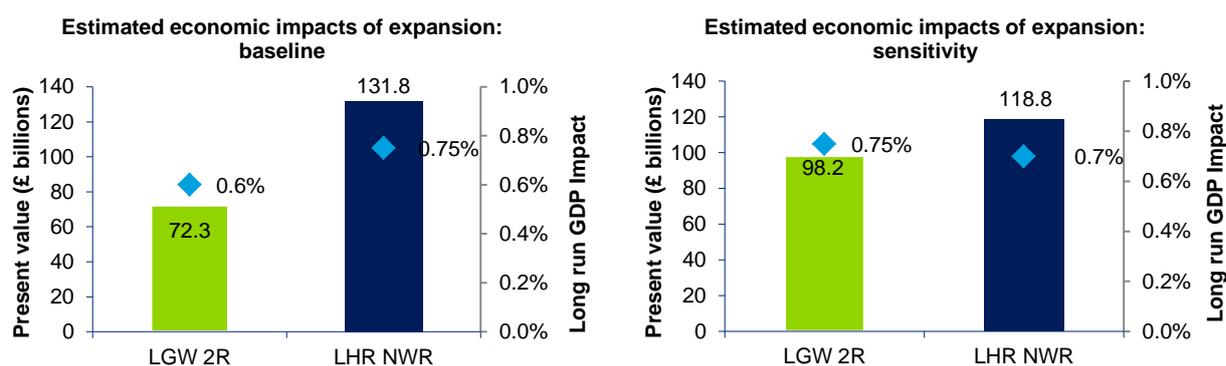
As can be seen in Figure 12 and 13, adjusting this assumption to reflect the same inbound/outbound mix of additional passengers under either scheme reduces the estimated overall gap between the economic impacts of the two schemes by about two-thirds. In the long-run, the relative performance of the two schemes is reversed: the PwC sensitivity analysis shows that Gatwick expansion generates a long-run impact of 0.75% of GDP compared to 0.7% through Heathrow expansion, shown in figure 13.⁴²

Figure 12: Drivers of the differences in economic impact, based on PwC sensitivity test



Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts

⁴² PwC “Airports Commission: Strategic Fit: GDP/GVA Impacts,”

Figure 13: Effect of changing the passenger mix assumption on the overall economic impact

Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts

It should be noted that the alternative figures used in the PwC sensitivity analysis are also inconsistent with Airports Commission forecasts, since they assume a much higher level of inbound traffic under both schemes. In practice, the fact that Heathrow and Gatwick expansion are both forecast to lead to more outbound traffic suggests that the passenger flow impact of both schemes may in fact be smaller than estimated in the PwC sensitivity analysis. Nonetheless, the assumption that the two schemes generate a similar mix of traffic remains a better reflection of the Airports Commission forecasts; on this basis, the difference of £35bn in the passenger flow impacts is a significant overstatement.

5.1.3 Other issues

In addition to using an assumption on passenger mix which differs from the Airports Commission forecasts, the passenger expenditure inputs in PwC's methodology appear inconsistent with their own methodology.

The Airports Commission estimates that by 2030, expansion at Heathrow would bring an additional 2.6m O-D passengers (excluding domestic) compared to 1.4m from expanding at Gatwick.⁴³ Using PwC's own methodology of allocating these to inbound/outbound passengers based on the current mix at each airport, this would translate into 1.3m additional outbound passengers following Heathrow expansion versus 1m in the Gatwick expansion.

However, whilst PwC assume that Heathrow has more overall additional outbound passengers in 2030 compared to the baseline, PwC's expenditure flows show that the additional passenger spending outside of the UK until 2030 is negligible under the Heathrow expansion but significant under the Gatwick expansion. Not only are these inputs inconsistent with the Airports Commission traffic forecasts, but they also appear to be inconsistent with PwC's own statements regarding their methodology. Given that PwC state that they assume a constant ratio of inbound to outbound passengers under each expansion, the ratio of inbound to outbound expenditure would be expected to be likewise constant. While this is the case for the expenditure inputs observed for Gatwick, the Heathrow inputs do not exhibit a constant ratio throughout.

⁴³ Airports Commission (2015) "Strategic Fit: Forecasts"

Figure 14: Passenger expenditure flow, LWR NWR

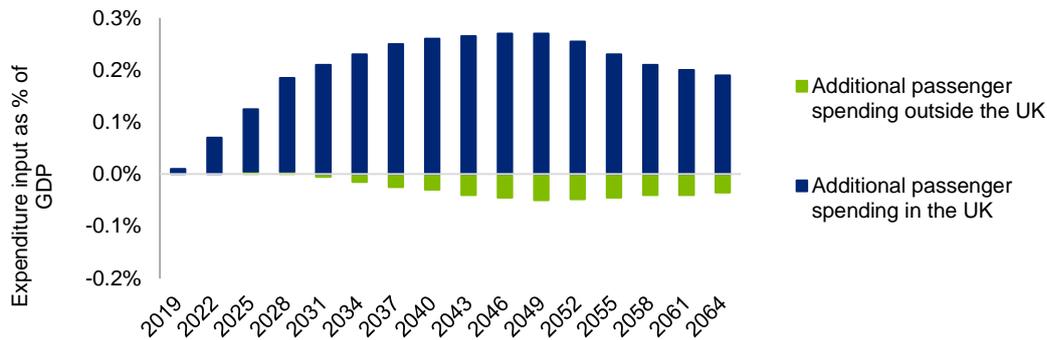
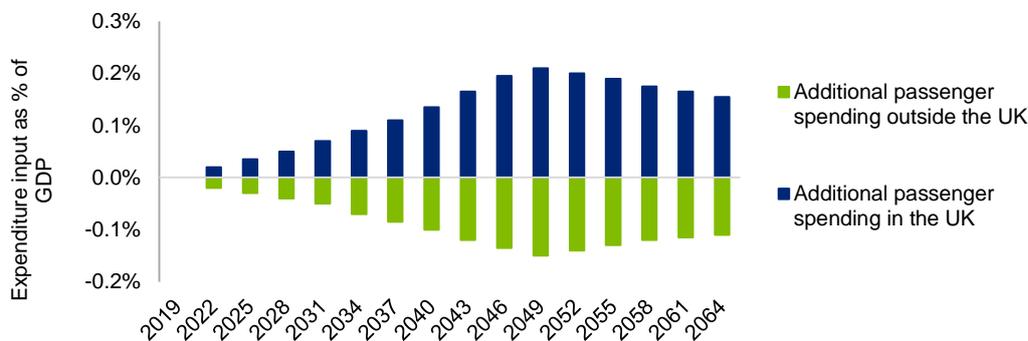


Figure 15: Passenger expenditure flow, LGW 2R



Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts. Figure 114, page 239 and figure 11, page 90.

It is unclear why the increase in outbound passengers that is expected to follow Heathrow expansion is not associated with any increase in spending outside the UK prior to 2030. The PwC analysis shows a different effect for Gatwick, where the ratio of inbound to outbound spending remains more consistent, in keeping with their stated assumptions. This discrepancy risks further overstating the passenger flow impact at Heathrow by failing to properly account for outbound spending. The substantial passenger flow expenditure inputs used prior to 2030 may also explain why the economic impacts of Heathrow expansion appear to be front-loaded, with about 40% of the eventual GDP impact being realised by 2030 despite there being only a small increase in UK-wide O-D traffic at this time⁴⁴.

⁴⁴ See, for example, figure 6.4 in the Airports Commission Final Report and figure 112 in the PwC Strategic Fit report.

5.2 Productivity

As shown in Figure 9, the second channel that drives the gap between the estimated economic impacts at Gatwick and Heathrow is the productivity effect. The PwC analysis indicates that by enabling greater connectivity and more potential for trade and knowledge spill-overs, expansion at Heathrow can generate about £71bn in additional GDP over the next 60 years, compared to the £52bn generated by expansion at Gatwick.

Aside from the passenger mix assumption discussed above, this difference in productivity impacts of £19bn accounts for the majority of the remaining difference in economic impacts. However, the Airports Commission's advisors and other experts have expressed concern that the approach used to estimate this impact may overstate the effects.⁴⁵ A review of the productivity inputs used in the PwC model also suggests anomalies in how this effect is entered into the model.

This section of the report reviews the approach taken to estimating the productivity impact and compares the PwC results to other estimates. This review is based on the information included in the PwC report, in particular Appendix C, which covers the econometric approach. It is therefore to some extent limited by the information available, since there are a number of details of the analysis which are not made clear.

Overview of PwC's approach

PwC argue that one channel through which an airport expansion will impact the UK economy is through increased productivity. An airport expansion is argued to increase aviation linkages, which, in turn, are linked to productivity for the following reasons:

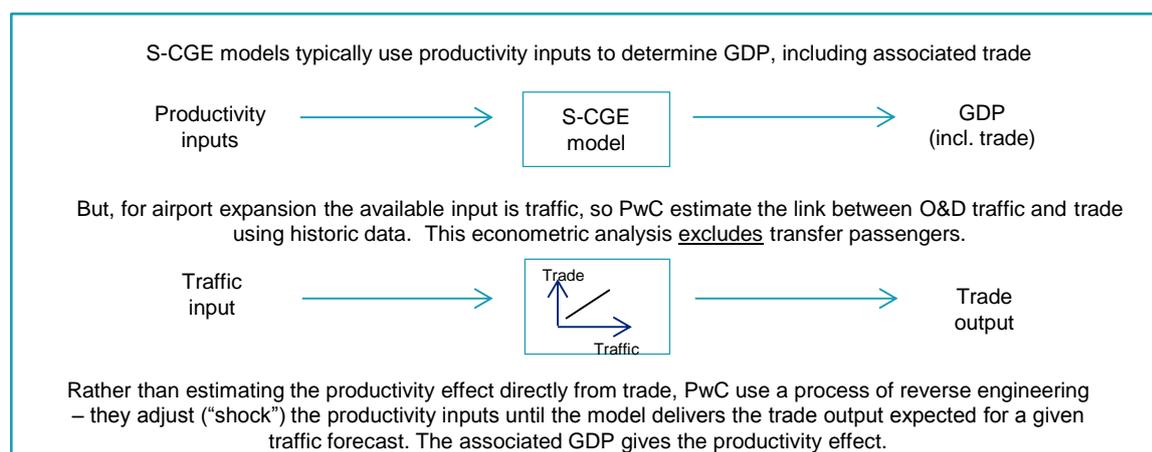
- Enable access to larger markets, allowing firms to exploit economies of scale in production and reduce per-unit costs.
- Allow for more knowledge spill-over and facilitate the exchange of ideas and technology.
- Facilitate international trade.

Productivity, in turn, impacts GDP by enabling firms to produce more output relative to the inputs used. The magnitude of this effect is estimated by PwC as follows:

1. PwC use data on O-D passenger flows and trade between the UK and 112 other countries to estimate the relationship between passenger numbers and trade.
2. This relationship is used to estimate the increase in trade that airport expansion would be expected to generate, based on the increase in passenger numbers.
3. Productivity, which is an input to the S-CGE model, is adjusted in order to ensure that the level of trade estimated in the model matches the impact on trade estimated in step 2.

A number of concerns have already been raised regarding this approach, including by the Airports Commission's own advisors, who describe the productivity effect as "reverse engineer[ed]." The approach used by PwC also differs from more standard analysis in this area, as set out in the graphic below.

⁴⁵ A Note from Expert Advisors, Prof. Peter Mackie and Mr Brian Pearce, on key issues considering the Airports Commission Economic Case, May 2015; Laird and Stroombergen, "Airports Commission. 2. Economy: Wider Impacts Assessment – Peer Review."



The Airports Commission’s advisors further argue that this approach means that “the implied elasticity (or responsiveness) of productivity to seat capacity in the model may be high and that this may partially account for the high model impacts on GVA.”⁴⁶ This point is also raised by Laird and Stroombergen in their peer review of the PwC work. There are a number of factors that may lead to an overstatement of the impacts:

- There may be issues in the underlying econometric estimation that is used to generate the productivity inputs used in the S-CGE model.
- There is a risk of double-counting impacts that are already accounted for elsewhere in the PwC model.
- The way in which productivity is entered into the PwC model is not well-tested. Rather than productivity being solved for directly in the model, it is an input that is calibrated so as to yield the desired trade impact.

These issues and the implications for the results are described in more detail below.

Relationship between passenger flows and productivity

The PwC analysis is based on the relationship estimated between passenger flows and trade, which is in turn linked to productivity. As Mackie and Pearce argue “given [the] statistical difficulties of understanding the direction of causality running through these interconnected, we think the estimation of this equivalence is both uncertain and crucial to the subsequent calculations.”⁴⁷

This difficulty arises from the fact that while trade and passengers flows are clearly linked, it is not straightforward to establish the direction of causation: the positive association between trade and passenger flows does not necessarily imply that an increase in passenger flows will increase trade. It is equally feasible that as trade between two countries increases, people travel more frequently between them. There may also be external factors causing both variables to increase. It is necessary to establish this causal relationship in order to conclude that a future increase in passenger numbers would directly increase trade.

While PwC recognise these challenges and state that steps have been taken to address them, the description of their methodology provided in Appendix C of their report is not sufficiently detailed to determine the robustness of their approach.

⁴⁶ A Note from Expert Advisors, Prof. Peter Mackie and Mr Brian Pearce, on key issues considering the Airports Commission Economic Case, May 2015, page 6.

⁴⁷ Ibid, page 5.

Double counting of productivity impacts

There is also a risk that the treatment of productivity in the PwC model double-counts impacts reflected elsewhere.

- Passenger flows: expenditure by passengers is already included as part of the balance of trade and therefore the relationship between passenger flows and trade estimated by PwC implicitly includes an effect due to passenger expenditure. There may be an overlap between this effect and the passenger flow impact incorporated into the PwC model.
- Frequency benefits: the positive relationship between passenger flows and productivity may be partially explained by the increased frequency of flights, which can increase convenience and reduce effective travel times. However, the PwC model also accounts for this separately through the frequency benefits effect.

A review of the PwC productivity estimates compared to those of other studies supports the hypothesis that their approach may overstate the productivity impact. The productivity inputs used by PwC suggest that a 1% increase in UK-wide origin destination traffic due to Gatwick expansion increases UK productivity by 0.15%. The corresponding figure for Heathrow is 0.29%. In contrast a Smyth and Pearce (2007) study for the International Air Transport Association finds an elasticity of labour productivity to connectivity of 0.007.⁴⁸

This suggests that the approach used by PwC may have led to a significant overstatement of the productivity impacts associated with both schemes.

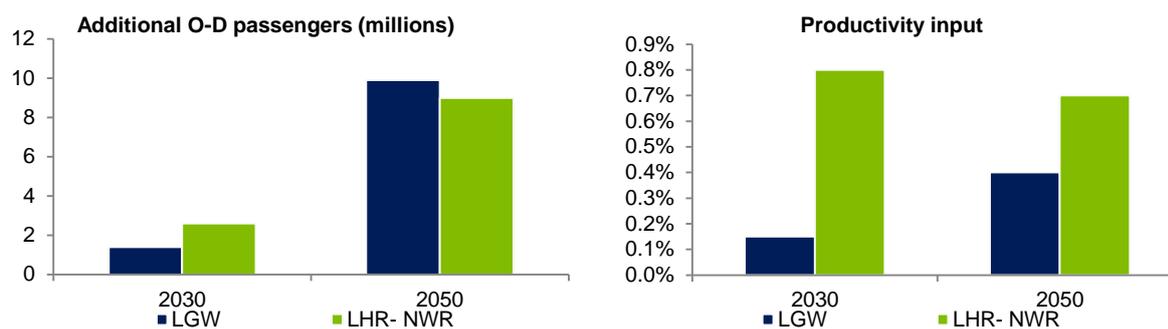
Productivity inputs used in the PwC model

As noted above, the way in which productivity is entered into the model is not well-tested. Productivity is not solved for directly in the model. Instead, as explained above, productivity is input into the S-CGE framework so that the productivity input delivers the increases in trade implied by PwC's separate statistical model.

Figure 16 shows the traffic forecasts and productivity inputs used in the model. Not only is the productivity effect significantly greater than that found in other studies, the productivity inputs are substantially higher for Heathrow than Gatwick. This is despite similar levels of the UK-wide O-D traffic, which drives the relationship between passenger flows and trade – and in turn productivity – estimated by PwC. This difference is particularly pronounced in 2030, when the productivity input used for Heathrow is over five times that used for Gatwick.

⁴⁸ Smyth and Pearce (2007), "Aviation Economic Benefits," IATA; https://www.iata.org/whatwedo/Documents/economics/aviation_economic_benefits.pdf.

This issue is also noted by Laird and Stroombergen in their review of the PwC analysis. However, they based their calculation on total passenger numbers, including transfer passengers. Since PwC's description of the methodology states that they focus on O-D passengers beginning or terminating their journeys in the UK we have done the calculation on this basis.

Figure 16: Traffic forecasts and productivity inputs used in the PwC model

Source: Airports Commission, PwC

It is unclear what is driving these differences in productivity inputs. The fact that the long-run GDP impact of 0.4% per year is similar across the two schemes (consistent with traffic forecasts) suggests that these anomalies in the productivity inputs are due to the novel way in which the model has been “shocked” in order to generate the required trade impact. However, the lack of detail provided by PwC on this matter mean that it is not possible to ascertain whether this has led to distortion in other outputs of the model, such as employment.⁴⁹

⁴⁹ This point is discussed further in Appendix B

6 Implications

The large difference in economic impacts suggested by the PwC analysis, and the prominence given to these figures by the Airports Commission and in the media, has tended to obscure other evidence suggesting that the cases for Gatwick and Heathrow are more finely balanced.

This review – along with previous reviews conducted by the Airports Commission’s own advisors and other experts – suggests that the difference in economic impacts found by PwC may be a significant overstatement, driven largely by flawed assumptions on passenger mix and by the treatment of productivity in the PwC model. It is not possible to precisely quantify the effects of addressing these issues based on the information available. However, PwC’s own sensitivity analysis shows that changing a single assumption and using a passenger mix figure more closely aligned to Airports Commission forecasts eliminates two thirds of the gap between the schemes.

Given the risk that the difference in economic impacts has been overstated, greater scrutiny should be given to other factors and risks that may affect the value of the schemes. This includes the costs of the schemes, the risks of delay and non-monetised impacts such as the effects on the environment, air quality and noise pollution.

This review of the PwC study into the economic impacts of expansion at Heathrow and Gatwick has identified a number of issues which may explain why the PwC estimates appear to be inconsistent with other evidence, including underlying traffic forecasts. Key issues include the use of assumptions that are inconsistent with the Commission’s traffic forecasts and an approach to analysing productivity that risks overstating the economic impact. The appendices to this report discuss additional questions arising from the PwC report, including the way in which their model accounts for displacement of economic activity from other parts of the economy and the treatment of consumer and producer surplus.

Without further details of the PwC methodology it is not possible to precisely quantify how addressing these issues may affect the conclusions of the report, however some high-level conclusions may be drawn:

- **Addressing the passenger mix assumption:** The assumptions that PwC make regarding the inbound and outbound passenger mix are a significant departure from the Airports Commission’s own forecasts, which show a similar number of additional inbound and outbound passengers for the UK under either scheme. PwC’s own sensitivity analysis shows that assuming the same split of inbound and outbound passengers under each of the schemes eliminates the difference in passenger flow impacts. This reduces the overall gap in economic impacts by about two-thirds.
- **Addressing the treatment of productivity in the model:** The methodology used to estimate the productivity impacts risks overstating the effects, whether by double-counting certain effects or by not fully establishing causality. These concerns are supported by the fact that the relationship between passenger flows and productivity estimated by PwC is an order of magnitude greater than that found in other studies. The fact that the S-CGE model uses significantly different productivity inputs for Heathrow and Gatwick – with the input for Heathrow expansion being two to five times

the value used for Gatwick expansion despite similar levels of O-D traffic – raises further questions about this approach.

The questions surrounding the magnitude of the productivity impact may affect both sets of estimates, suggesting that the productivity impacts may in fact be lower for both Gatwick and Heathrow expansion. This would also suggest that the difference between the two is substantially less than the £19bn found in the PwC analysis.

Overall, therefore, this review would suggest that the PwC analysis overstates the difference in economic impacts between the Heathrow and Gatwick schemes. This large gap in economic impacts, £147bn compared to £89bn, has tended to obscure other factors that should be taken into consideration, including the relative costs and the risks associated with construction and operation.

If the estimated difference in economic impacts is in fact an overstatement, as this review and PwC's own sensitivity tests would suggest, then it becomes particularly important to consider other factors that may affect the net value and the viability of the schemes.

These other factors to be considered include:

- **Costs of construction and surface access:** the Heathrow North West Runway scheme is estimated to cost £16.1bn in present value terms, compared to the £6bn PV cost of expansion at Gatwick. While the majority of these costs will be privately funded they will be borne by the users of the airports and are therefore relevant to the assessment of the economic impacts of the schemes, especially since potential increases in airport charges are not accounted for in the Airports Commission's passenger forecasts. Moreover, the costs of surface access – which amount to £5bn at Heathrow – may be borne by the public sector. That being the case, the net present value and the returns on public investment should be taken into account.
- **Risks associated with the schemes:** in their response to the Airports Commission report, Gatwick highlighted a number of additional risks associated with Heathrow expansion that are not fully addressed in the Airports Commission report or in the PwC analysis.
 - **Risks of construction delay:** given the scale and the timeline of the Heathrow North West runway scheme, it carries additional risks of delay. Such a delay could have a significant impact on the present value of the economic impact by delaying the start of operations or slowing the rate at which traffic can grow. Given that the assumption of rapid traffic growth at Heathrow drives part of the difference in economic impacts, this risk should be reflected in the modelling.
 - **Constraints on night flights:** as part of their recommendation in favour of Heathrow expansion, the Airports Commission mandated additional restrictions on night flights. The traffic forecasts that underpin the PwC analysis do not take into account these restrictions, which may have a particular impact on long-haul arrivals from East Asia. Given that the traffic forecasts are the fundamental driver of the economic impacts, this may have a significant impact on the estimates.
 - **Risks associated with air pollution legislation:** the Heathrow scheme also creates additional risks due to the possibility that the expansion places Heathrow in breach of EU legislation on air quality. This would in turn either increase the costs of the scheme – whether through fines or abatement costs – or lead to lower traffic if the third runway cannot be used at full capacity.

Appendix A: Airports Commission traffic forecasts

This Appendix provides an overview of the traffic forecasts upon which the economic analysis is based and reviews the results of the economic impact analysis under different traffic scenarios.

The results under these different scenarios exhibit a similar pattern to that seen under the core “Assessment of Need” scenario that is the focus of the Airports Commission Final Report and this review:

- By 2050, Heathrow NWR expansion and Gatwick expansion both generate a similar level of UK-wide O-D traffic (or in the case of the Low Cost is King scenario, Gatwick expansion leads to significantly more traffic).
- Heathrow expansion is generally expected to lead to slightly faster growth and a greater increase in traffic prior to 2030. However, relative to the baseline the increase in traffic following Heathrow expansion represents at most about 1.3% of total UK traffic. The exception to this is the Low Cost of King scenario, in which Gatwick expansion also leads to faster growth prior to 2030.
- Under each scenario, Heathrow expansion is estimated to lead to a significantly greater impact on economic growth, driven mainly by the passenger flow and productivity impacts.

Traffic forecasts under other scenarios

The Airports Commission traffic forecasts are a main input of PwC’s results and different passenger growth assumptions can have significant impacts on the estimated benefits of airport expansion.⁵⁰ To account for the uncertainty in the future of the aviation sector, the Airports Commission considers five different passenger forecasts scenarios. PwC estimate the benefits of each expansion scheme for each scenario. The different scenarios are:

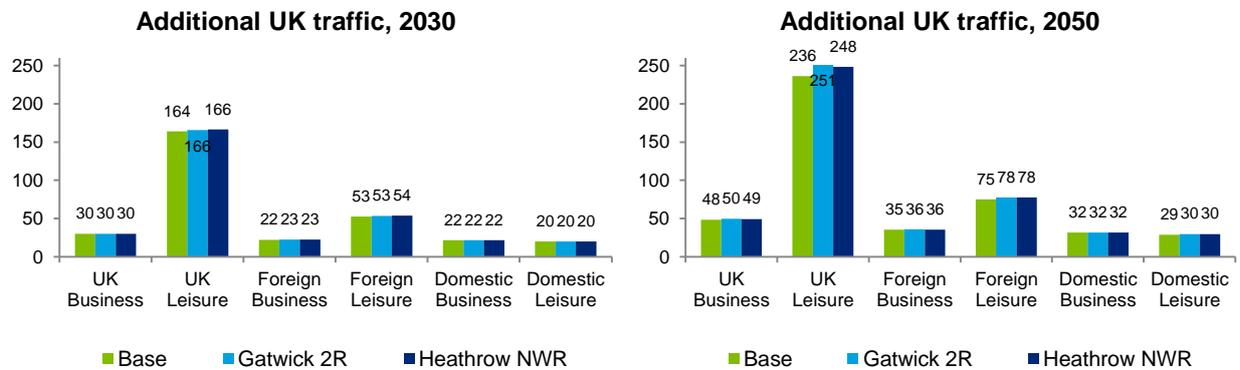
- **Assessment of Need:** Future demand is based on the existing operational model with GDP growing according to the current trends.
- **Global Growth:** Future demand is higher due to more rapid GDP growth across all regions and lower operating costs.
- **Relative Decline of Europe:** Future demand in emerging economies is higher than in developed ones, with a growth of Far and Middle Eastern aviation hubs and airlines.
- **Low Cost is King:** Strong global growth with low-cost carriers strengthening their position and gaining shares of the long-haul market.
- **Global Fragmentation:** Decline in GDP growth rates across all regions resulting in lower demand.

As discussed in the report, the UK-wide O-D passengers (as opposed to airport specific and international transfer passengers) drive the economic impact of each expansion scheme. Similar mix and numbers of O-D passengers would therefore be expected to translate into similar economic impacts, which we have already seen is not the case under the Assessment of Need forecast scenario. The same issues arise across other scenarios; when international transfer passengers are

⁵⁰ The estimated benefits of Gatwick R2 under PwC’s core assumptions vary from £29.4bn to £124.3bn based on different growth scenarios. Source: PwC (2015), *Airports Commission 1. Strategic Fit: GDP/GVA Impacts based on Airports Commission forecasts*, p79

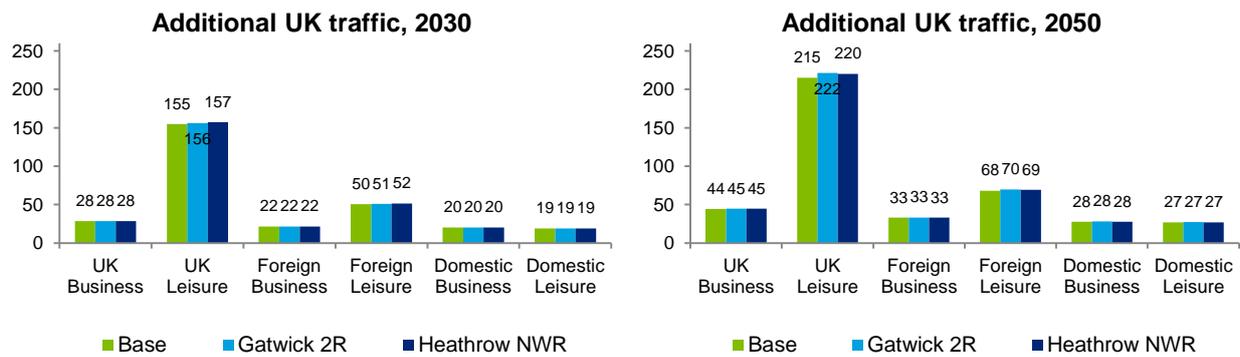
excluded, the mix and overall number of passengers are highly similar in Heathrow NWR and Gatwick 2R. The following figures show the Airports Commission forecasts under each of the scenarios.

Figure 17: AC passenger forecasts excluding I-to-I, Global Growth, 2050



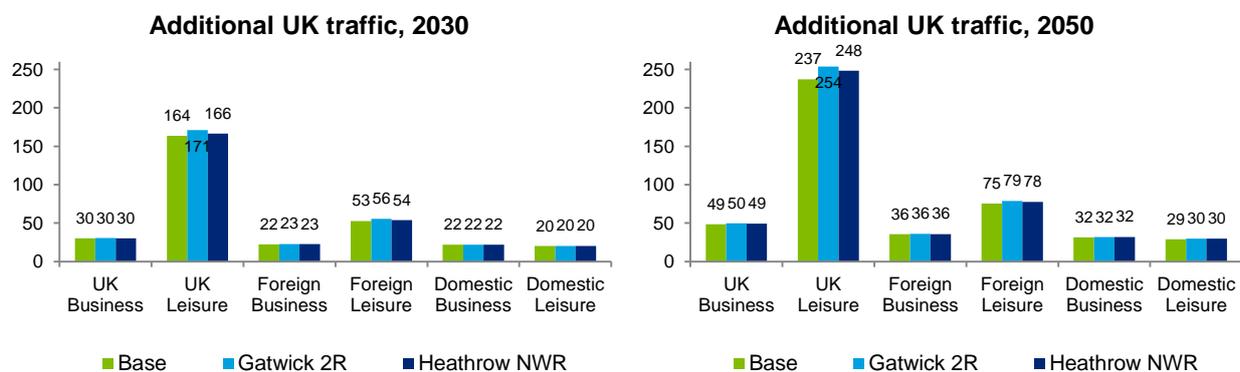
Source: Airports Commission (2015) "Strategic Fit: Forecasts"

Figure 18: AC passenger forecasts excluding I-to-I, Relative Decline of Europe, 2050

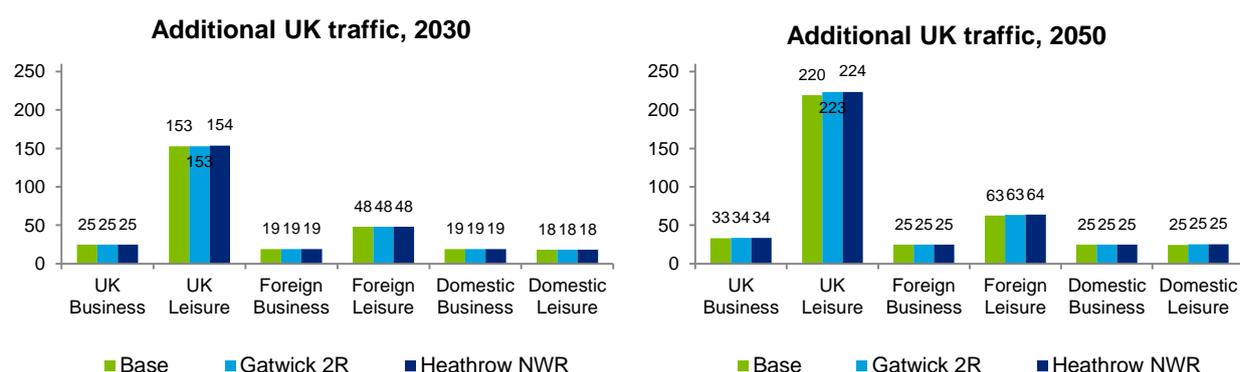


Source: Airports Commission (2015) "Strategic Fit: Forecasts"

Figure 19: AC passenger forecasts excluding I-to-I, Low Cost is King, 2050



Source: Airports Commission (2015) "Strategic Fit: Forecasts"

Figure 20: AC passenger forecasts excluding I-to-I, Global Fragmentation, 2050

Source: Airports Commission (2015) "Strategic Fit: Forecasts"

Across these five scenarios, there is generally little difference in the volume or mix of additional UK traffic generated across the two schemes. In two of the schemes, "Global Growth" and "Low Cost of King," Gatwick generates more traffic than Heathrow by 2050. This would in turn suggest that the two schemes are quite finely balanced, both in terms of the traffic forecasts and the resulting economic impacts.

However, as seen in the Assessment of Need scenario, the similar mix and numbers of O-D passengers do not translate into similar economic impacts in the PwC estimates, as illustrated in the table below.

Table 5: Net present value of real GDP impacts by scheme and scenario (£bn, 2014 prices)

	Gatwick 2R	Heathrow NWR
Assessment of Need	73.3	131.8
Global growth	93.1	184.5
Relative decline of Europe	41.8	95.2
Low cost is king	124.3	183.2
Global fragmentation	29.4	103.0

Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts based on Airports Commission forecasts

This suggests that the issues with PwC's methodology raised in this report are not specific to the Assessment of Need scenario, but would impact the estimated benefits of each expansion across all different passenger forecasts. As with the Assessment of Need scenario, the differences are generally driven by the passenger flows impact and the productivity impact, as shown below.

Table 6: Net present value of real GDP impacts following Gatwick 2R expansion, by scenario (£bn, 2014 prices)

	Assessment of Need	Global Growth	Relative Decline of Europe	Low Cost is King	Global Fragmentation
Passenger Flows	-2.3	-20.5	-8.3	-32.7	-6.6
Productivity	52.1	47.7	22.3	90.1	17.9
Frequency Benefits	3.6	10	3.5	9.6	2.7
TEE	20	55.9	24.2	57.3	15.3
Total	73.3	93.1	41.8	124.3	29.4

Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts based on Airports Commission forecasts

Table 7: Net present value of real GDP impacts following Heathrow NWR expansion, by scenario (£bn, 2014 prices)

	Assessment of Need	Global Growth	Relative Decline of Europe	Low Cost is King	Global Fragmentation
Passenger Flows	32.8	24.7	16.7	25.9	21.1
Productivity	70.9	79.7	41.8	73.1	54.5
Frequency Benefits	6.5	8.5	8.9	10.6	4.5
TEE	21.6	71.6	27.8	73.6	23
Total	131.8	184.5	95.2	183.2	103

Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts based on Airports Commission forecasts

The table below shows the differences between the schemes. In four of the five scenarios, the passenger flows impact makes up the largest share of the apparent gap in economic impacts between Heathrow and Gatwick. As noted, this effect is highly sensitive to the input assumptions made by PwC. The issues surrounding this effect are discussed in detail in Appendix B.

Table 8: Drivers of the difference in economic impacts between Heathrow and Gatwick, by scenario (£bn, 2014 prices)

	Assessment of Need	Global Growth	Relative Decline of Europe	Low Cost is King	Global Fragmentation
Passenger Flows	35.1	45.2	25.0	58.6	27.7
Productivity	18.8	32.0	19.5	-17.0	36.6
Frequency Benefits	2.9	-1.5	5.4	1.0	1.8
TEE	1.6	15.7	3.6	16.3	7.7
Total	58.5	91.4	53.4	58.9	73.6

Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts based on Airports Commission forecasts

Appendix B: Methodological approach

Introduction

This appendix reviews in more detail the analysis conducted by PwC and any potential methodological issues. This review is based on the information provided by PwC in the following documents:

- “Airports Commission: Strategic Fit: GDP/GVA Impacts,” Final Report, June 2015.
- “Econometric analysis to develop evidence on the link between aviation and the economy,” December 2013.

Our analysis is therefore constrained by the level of methodological detail provided in these reports and there are some areas in which a lack of detail has made it challenging to ascertain the precise approach used by PwC. Where there is uncertainty regarding the approach used, this is noted in the discussion.

As explained in the main report, the PwC analysis is based on a Spatial Computable General Equilibrium (S-CGE) model of the UK economy. Such models are widely used in evaluating the economic impacts of fiscal policy, although their use in connection to transport infrastructure projects is less well-established. The advantage of such models is that by accounting for the links between different sections of the economy they can capture the full economic impacts of policy change, including the knock-on effects resulting from increases in employment and investment and the wider impacts resulting from changes in prices.

Within this context, PwC consider four main channels through which an expansion of airport capacity may affect the UK economy. Each of these channels is then used to “shock” the CGE model.

- **Passenger flows:** accounting for the potential impacts of increased spending by inbound visitors to the UK, as well as the potential for spending to be displaced as more UK residents travel overseas.
- **Productivity:** this captures the fact that improved connectivity and increases in passenger traffic can improve businesses’ access to international markets and facilitate the transfer of skills and technology, thereby increasing productivity.
- **Frequency benefits:** more frequent flights can increase the convenience of air travel, thereby reducing effective travel times and allowing more time to be spent in productive tasks.
- **Transport Economic Efficiency:** improvements to consumer welfare through lower fares and improved services – some of which may come at the expense of profits for the airports and airline operators – can have wider impacts on spending and investment in the economy.

As others, including the Airports Commission’s expert advisors, have argued, the underlying CGE approach is well-tested and methodologically sound, although some care should be taken in interpreting the results. However, the use of CGE models in the context of assessing the impacts of transport projects generally and airport expansion in particular is less common. The approach through which the impacts are introduced in the PwC model is therefore not well-tested, so it is important to understand the key drivers of the results and how they relate to the inputs.

This appendix begins by providing an overview of the S-CGE approach used by PwC and the scope and limitations of this type of economic analysis. The channels through which increased aviation capacity can impact the wider economy are then discussed in turn, along with the potential issues arising from the treatment of these effects.

S-CGE Methodology

The PwC analysis is based on a CGE model of the UK economy. These models aim to represent the behaviour and interactions of all segments of the UK economy, including, for example, the government, firms, households, investors and the foreign sector. The relationships between these agents in the economy and between different sectors are based on the circular flow of income, which describes how agents receive and spend income throughout the economy. This is captured through a series of equations, calibrated to the UK economy using national accounts data.

These models have a number of advantages, outlined by PwC in their explanation of the approach. The principal advantage of general equilibrium modelling over partial equilibrium modelling is the fact that it can take into account the full chain of impacts through the economy, via, for example, changes in prices and increases in investment and employment in other sectors. The model can also account for dynamic impacts by simulating the diffusion of the impacts through the economy over time. Lastly, by including a regional dimension the S-CGE model can evaluate the effects on different parts of the UK.

The Airports Commission's advisors have noted these advantages and approve of the use of the CGE model in this capacity.

In principle the use of a Computable General Equilibrium (CGE) model, particularly with spatial dimensions, could be a useful framework within which to measure these market interactions and assess the impacts on final prices and outputs, allowing the estimation of a general equilibrium measure of the change in economic welfare. Even this might, according to some commentators, underestimate possible dynamic or step-change economic responses (see below). Therefore we were fully supportive of trying a different approach.

While the advantages of the CGE approach are well-recognised and the underlying methodology is technically sound, these models are complex, often described as a "black box." Care should therefore be taken when interpreting the results of the PwC or any similar model.

First, the GDP impacts estimated in the PwC model cannot all be directly attributed to airport expansion and therefore it would be incorrect to interpret the results as a return on investment. As PwC state, "the GDP result could not be achieved by investment in airport capacity alone without this follow-on investment. If a comparison with ratios from other types of appraisal were attempted, this additional investment would need to be included in order for the comparisons to be like for like." It therefore needs to be recognised that the economic impacts calculated in the PwC model are contingent on the additional investment or employment predicted being realised.

As a corollary to this point, the outputs of the PwC model may therefore depend significantly on the underlying assumptions that are made about the economy's capacity for additional investment and employment. This will determine to what extent changes in employment and investment – and the resulting impacts on GDP – are additional to the UK economy, as opposed to displacing existing economic activity. The assumption of a flexible labour supply included in the PwC analysis is indicative of excess capacity in the UK economy, which would generally lead to a higher level of additionality.

The sensitivity of the model to this labour market assumption is tested by PwC. While completely fixing the labour supply has a significant impact on the GDP estimates and intermediate scenario in which the number of workers is fixed but they are able to increase their hours shows little difference compared to PwC's core estimates.

Second, CGE models are intended to estimate monetised GDP impacts of a policy change, but this is not equivalent to a change in consumer benefits or aggregate welfare. This is best illustrated by consideration of the passenger flow impacts: while outbound spending by UK residents travelling overseas leads to a negative GDP impact, this would generally be recognised as an increase in the welfare of UK consumers. The positive effects on consumers through reduced capacity constraints and lower costs are captured in the Airports Commission economic impacts analysis (discussed below).

Use of the S-CGE methodology to address the strategic case

As discussed, the results of the PwC analysis are included in the Strategic Fit section of the Airports Commission's final report. The strategic case is intended to address the following: capacity, the passenger experience, competition and spatial development. The first two issues are clearly out of the scope of this type of methodology. Furthermore, it is not clear that the S-CGE model used in this case is best-placed to address either spatial or competition issues.

- **Modelling of spatial and regional impacts:** the S-CGE model contains a spatial element, splitting the UK into three different regions: London and the South-East; the rest of England; and the rest of the UK. By considering the linkages between the regions, the S-CGE model can account for how the effects diffuse through the UK. In theory, this would also allow the model to distinguish between airport expansion in different parts of the UK, based on the structure of the local economy and the sectors that may be most affected by aviation expansion.

However, with both Heathrow and Gatwick being in the same region, the PwC model is insufficiently granular to distinguish between the two. In particular, this means that the model is unable to account for any local agglomeration or clustering effects, unlike the Airports Commission analysis. Given this issue, it is unclear how much value the spatial element of the model brings to the analysis, particularly since it requires the estimation of Supply and Use Tables for each of the regions in the model. Given that these tables have to be estimated and are not publicly available, this decreases the transparency and replicability of the analysis.

- **Competition and pricing in the aviation sector:** demand for aviation and the resulting traffic is treated as exogenous to the PwC model. The traffic numbers are based on Airports Commission's forecasts using a Department for Transport model. This DfT model reflects capacity constraints in the UK system through the shadow prices facing consumers; however, it does not reflect prices on specific routes or at specific airports. This in turn means that traffic will not respond to other changes in the UK economy; for example, increases in household incomes or the relative price of air travel will not be reflected in a change in UK demand for air travel. While this may not have a significant impact on the results, the S-CGE model itself is unable to fully account for competition or changes in prices in the aviation sector.

Since the S-CGE model itself is not able to account for differences between Heathrow and Gatwick expansion or to endogenise the effects of expansion on prices and demand in the aviation sector, the analysis is therefore dependent on the channels through which the PwC model is shocked and the inputs used. As the Airports Commission's expert advisors have commented, the "front-end" of the PwC model and the channels through which airport expansion is expected to impact the economy are not well-tested. The specific channels analysed by PwC are discussed in subsequent sections of this appendix.

Comparison to Airports Commission analysis

The extent to which comparisons can be drawn between the Airports Commission methodology and the PwC analysis is limited, since they are aiming to quantify fundamentally different things: the Airports Commission analysis focusses on the welfare gains resulting from expansion, while PwC assesses the GDP impact.

The Airports Commission analysis of the economy impact is based on a more conventional cost-benefit methodology. The cost-benefit analysis focuses on welfare impacts that are incremental to the UK economy as a whole. These impacts include:

- Increases in aggregate welfare due to the relaxation of capacity constraints which had previously limited supply in the market. The Airports Commission also takes into account the reallocation of existing surplus from producers to consumers due to a reduction in prices and shadow costs.
- Positive externalities such as agglomeration effects created by increased clustering and knowledge spillovers generated in the local economy.
- Negative externalities arising due to noise pollution, carbon emissions and environmental damage due to airport expansion.

By focussing solely on the direct welfare-improving impacts of the scheme, rather than considering the indirect benefits arising due to increased employment and investment, the Airports Commission figures are not dependent on assumptions made about displacement and crowding-out. The issues surrounding displacement that may apply to CGE analysis are therefore not applicable here.

The fact that the Airports Commission analysis is based on welfare rather than GDP means that the results are not comparable to the PwC estimates. Many of the benefits included in the welfare analysis are non-pecuniary, including greater convenience or reduced travel times for leisure passengers. Therefore they would not be reflected in GDP. The exclusion of certain benefits from GDP would generally suggest that the GDP impacts should be smaller than the welfare impacts. At the same time, it is incorrect to attempt to quantify these welfare benefits by assuming an equivalence with GDP or by representing an increase in consumer welfare as an increase in income. This point is discussed further in the section on the TEE impact below.

Passenger flows

Overview of the approach

The first effect considered in the PwC report is the impact of increases in inbound and outbound passenger expenditure associated with the increase in O-D traffic. Additional passengers brought about by the expansion will spend money inside or outside the UK. The passenger flows estimate in PwC's analysis intends to quantify the impact that this associated additional spending has on UK GDP.

PwC's analysis rests on the mix of passenger types, which will determine the net effects on UK spending:

- Inbound passengers, i.e., foreign passengers who travel to the UK, will spend money in the UK economy and will therefore contribute to increasing UK GDP.
- Outbound passengers, UK passengers travelling abroad, will spend money outside of the UK, representing foregone consumption that may otherwise have been spent in the UK economy. The spending of these additional passengers will have a negative impact on GDP.

International transfer passengers passing through the UK are assumed by PwC to have no impact on expenditure.

This additional or displaced spending in turn has a diffusion impact on the UK economy. As additional inbound passengers spend money in hotels, restaurants and other UK goods and services, the affected sectors may expand as a result of this increase in demand. Firms in these may hire more workers or increase investment in capital in order to support this extra demand, and in turn the additional workers may have more money to spend in the economy. This leads to a multiplier effect: the direct impact of a £1 increase in spending is multiplied throughout the economy to give an overall increase in GDP. In the case of increased spending in the UK, the multiplier will be positive. However, as foregone UK consumption reduces demand in the affected sectors, there will be negative knock-on impacts on the economy leading to a multiplier effect on GDP that is negative.

As the characteristics of additional passengers affect how much and in which sector they spend, these factors are also important in determining the overall impact on GDP. Additionally to the inbound/outbound split, PwC differentiates between three types of passengers:

- Passengers travelling for business;
- Passengers travelling for leisure; and
- Passengers visiting friends and family.

Using data from the ONS⁵¹ and TSA⁵², PwC estimated the expenditure per passenger type per visit in different sectors of the economy (e.g. agriculture, construction, wholesale and retail trade etc.). This ensures that the model picks up the fact that where the expenditure takes place in the economy matters: different sectors will have different interactions with other parts of the economy.

An important output of the PwC model is the difference in the inbound and outbound passenger expenditure multipliers. The S-CGE model suggests that the "outbound multiplier" is relatively large compared to the "inbound multiplier". This suggests that the forgone consumption has stronger supply chain linkages into the UK economy than additional inbound spending by foreign passengers. As such, a £1 increase in inbound spending would not compensate for a £1 increase in outbound spending (or £1 increase in forgone consumption) and the overall impact on GDP of additional passengers through this channel could be negative.

⁵¹ Office for National Statistics

⁵² Tourism Satellite Accounts

Potential Issues

As discussed above, the key driver of the passenger flow impact is the mix of inbound and outbound passengers. On the advice of the Airports Commission, PwC has assumed that the share of inbound and outbound passengers and their associated spending patterns stay constant under either expansion scheme. This is particularly important when considering the different magnitude of the multipliers. As Gatwick currently has a higher share of outbound passengers (73%) compared to Heathrow (51%), assuming that these shares will also apply to the additional passengers implies that the Gatwick expansion will lead to relatively more foregone consumption than the Heathrow expansion.

Since PwC's model suggests that the multiplier of passenger expenditure outside the UK is greater than the multiplier of passenger expenditure inside the UK, the net impact of the passenger flow in the Gatwick 2R scheme is to reduce GDP (in terms of NPV). As seen in Appendix A, this is the case across all five traffic forecast scenarios.

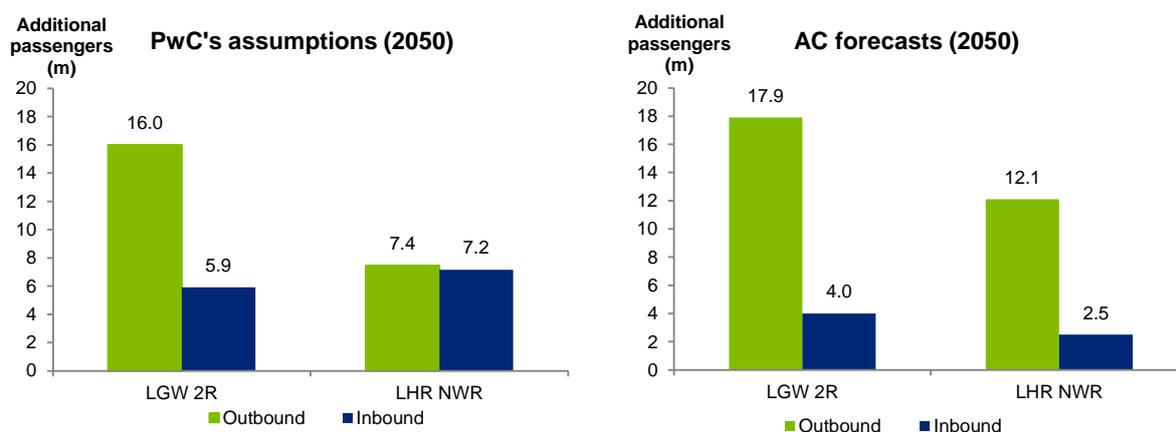
However, this assumption that the split of additional inbound and outbound passengers is significantly different across the two schemes is a departure from the Airports Commission's own published forecasts. It is also counterintuitive: to the extent that increases in UK O-D traffic are driven by global trends in the level of demand for air travel to and from the UK, this demand would not be expected to depend on whether it is Heathrow or Gatwick that expands.

As discussed in the main report, the assumptions made by PwC depart from the Airports Commission forecasts, for reasons that are unclear. Similarly to the Assessment of Need scenario, the Airports Commission forecasts actually suggest that in 2030 and 2050, most of the increase in O-D passengers – about 65%-75% in the shorter-term and about 80% by 2050 - will come from outbound passengers under all of the scenarios considered, regardless of which airport is expanded.

PwC undertake a similar sensitivity analysis to that done for the Assessment of Need scenario for two of the other traffic scenarios: Low Cost is King and Global Fragmentation. As seen in Appendix A, the former is the most aggressive of the growth forecasts considered and suggests that Gatwick expansion will generate more traffic; the latter is more conservative and shows Heathrow expansion leading to slightly more traffic in the short-run, before the two schemes reach parity by 2050. The figures below show the assumptions made by PwC regarding inbound-outbound passenger mix under these two scenarios⁵³, along with the figures from the Airports Commission's own analysis.

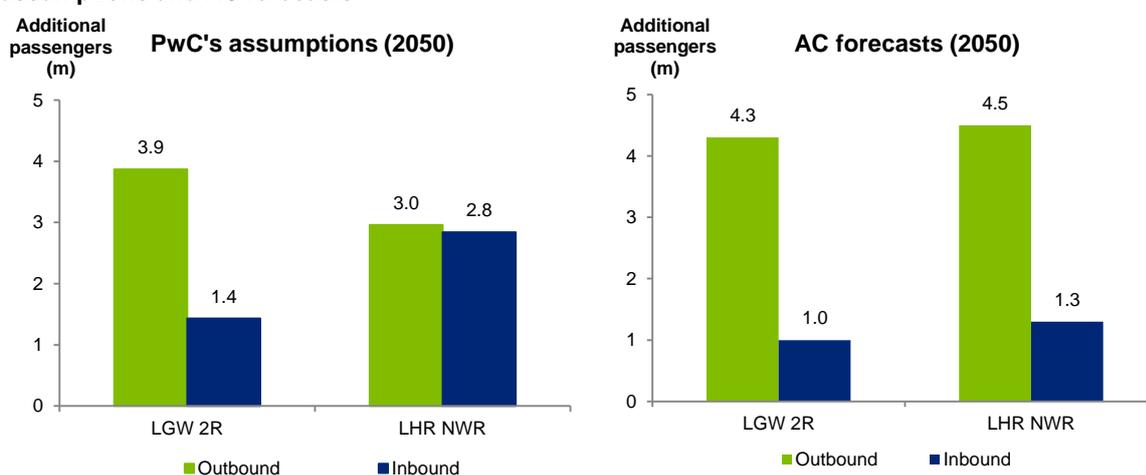
⁵³ PwC do not explicitly state the absolute number of inbound and outbound passenger that they assume in their analysis. The figures are therefore based on Airports Commission forecasts for the total number of additional O-D passengers passing through the UK system in 2050 and the stated split of inbound and outbound passengers: 27:73 following Gatwick expansion and 49:51 following Heathrow expansion.

Figure 21: Implied additional UK-wide O-D passengers, Low Cost is King scenario – PwC's assumptions and AC forecasts⁵⁴



Source: PwC, Airports Commission

Figure 22: Implied additional UK-wide O-D passengers, Global Fragmentation scenario – PwC's assumptions and AC forecasts⁵⁵



Source: PwC, Airports Commission

The Airports Commission estimates suggest that under the Low Cost is King scenario 18% of additional UK-wide traffic in 2050 is inbound following Gatwick expansion and 17% under Heathrow expansion. Under the Global Fragmentation scenario, the figures are 19% and 22% respectively. This suggests that, while not exactly accurate, the assumption that the two schemes generate the same mix of additional traffic is more closely aligned with the Airports Commission forecasts.

The sensitivity test carried out by PwC is based on the assumption of the same mix of traffic being generated under both schemes (42% of additional traffic is assumed to be inbound, based on the current London average). The effect of altering this assumption on the estimates is shown in the figures below.

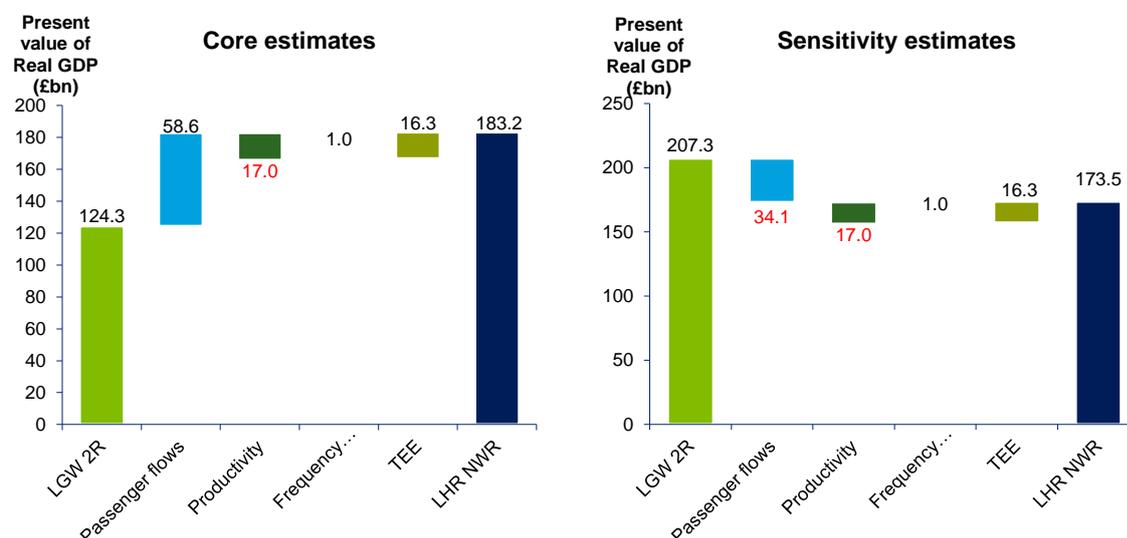
Under the Low Cost is King scenario, correcting the passenger mix assumption to align more closely with Airports Commission forecasts (which show the two schemes generating a similar inbound/outbound passenger mix) reverses the relative impacts, with Gatwick now outperforming Heathrow. In practice, these estimates are likely to significantly overstate the economic impact due to

⁵⁴ Excluding domestic passengers

⁵⁵ Excluding domestic passengers

passenger flows, since the PwC sensitivity assumption that 42% of traffic is inbound is much higher than the Airports Commission estimates of 17% to 18%. This suggests that the additional traffic could in fact lead to a large negative GDP impact (the assumption of 27% inbound generated a negative impact of almost £43bn for Gatwick).

Figure 23: Drivers of the differences in economic impact, Low Cost is King scenario – PwC’s core estimates and sensitivity test⁵⁶

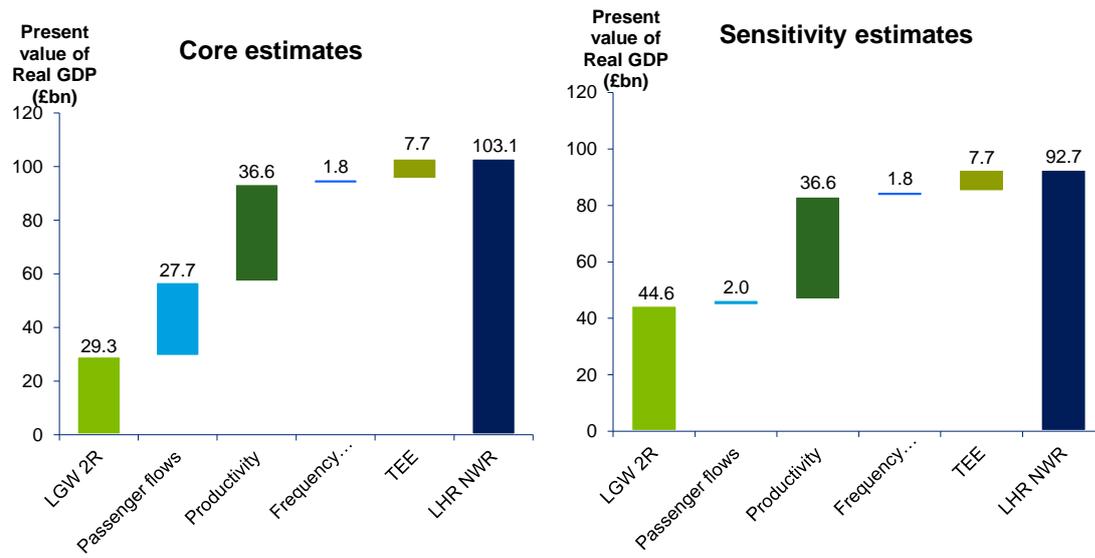


Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts

Similarly, most of the estimated difference in economic impact between the schemes in the Global Fragmentation scenario is due to the passenger flows and productivity effects. The sensitivity analysis under this scenario shows that when a similar passenger flows impact is estimated under both expansion schemes, which would be the case using the Airports Commission forecasts, the remaining difference is almost entirely due to the productivity effect.

⁵⁶ The PwC report provides a different figure for the overall economic impact of Gatwick expansion under the sensitivity test (see Table 30) This figure is based on estimates of the other impacts (productivity, TEE and frequency benefits) that are not found anywhere else in the report. Given that only the passenger flow impact would change under this sensitivity test, the estimates of the other impacts ought to remain constant (as they do in the other scenarios). The figures above therefore keep these other impacts unchanged and so do not match the figures reported by PwC.

Figure 24: Drivers of the differences in economic impact, Global Fragmentation scenario – PwC’s core estimates and sensitivity test



Source: PwC (2015), Airports Commission 1. Strategic Fit: GDP/GVA Impacts

Productivity impact

This section turns to the treatment of the productivity impact, which is estimated by PwC using a two-stage approach:

- First, PwC use econometric analysis to estimate the effect that an increase in passenger flows between UK and other markets has on trade.
- Second, this is incorporated into the PwC model via an exogenous productivity parameter, which is set so as to yield the desired effect on trade. This in turn leads to an effect on GDP, described as the “productivity impact.”

The econometric analysis undertaken by PwC, described in Appendix C of their final report, and the use of these results in the model are discussed. While Appendix C describes the methodological approach taken in the econometric analysis, this Appendix is lacking in detail in some areas. Therefore in some instances an earlier PwC report published in December 2013 entitled “Econometric analysis to develop evidence on the link between aviation and the economy” is referenced. The June 2015 report appears to build on this analysis with the methodological approach described as being similar in both reports.

However, while the December 2013 report helps fill in some of the gaps, there are still open questions around some of the details of PwC’s methodological approach. Without more information, it is difficult to appraise the robustness of the results.

Along with providing a more detailed description of the PwC methodology, this section also addresses the following issues that have been identified with this approach:

- The use of passenger flows as a measure of connectivity;
- While the econometric estimation identifies a connection between passenger flows and trade, it is unclear from PwC’s methodology how the direction of causality is established;
- The way in which productivity is then entered into the PwC model is also not well-tested;
- The elasticity of productivity with respect to connectivity, derived from the PwC’s econometric model is high compared with existing literature.

Econometric methodology

The first stage of the PwC analysis is based on the statistical estimation of the relationship between greater airline passenger flows and economic activity.

Initially, PwC sought to estimate the link between passenger numbers and GDP. However, this research found only a weak relationship. PwC reason that this is because “UK GDP is a national measure of UK economic activity, which [...] is influenced by the totality of aviation activity, and its relationship with passenger flows to and from particular global regions is not necessarily strong”. Therefore, PwC instead examine the relationship between passenger flows and international trade, i.e. exports and imports. They argue that international trade represents the component of GDP through which increased aviation linkages are most likely to impact productivity, by enabling businesses better access to lucrative overseas markets.

PwC estimate the impact of passenger flows on trade using a panel of 112 countries over a 10 year period, 2001-2010. They use a “gravity model”, which considers bilateral trade flows between the UK and other countries.

Trade data is sourced from UNCTAD and is split into

- Exports of goods;
- Exports of services;
- Imports of goods; and

- Imports of services.

Passenger flows are measured using data from SABRE/ADI which captures all passengers whose journey originated in the UK regardless of the destination. This data is historic, covering the period 2001-2010. The effect of passenger flows is estimated separately for four regions: Asia, Europe, North America and others.

Additional variables are controlled for, including

- UK GDP;
- GDP and income group (high, upper middle, lower middle and low) of country i;
- Exchange rates;
- Distance of country i's capital to London;
- Whether country i is English speaking;
- World region (Asia, Europe, North America and the rest of the world)

PwC uses this approach to calculate the responsiveness, or elasticity, of international trade to an increase in passenger flows. PwC's results are summarised in Table 9 below. The parameters of interest are the passenger flow coefficients for each region. For example, the coefficient for the export of goods equation for Asia is 0.293. This can be interpreted as a 10% increase in passenger flows between the UK and Asia leads to a 2.9% increase in exports of goods.

Table 9: PwC's estimates of the relationship between passenger flows and trade by region

	Imports: goods	Exports: goods	Imports: services	Exports: services
Asia	-0.006	0.293	0.612	0.297
Europe	0.034	0.256	0.581	0.246
North America	-0.078	0.237	0.586	0.257
Others	-0.071	0.269	0.601	0.293

Source: PwC.

Moreover, within each equation the coefficients are broadly similar across regions. This implies that the world region to and from which passengers flow does not substantially alter the effect of passenger flows on trade. Thus, there is no advantage accruing to either airport from having better connections with particular regions of the world.

Potential issues

A summary of the issues around PwC's approach is included in the main report. This appendix focuses on some of the more technical issues surrounding the econometric approach.

The objective of the econometric analysis is to assess the extent to which an increase in passenger flows can be expected to lead to an increase in international trade. In order to do this, it is key to establish that an increase in passenger flows *causes* an increase in trade, rather than the two merely being positively associated. While it may be straightforward to establish a positive association between two variables, it does not automatically follow that one variable causes the other.

In this case, for example, the positive relationship between international trade and passenger flows may be due to the fact that increased trade strengthens business ties and in turn leads to an increase in business travel. Alternatively, there may be additional, unobserved variables driving both effects; strong historical and cultural ties would be expected to lead to both a strong trading relationship and a high level of passenger traffic between the two markets.

In the Appendix to their report, PwC provide an overview of their approach to addressing this issue, through the use of instrumental variables. However, they do not specify the instruments used so it is difficult to assess to what extent they can solve the issue of establishing causation.

The following sections of the report describe the challenges arising from this econometric estimation in more detail.

Misspecification

The use of passenger flows as a measure of connectivity has been criticised by Laird and Stroombergen in their peer review.⁵⁷ They argue that in addition to air travel, volumes of international trade are affected by other factors such as the quality of surface access infrastructure or other potential measures of “connectivity.” These different variables are also likely to be strongly correlated, making it difficult to isolate the effects of passenger numbers specifically. Thus, the estimated trade elasticities will be confounded by the impact of other forms of transport accessibility.

Simultaneity

PwC define passenger flows as sub-component of trade⁵⁸. This may create a problem of simultaneity, i.e. passenger flows explain trade, but trade simultaneously explains passenger flows. It can be said that passenger flows are “endogenous” to the model. This may in turn lead to bias in some econometric estimates.

Similar issues apply to GDP, used as a control variable. PwC’s stated goal is to estimate the impact of greater airline passenger flows on economic activity. As explained above, they initially estimate the link between passenger numbers and GDP, but then revert to using trade as a proxy for GDP. Therefore, including GDP as a control variable becomes problematic if endogeneity is not correctly controlled for.

PwC address these problems by “test[ing] for the presence of endogenous variables” and “using instruments and proxies instead of the endogenous variable”.⁵⁹ However, while PwC report the results of the endogeneity tests, the way in which these results are reported leaves open a number of questions. In particular, these tests are *post-estimation* tests, i.e. they are calculated using predicted values that need to be estimated first. The results of the post-estimation tests are linked with the specification used for the estimation and can change in the latter changes. PwC do not report the specification on which the tests are based. Without this information and details of the instruments used in the analysis, it is difficult to comment on the robustness of the econometric estimates.

Treatment of productivity in the PwC model

Based on this relationship, PwC then estimate the effect that the increase in traffic following airport expansion would have on trade by applying the elasticities to the passenger flow forecasts provided by the Airports Commission. This effect is then incorporated into the S-CGE model via productivity. This is not calculated directly, but rather the productivity input is set so as to generate the appropriate impact on trade.

PwC report the present value of real GDP impacts from productivity to be £52.1 bn for LGW 2R and £70.9 bn for LHR NWR under the Assessment of Need scenario. Figure 25 and Figure 26 show more detailed results for the assessment of need scenario for LGW 2R and LHR NWR, respectively. They show

- The productivity input required to deliver the implied trade increases;
- The real GDP impact resulting from increased productivity; and

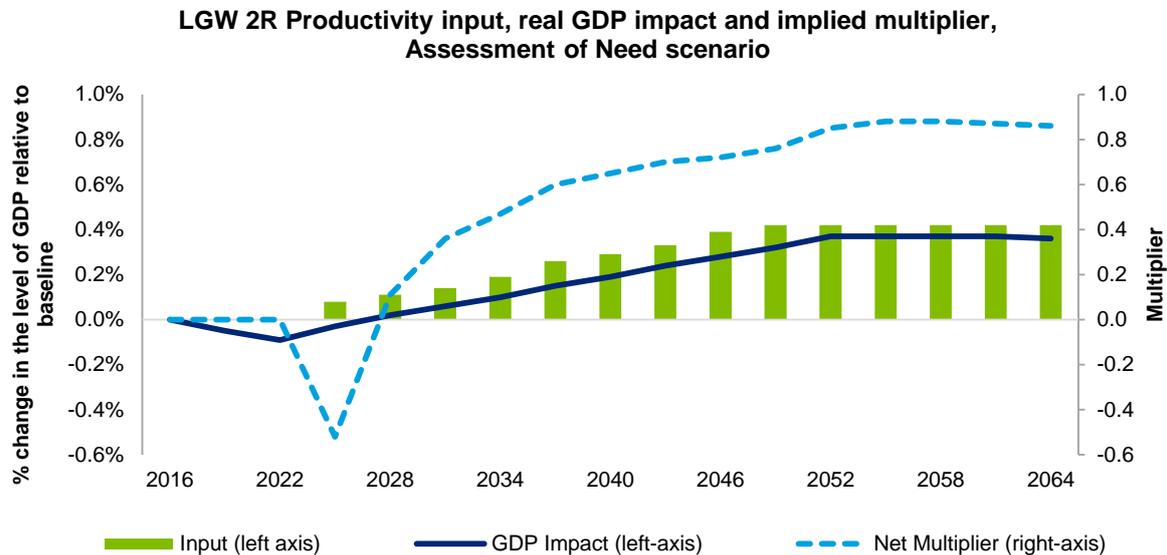
⁵⁷ Laird and Stroombergen (2014).

⁵⁸ See, for example, PwC (2015), p. 79.

⁵⁹ PwC (2015), p. 331.

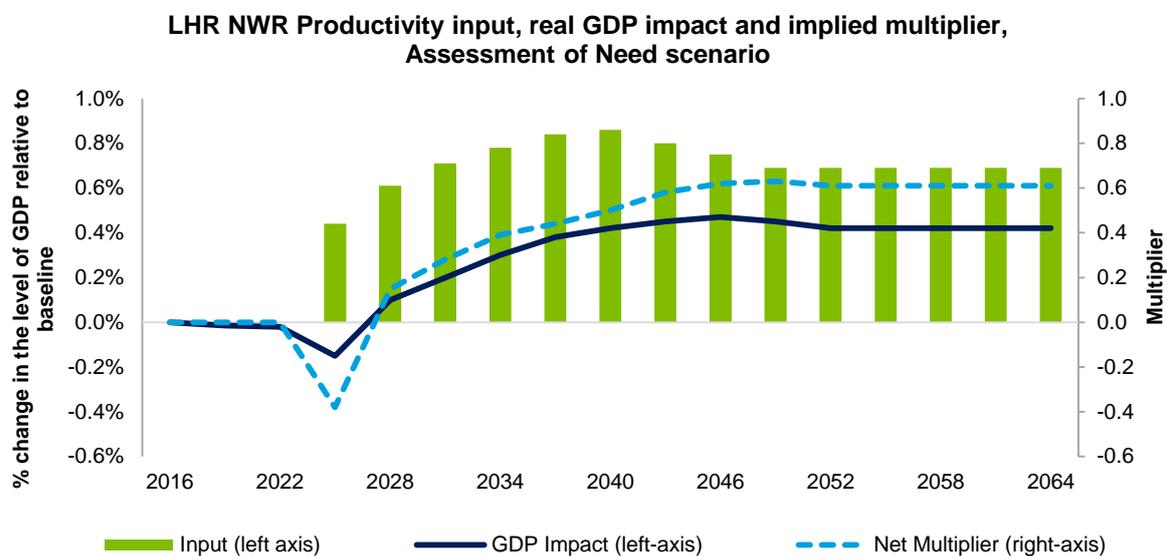
- The implied multiplier, which captures the idea that an increase in GDP will have positive knock-on effects along the downstream supply chain, thus multiplying the effect of the initial GDP impact.

Figure 25: Productivity effects for LGW 2R



Source: PwC Strategic Fit report, Figure 12

Figure 26: Productivity effects for LHR NWR



Source: PwC Strategic Fit report, Figure 115

Potential issues

The figures raise a number of questions with regard to the way in which the productivity impact is incorporated into the model. In particular, the size of the productivity inputs for Heathrow relative to Gatwick appears to be inconsistent with both the traffic forecasts that form the key input to the analysis and the GDP impact that is the key output. As can be seen in these figures, by 2050 Heathrow requires higher inputs to generate the same level of GDP impact as Gatwick. However, by

2050 both schemes generate approximately the same volume of additional UK-wide O-D traffic, which is the variable driving the relationship between passenger flows and trade.

Based on these figures, the traffic generated through Heathrow expansion appears to lead to a greater productivity impact than those additional passengers arising from Gatwick expansion. This is despite there being negligible differences in the mix of business and leisure passengers on in the destinations served. At the same time, the eventual impact of increased productivity on GDP is lower for Heathrow expansion than for Gatwick expansion, with multipliers of 0.6 and 0.8 respectively. This implies that “crowding out” effects are higher for Heathrow.

The lack of detail about the precise way in which the S-CGE model operates make it challenging to assess the extent to which these apparent incongruities in the analysis may impact the eventual results. In the long-run, the GDP impact relative to the increase in passenger flows is broadly similar across the two-schemes, suggesting that these issues are not markedly distorting the overall effect. This may indicate that the discrepancy in the productivity inputs is a by-product of the model design and the channels through which the model is “shocked.” However, it would be useful to have some clarification of exactly how the productivity effect is calibrated in the PwC model. It would also be helpful to test the extent to which the difference in the productivity inputs may distort other outputs of the model, for example labour demand.

Comparison to other benchmarks

In order to better understand the validity of the PwC findings the results can be benchmarked against those of other studies. Table 10 shows the elasticity of productivity (that is, the percentage change in productivity resulting from a 1% increase in passenger flows) for the Gatwick and Heathrow Assessment of Need scenarios. These figures are calculated by dividing the productivity input required to produce the change in trade implied by the econometric model (0.4%) by the increase in passenger numbers for that scenario (2.6% for Gatwick and 2.4% for Heathrow). The increase in passenger numbers excludes I-I passengers. The calculated elasticity of productivity is 0.15 for Gatwick and 0.29 for Heathrow.

Table 10: Elasticity of productivity

	Gatwick excluding I-I passengers	Heathrow excluding I-I passengers
% change in passenger numbers (2050)	2.6	2.4
Productivity input (2050)	0.4	0.7
Implied elasticity of productivity	0.15	0.29

Source: PwC (2015), Airports Commission (2014) “Strategic Fit: Forecasts”, Deloitte analysis

These figures can be benchmarked against findings reported in other studies. In particular, a study for the International Air Transport Association (IATA) found⁶⁰ an elasticity of labour productivity to connectivity of 0.007. This differs significantly from with PwC’s figures: the IATA study found that a 10% increase in connectivity (here proxied by passenger flows) could increase productivity by 0.07%; PwC estimate that it would increase UK productivity by 1.5% and 2.9% for Gatwick and Heathrow, respectively.

⁶⁰ IATA (2007).

Another study by Oxford Economics⁶¹ found an elasticity of 0.05, meaning that a 10% increase in connectivity could increase productivity by 0.5%. The same study found that a 10% increase in business traffic had the potential to increase long-run GDP by 0.5% through its effect on productivity. In the PwC study, an increase in business travel of up to 1.4% is associated with a GDP increase of about 0.4%. This means that a 10% increase in business travel would be associated with a GDP increase of up to 2.8%, over five times that found in the Oxford Economics Study.

As mentioned in the main report, the Airports Commission's own advisors have commented that "the implied elasticity (or responsiveness) of productivity to seat capacity in the model may be high and that this may partially account for the high model impacts on GVA".⁶²

Laird and Stroombergen, who conducted a peer review in which they assess the validity of PwC's estimates, suggest that this may be driven by differences in the way connectivity is measured. They note that IATA defines connectivity as "the frequency of each service multiplied by its seat capacity, weighted by the importance of the destination airport, summed across all services". Thus, passenger flows may be over-simplifying the concept of connectivity. Laird and Stroombergen suggest including the increase in the number of destinations and frequency of routes. However they also comment that this is nonetheless unlikely to fully explain the discrepancy between the PwC estimates and those found elsewhere.

If, in fact, the PwC estimates do overstate the productivity impact associated with airport expansion then this issue will apply to both sets of estimates. It would therefore be expected that the level of the productivity impact should be lower for both schemes. This would also affect the absolute value of the difference between the schemes, suggesting that it might be less than the £19bn figure estimated by PwC under the Assessment of Need scenario.

⁶¹ Oxford Economics, (2013), 'Impacts on the UK economy through the provision of international connectivity.' Prepared by Oxford Economics for Transport for London in support of the Mayor's Aviation Work Programme, which was convened to develop a submission to the Airports Commission.

⁶² Mackie and Pearce (2015), p.6.

Frequency benefits

PwC argue that greater frequency of services can increase productivity by, for example, enabling people to travel at more convenient times, reducing the time passengers may have to wait prior to or after taking a flight, or when transferring.

PwC use estimates of frequency benefits provided by the AC as inputs to the S-CGE model. These estimates are derived from the DfT aviation model and are produced by combining estimates of the value of time with the forecast time benefits from increased frequency. The effect of frequency benefits on GDP is relatively modest in magnitude: it may amount to around 0.05% to UK GDP under both the Gatwick and Heathrow schemes.

The frequency benefits are then incorporated into the S-CGE model as positive effects on total factor productivity. In particular, whole-economy total factor productivity is increased to the point at which the value of the increase is equal to the increase in forecast frequency provided by the Airports Commission. PwC explain that the transmission of the effect through the economy is very similar to that described for the productivity effect: “frequency benefits contribute to increased connectivity for businesses can facilitate improvements in productivity. This in turn can lead to increases in profitability and in additional investment in the long-term.”⁶³

In contrast to the other impacts considered in the PwC analysis, the frequency benefits can be positively affected by the volume of international-international transfer passengers. By increasing demand, transfer passengers can increase the profitability of certain routes and in turn support the delivery of more frequent services. Therefore, the Heathrow scheme would be expected to generate greater benefits, since by 2050 it generates about 60% more aggregate (inclusive of I-I) UK traffic than the Gatwick scheme.

Nonetheless, other reviews have raised a number of issues surrounding the estimation of the frequency benefits. For example, there is a chance of double counting: the increased productivity from frequency benefits may also be measured as part of the productivity impact or as part of the TEE impact.

With respect to the risk of double-counting between the frequency benefit effect and the productivity effect, PwC acknowledge this possibility and argue that because “the estimation period used to inform the productivity effect did not include any step-changes in frequency benefits, [...] frequency benefits are unlikely to have been captured in the coefficients estimated as part of the econometric analysis, meaning the frequency benefits are not included in the productivity effect”.⁶⁴ The fact that trade, rather than productivity directly, is the dependent variable in the econometric estimation used by PwC may also mitigate this risk.

With respect to the TEE effect PwC state that they were advised by the Airports Commission that the framework used is internally consistent and that frequency benefits should be treated as a separate effect.⁶⁵ However, PwC limit their analysis to frequency benefits accruing to business passengers. They argue that while leisure passengers are likely to experience some benefits, these are unlikely to represent a substantial share. While it may be reasonable to assume that the effect of frequency benefits on GDP is likely to be small for leisure passengers, they are likely to experience some benefits which contribute to an increase in consumer surplus. These benefits are captured in the welfare analysis undertaken by the Airports Commission, but appear to be excluded from the PwC analysis. Given that welfare benefits should not be assumed to be equivalent to GDP impacts, this approach is in many respects the correct one. However, given that other components of consumer welfare are included in the model via the TEE impact this may lead to some inconsistencies in the treatment of different effects.

⁶³ PwC (2015), p. 93.

⁶⁴ Ibid.

⁶⁵ PwC (2015), p. 53.

Transport Economic Efficiency Impact

This section considers the Transport Economic Efficiency (TEE) impacts. While the TEE impacts included in the PwC analysis are not an important driver of the differential between Heathrow and Gatwick, there are concerns about the reliability of this analysis.

Overview of the approach

The objective of the TEE impact is to reflect the wider economic impacts that may result from a reallocation of benefits from producers (for example airport operators and airlines) to passengers. PwC and the Airports Commission argue that by relaxing the capacity constraints facing the London airport system, expansion can promote greater competition and reduce the mark-ups that can be charged by producers. This may in turn translate into greater benefits for passengers and consumers, whether through lower prices or through greater convenience, improved facilities or reduced congestion. At the same time, however, airport owners and airlines may experience a reduction in their profits.

The inputs used for this analysis come from Airports Commission estimates of the benefits and costs for passengers and producers associated with increased capacity. These effects are based on the calculation of “shadow costs,” which are the additional costs of flying that would be required to reduce consumer demand to the point that it equals supply. This can be interpreted as the premium or economic rent associated with congestion in the UK airline network. To the extent that they have market power, airport operators and airlines can pass on these costs to passengers through higher fares. The costs may also be reflected in greater congestion or in the fact that passengers need to incur additional costs by using less convenient airports.

By reducing constraints on capacity, airport expansion can increase the supply of air travel, meaning that the additional shadow costs required to equalise supply and demand fall. These benefits may be passed on to consumers through lower fares, increased frequency or reduced congestion. At the same time, airport owners and airline operators are less able to extract a premium due to congestion, so their profits may fall.

The reallocation of benefits is reflected in the PwC model in two ways:

- Consumer surplus: the additional benefits to consumers are incorporated into the model through an increase in economy-wide productivity. This in turn increases firms’ outputs and profits, with consumers ultimately benefitting as the owners of firms;
- Producer surplus: this is reflected through a reduction on the returns to investment in the aviation sector, which may in turn reduce incentives to invest.

Potential issues

This approach raises two potential issues. First, it assumes equivalence of consumer benefits and GDP. PwC argue that the benefit accruing to consumers can be “used” through increased spending or saving; they therefore monetise these benefits and treat them as an increase in real income. While this may be plausible in some cases, for example if the consumer surplus is entirely generated through a reduction in prices, it is not generally correct to treat consumer surplus in this way since it may also reflect intangible benefits such as reduced congestion or improved facilities. This issue is raised in the Airports Commission report on the TEE impacts from which the input assumptions are taken.⁶⁶

Second, it is unclear from the PwC report how the consumer surplus of foreign passengers or the producer surplus of international airlines is treated in the model. While it is reasonable to assume that some part of the consumer surplus of UK passengers may lead to increased spending in the UK

⁶⁶ Airports Commission, “Economy: Transport Economic Efficiency Impacts”

economy, it is less plausible to believe that foreign passengers (and particularly transfer passengers) will make use of these benefits in the UK. While the final PwC numbers may only represent the benefits for UK passengers, there would be value in having clarification on this point.

The table below shows the contribution of domestic, foreign and transfer passengers to the TEE impact (excluding the contribution of frequency benefits to total consumer benefits, since these are captured separately in the PwC model. As this figure shows, the share of the TEE effect attributable to foreign passengers and international transfer passengers is higher following Heathrow expansion. This means that if the surplus accruing to these passengers is included in the TEE estimates then these impacts may be overstated in Heathrow's favour.

Table 11: Passenger benefits generated under the Assessment of Need scenario, (PV £bn)

	Total	UK Business	UK Leisure	Foreign Business	Foreign Leisure	I-I transfer
Gatwick 2R	43.9	9.1	21.9	4.2	7.2	1.4
Heathrow NWR	49.2	11.2	20.8	5.4	7.8	4.0

Source: Airports Commission, "Transport Economic Efficiency Impacts"

More generally, the rationale for including the consumer surplus impact through a productivity effect is unclear, particularly since both the direct productivity effect and the frequency benefits are already introduced into the model through this channel. By introducing this through an increase in productivity across all sectors, the model treats the increase in consumer surplus as an across-the-board increase in spending power, rather than as a reduction in the shadow costs associated with a particular product. This is related to the point made above that the PwC model does not endogenise demand for air travel and therefore the benefits in terms of consumer surplus cannot be concentrated in aviation and related sectors.