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Economic Evaluation of Investments in Airports: Recent Developments

Abstract: The problem of how to evaluate investments in airports has now been studied for over 50 years. This paper analyzes the use of different methods like cost–benefit analysis (CBA), economic impact analysis (EIA), and computable general equilibrium (CGE) models to address the question. It assesses the strength and weaknesses of each method, and it discusses which methods have been used in different countries. The paper argues that the CBA approach and the newer CGE modeling approach address the policy issue well and that both methods are appropriate, although improvements are possible, especially in the newer aspects of evaluation. Furthermore, more data intensive CGE models are able to analyze broader aspects of the evaluation question for which CBA has had difficulty. EIA does not address the problem satisfactorily, and it misleads air transport policy. But this evaluation contrasts sharply with practice. EIA has been extensively used to decide on airport investment. CGE approaches are very promising, though further work is needed for them to reach their full potential. This paper pays particular attention to the relationship between CBA and CGE in airport investment evaluation and also the possible role of wider economic benefits (WEBs) of aviation in evaluation.

Keywords: airport investment; computable general equilibrium models; cost–benefit analysis; economic impact analysis; wider economic benefits of aviation.

> *"At least in some instances, impact studies will be employed, explicitly or implicitly, deliberately or unintentionally, as justification for adopting a specific course of action. Analysts may wish their hands of any blame for the subsequent misuse or misinterpretation of the findings of an impact study. No*

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professional error has been committed on their part. But this does raise the moral conundrum of whether or not an analyst might be guilty of a professional 'sin' of omission."

W. G. Waters (1976)

1. Introduction

The continuous growth of air transport has led to a situation that, in many countries, demand exceeds airport capacity. Expanding airport capacity in large urban areas has proven to be difficult. Airports are very land intensive, and they are the source of negative externalities, such as noise, local traffic, and local emissions. While the positive effects, in the form of better connectivity and additional production and income, are distributed in the wider region of the airport, the negative effects are borne by the local neighbors. This has led to long-lasting public planning processes, often with still unresolved conflicts, and the legitimacy and rationality of these planning processes have often been criticized. Rural areas often see good air transport connections to centers as being vital for promoting growth and tourism. However, while many airports can be justified in terms of territorial accessibility, many airports have been built where there is no lack of capacity. There is evidence that airports have extended runways for intercontinental flights which have never materialized. There is also evidence of "white elephant" airports such as the airport of Kassel-Calden (Germany) and Don Quijote Airport (Spain). Getting the investment decision right is very often as challenging as it is important for urban and rural regions. This raises the question of how airport investment be best evaluated? There is no single way in which airport investments are assessed – there are several techniques of assessment, and these differ widely in terms of their implications. Thus, there is a problem of how best to evaluate investments, whether they are for small changes or major new airports.[1]

There are several techniques which have been used in evaluating airport investments – we focus our attention on three, which are probably the most widely used ones. These are cost–benefit analysis (CBA), economic impact analysis (EIA), and computable general equilibrium (CGE) models. There have been other techniques of evaluation which have been suggested – one of these is multicriteria analysis (Quinet, 2000). As the name suggests, it is a means of taking a broader set of aspects into account than is common with CBA. Another technique is that of strategic environmental assessment (Partidario & Miguel, 2011), which has been used to evaluate

1 While this paper is focussed on airports, it should be noted that many of the issues are relevant to other transport evaluations, such as those for road and rail investments.

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airport choices in Portugal. In the past, this question was answered by recommending CBA. More recently, other techniques have been used. There has been a strong growth in the use of EIA models. While popular among proponents, EIA models have fundamental flaws, which render them inappropriate for investment evaluation. More recently, there has been the use of CGE models in airport evaluation.

Boardman *et al.* (2017, p. 2) define CBA as a "policy method that quantifies in monetary terms the values of all consequences of a policy to all member of the society." EIA models estimate how a project or policy affects the level of economic activity in a given area. CGE models may be defined as a system of equations that represent the economy, taking into account the interdependence between industries, as well as the interaction between the agents in the economy. It is important to note that EIA is not the same as CBA and that EIA, while having some similarities to CGE models, differ due to their underlying assumptions. EIA focuses on measurable changes in jobs, output, and earnings. This is different from CBA, which estimates the equivalent monetary value of the costs and benefits to the society of a project or policy. CGE models are based on both micro- and macroeconomic theoretical foundations, and unlike EIA, the impact of prices on decisions is crucial in a CGE model. Furthermore, the economy in a CGE model operates under technological and institutional constraints. Some CGE models can quantify all consequences of a policy, including welfare effects, in the manner of CBA.

CGE models are rigorous and appropriate for the task. At present, these models have only recently been applied to the airport evaluation task, and there are several questions concerning how best to use them. However, as techniques improve, they are a promising development.

This paper seeks to explore several aspects of the airport evaluation issue:

(i) Firstly, we examine the nature of the evaluation problem for airports, drawing attention to several key problems;
(ii) Next, we look at the history and current use of the different techniques as used in a range of countries;
(iii) Then, we recognize the old problems, such as those of noise and value of time, and pay particular attention to newer problems, such as connectivity and tourism benefits, and the possible existence of wider economic benefits (WEBs);
(iv) After this, the three techniques – CBA, EIA, and CGE are evaluated, and the positives and negatives of the three are discussed critically.
(v) Finally, we discuss how CBA and CGE approaches can be improved to make full use of their potential.

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The results provide a current road map to airport investment evaluation.

In exploring these questions, two new significant issues emerge. The first concerns the relationship between CBA and CGE – how different are these, especially in well-functioning market economies? Will CBA be superseded by CGE? The second concerns a new aspect of benefits, specifically, WEBs. What is the progress on measuring these benefits in the aviation context, and how large are they likely to be? In what ways are they comparable to catalytic effects, a new aspect from the EIA literature?

We acknowledge that the deficiencies of EIA have been well recognized in the past. However, we do discuss the technique for at least two reasons. Firstly, EIA continues to be used very often in airport evaluation, and any survey of approaches needs to take it into account. Secondly, we wish to discuss the relationship of WEBs, which is discussed in the CBA, and now CGE context, and the growing references to catalytic benefits, which stem from the EIA literature.

Airport investments can have a range of impacts within the region in which they are located. Measuring and evaluating these can be difficult and controversial. In this paper, we do not go into these broader regional policy aspects of airports (though we note that catalytic effects, discussed in Section 4.2.2, are often an attempt to address these).

In Section 2, we provide an overview of the key aspects of investment evaluation as it applies to airports. We then look at the main old and new issues for evaluation and then the three main techniques of evaluation – we note the history of their use and discuss some of the main issues to do with their use, paying particular attention to the relationship of CBA to CGE and to WEBs. In Section 5, we summarize the findings and discuss these techniques in perspective.

2 The evaluation task for airport investment

2.1 The three techniques

There are several techniques which have been used in evaluating airport investments – we focus our attention on three, which are probably the most widely used ones. These are CBA, EIA, and CGE.

Fundamentally, the evaluation task requires the welfare question to be answered – will the economy be better or worse off as a result of the investment?

(i) CBA answers this question;
(ii) CGE can answer it, as long as there is a welfare measure embodied in the model; and
(iii) EIA cannot answer it.

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The first of these is not surprising. CBA was developed specifically to answer this question, and it is recognized as being successful in doing so, though of course, there are always limitations. CGE models often, but not always, are able to answer the question when they include a (properly derived) welfare measure.

By contrast, EIA cannot answer the question. As mentioned above, EIA makes an estimate of several of the impacts of the investment – its impact on output, its impact on employment, and so forth. However, it does not measure the impact on welfare or the benefits and costs of the investment. While users of EIA very often state that they are measuring the "benefits" of the investment and they are using the term quite differently from the normal welfare economics sense. Thus, EIA cannot provide a rigorous measure of the welfare effects of the investment – that is, assess whether the economy is better off as a result of the investment.

CBA and CGE can provide an answer to the central question of whether the country gains from the investment. However, there are further issues to do with the impacts of the investment – these might be to do with the impact on GDP, employment, or other variables of interest. These may be of interest to the decision makers, even though they may not be of primary interest to the economist making the evaluation. CBA is not of great use here – it focuses on the welfare question alone. The other techniques appear to cast light on these further issues – for example, a CGE model or an EIA will provide estimates of the impact on nonwelfare aspects, such as the impact on Gross Domestic Product (GDP) or on employment.

There is, however, a large difference between the outputs of a CGE analysis and those of an EIA. Properly done, a CGE model provides a rigorous assessment of impacts. This is not the case with an EIA – these are discussed below. EIA makes an exaggerated estimate of the effect on output and employment since it assumes that the resources to make the investment are costless. A CGE approach is the only reliable means of estimating the broader impacts of the investment.

2.2 Benefits and impacts

There is widespread confusion about the terms "impacts" and "benefits," especially in the EIA literature. The term "impact" is also increasingly being used in the CBA literature. However, it is important to emphasize that impact should not be used beyond EIA and CGE. Impacts and benefits are not the same (see Waters, 1976). By benefits, we mean the monetized value of benefits, as used in CBA, or in welfare economics generally. Welfare rises if benefits increase, ceteris paribus. These can be compared to costs, and the usual investment criterion is that benefits exceed costs. "Impacts" is a much broader term. There can be positive or negative impacts of an

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Table 1 Evaluation of impacts and benefits.

Technique	Evaluating impacts	Evaluating trade-offs between benefits and costs
Cost–benefit analysis	No	Yes
Economic impact analysis	Yes (inaccurately)	No
Computable general equilibrium models (without welfare measure)	Yes	No
Computable general equilibrium models (with welfare measure)	Yes	Yes

investment on many variables, such as employment, industry output, GDP, Gross National Product (GNP), interest rates, and national consumption – some of these may increase welfare and others may not. Two possible impacts could be on benefits or costs. In recent years, the terms WEBs and also wider economic impacts (WEIs) have been used in the transport economics literature – in keeping with the terminology above, we understand WEIs to include impacts such as those on GDP and employment.

CBA seeks to measure benefits and costs and determine whether a policy or investment increases net social benefits (NSBs) or welfare. Models which seek to measure impacts may or may not be capable of measuring welfare. EIAs are not capable of doing this, and CGE models can only measure it if they have a welfare component included. Thus, in evaluating investments, only CBA and some CGE models can measure whether the nation is better off as a result of the investment (see Table 1).

3. Key problems for airport evaluation

In this section, we analyze the key problem areas which need to be addressed when using the techniques. It is useful to note that these problems are not the same for the three techniques. Many of the CBA issues are very relevant in the case of CGE models. Not all of these problem areas are addressed with specific techniques – EIA in particular does not address several of these. EIA models have different issues, such as the estimation of catalytic effects.

3.1 Major issues for evaluation

We set out the major issues that a good airport evaluation study should address, drawing on examples of our findings.

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It is useful to make a distinction between issues which have been recognized for many decades (traditional issues) and those which have only recently been given much attention (new issues).

Some of the traditional issues (see below table) are noise and externalities, the distribution of benefits and costs, the value of time, airport pricing and congestion, unemployment, and land use.

Some new issues are tourism benefits, climate change externalities, WEBs, connectivity, and hubs.

Much of the theory of evaluation has been developed in the context of CBA, but many of these issues are very relevant in the case of impact models and CGE models.

3.1.1 Noise and externalities

CBA uses the established methods of quantifying externalities for airport projects, namely either revealed preference or stated preference methods (for an overview see de Rus, 2010). In practice, the "dominant method" (Boardman *et al.*, 2017) of CBA in general, and particular for transport, is the hedonic pricing method. The effect of noise on house prices is measured by the noise depreciation sensitivity index defined as the percentage change in the house price due to a unit increase in the noise level. An early example occurs in the Roskill Study[2] (Roskill, 1971). Based on various studies, the literature has established estimates for the shadow price for noise and other emissions (see Table 2). We note that compared to the 1970s, substantial progress has been made to estimate the local external costs of air transport (Dings *et al.*, 2003). CGE models typically do not measure externality costs directly, but estimates can be made in much the same way as with CBA, and the results added in.

3.1.2 Distribution of benefits and costs

Many, though not all, airport investments create benefits and costs which are unevenly distributed to individuals with different income levels. One option is to use a Kaldor–Hicks potential compensation test and not consider distributional issues – these can be dealt with using other policy instruments like income taxes. This standard approach has also been followed by most CBAs of airports. Nearly all studies put the distributional aspect aside (see Table 2). There are good reasons for this approach partly because the distributional aspects depend on many factors which a partial method has difficulty in analyzing. Earlier texts on CBA, such as those of Little and Mirrlees (1968, 1974) and Ray (1984), recommended that distributional effects be included in a CBA. One major difficulty in analyzing distributional impacts

2 This study is discussed in more detail in Section 4.1.1 below.

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Table 2 Issues of CBA in airport investment evaluation: Summary.

Study (year)	Noise	Distribution	Values of time	Airport pricing	Unemployment	Land	Tourism benefits	Carbon emissions	WEBs/ WEIs
CBA runway extension in Nicosia (1968)	Not applied	Not applied	Not applied	Not applied	No effect	Not applied	Estimated	Not applied	Not applied
Grand Ouest Airport, CE Delft (2011)	Acoustic study/ population within noise zone	Not applied	€ 15.50	Not applied	No effect	Valuation of land (€ 26 million)	Not applied	Shadow pricing method	Not applied
Roskill commission (1971)	Hedonic pricing method	Not applied, but later studied	–	–	No effect	–	Not applied	Not covered	Not applied
White Paper London (Dft, 2003)	Acoustic study	Applied	Not applied	Not applied	No effect	Not applied	Not applied	Carbon tax on demand	Applied
Lisbon (NERA economic consulting, 2007)	Acoustic study of noise level and hedonic pricing	Not applied	Value of time for air travel €28.5	Not applied	Shadow wages	Valuation of land (€832 million)	Not applied	Prevention and damage cost method	Not applied
Third London airport Nwaneri (1970)	Hedonic pricing method	Applied	–	–	No effect	–	Estimated from revenues	Not covered	–

(Continued)

Table 2 (Continued)

Study (year)	Noise	Distribution	Values of time	Airport pricing	Unemployment	Land	Tourism benefits	Carbon emissions	WEBs/ WEIs
Second National Airport, Central Planning Bureau (1974)	Acoustic study	Not applied	Not applied	Not applied	No effect	Land acquisition	Not applied	Not covered	Not applied
London Airports Commission	Acoustic study	Effects on regions	Use of government recommended values	Recognized	Recognized in WEI modeling	Cost of additional land recognized	Estimated	Emissions assessed	WEI measured with CGE modeling
Chicago O'Hare modernization program	Acoustic study	Not applied	Use of government recommended values	Not applied	No effect	Not applied	Not applied	Not covered	Not applied

Abbreviations: CBA, Cost Benefit Analysis; WEBs, wider economic benefits; WEIs, wider economic impacts.

is that what is needed is for the ultimate incidence to be estimated, but it is normally difficult to go beyond the initial incidence. A CGE approach can be very helpful in this regard. Since CGE models adopt a general equilibrium approach, it is straightforward to estimate gains and losses to different groups – that is, ultimate incidence. Boardman *et al.* (2017) suggest using a "distributionally weighted CBA," which so far has not been applied to airports, to our knowledge.

3.1.3 The value of time

The value of time is almost always a critical parameter when evaluating airport investments. This is so because one of the major costs is the cost of travel time. Time is used in accessing the airport and moving through it and, in particular, where there are airside and landside delays (which are why additional airport capacity is being considered in the first place). The Roskill study was done soon after economists had become interested in the value of time, and it adopted the then developing approach. By the time of the Second Sydney Study, several other aspects had been recognized. For example, there was a recognition that time spent is not necessarily time wasted. A traveler might use the time in a plane for productive work. Other aspects included the disutility of time, employer on-costs, and possible taxes (Carruthers & Hensher, 1976). There have been empirical studies, using surveys (Carruthers & Hensher, 1976) and revealed preference approaches. Currently, most countries and the EU have recommended time values for investment evaluation studies.

3.1.4 Airport pricing and congestion

One of the key reasons why investments are made in airports, either through additional runway or terminal capacity or new airports, is that demand is pressing on capacity. If nothing is done, delays will rapidly increase. The Roskill approach was to estimate the costs of delay with and without additional capacity – rather like the US system of delay rationing (Roskill, 1971; Abelson & Flowerdew, 1972). However, at the time of this study, it became recognized that increasing delay was an inefficient means of rationing airport capacity (Levine, 1969). If pricing were to be used, the need for additional capacity would be less and the additional capacity could be postponed for several years, at a considerable saving in cost (Forsyth, 1972). As it turned out, prices were not used in most busy airports. Rather the system of slot rationing developed – only flights for which the airline had a slot were permitted to use the airport (Czerny *et al.*, 2008). The slot system effectively rations the airport rather than prices, and avoidable delays are not present. It is an effective system, assuming that slots are allocated efficiently – something which is often not the case

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(in a world of uncertainty, either prices or slots can be the more efficient, depending on factors such as elasticities – see Czerny, 2008).

3.1.5 Unemployment

If there is unemployment in the economy, a recognized way of taking this into account in a CBA is to use a shadow wage different from a market wage (e.g., use 80 % of the market wage). For instance, Del Bo *et al.* (2011) show that a range of wage conversion factors can be estimated for a group of regions, on the level of unemployment. There are practical difficulties in implementing this recommendation – in working out what the shadow wage should be and in determining how an investment affects employment. CGE models can help, particularly, through estimating the implications of different labor market assumptions, though not in estimating shadow prices of labor. In popular discourse, airports are depicted as "job machines," and impact studies became popular as ways of illustrating (claimed) job benefits (see below). The proper treatment of the reduction of unemployment in an evaluation is of high practical importance. CBA differentiates between voluntary and involuntary unemployment.

3.1.6 Land use

Handling land issues can often be a difficult problem for an evaluation, especially when a new airport is being evaluated. The value of the land on which the airport sits will typically depend on whether the airport is built or not – if it is built, the value of the land surrounding it will be higher (and potentially, the value of the land surrounding the old airport may fall). These types of issues need to be resolved. Even though demand may be pressing against capacity at the old airport, the new and old airports are unlikely to be good substitutes. Estimating demand and the split between the two airports is difficult. Pricing and regulation of the two airports will be an issue, how well slots allocate capacity, as will the travel time between the two airports and main centers of population.

New Issues

3.1.7 Tourism benefits

Airports can be evaluated from a global or individual country/regional perspective. If a global perspective is used (e.g., see the European Investment Bank, 2013), there are no tourism benefits since all travelers belong to the globe. If an individual country

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perspective is used, (as was the case in the Second Sydney Airport study – see Australian and NSW Governments, 2012) there will be inbound and outbound benefits and costs. Tourism benefits can be a substantial proportion of the total benefits from an airport when the evaluation is being done from the perspective of a country or region – in the recent CBA of a new Sydney airport, almost 40 % of benefits were accounted for by inbound tourism (Australian and NSW Governments, 2012). Tourism impacts are often measured in terms of changes in real GDP, capital formation, and output in both tourism and nontourism sectors resulting from changes in tourism expenditures. With tourism, which is an economy impact, it is important to avoid double-counting of effects, such as those on employment and time savings.

Tourism benefits are the change in welfare as a result of additional inbound tourism. The importance of tourism benefits has long been recognized – the 1969 study by Ody (1969) puts high weight on them, though until recently, there were no rigorous methods of valuing tourism benefits. For example, in the recent Sydney study, inbound tourism benefits were *assumed* to be 25 % of tourist expenditure (Australian and NSW Governments, 2012) – and the cost or benefit from outbound tourism zero. Outbound tourism costs or benefits are normally not measured – which is questionable. It is understandable that measuring tourism benefits is difficult – tourism benefits come about as a result of a large number of small effects in many markets. As a result, a CGE approach can shed some light on the costs and benefits of inbound and outbound tourism.

3.1.8 Climate change

Concern about climate change has grown markedly over the past decade. As a result, climate change aspects now need to be factored into airport evaluation. For example, the Airports Commission has an extended discussion about the climate change assumptions it used when assessing airport strategies for London (Airports Commission, 2015*b*). Airlines are the main generators of greenhouse gases in aviation, though airports directly make a contribution. The main importance of airports is that they facilitate additional air travel, and restrictions on airport developments have been actively advocated as a means of reducing gases.

Some externalities are essentially widely spread out in nature – a classic case is greenhouse gas emissions. The net effect of an airport investment on emissions could be quite different from the direct effect, since other effects come into play (e.g., emissions from cars may fall). A CBA can include a shadow price of emissions of greenhouse gasses, though this would be a partial measure. A CGE study can provide a general equilibrium measure which takes indirect effects into account.

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3.1.9. Wider economic benefits, connectivity, and hubs

The economic evaluation of airports is now taking note of a range of disparate, though connected effects, often grouped under the term "WEBs" or "wider economic impacts." This is reflecting what has been going on in the evaluation of surface modes (Graham, 2007; Venables, 2007), though the application of the concept in aviation is more recent. These benefits are in addition to the traditional benefits. In the surface transport context, their existence has been suggested by the economic geography literature, and there is some evidence that they exist, though the measurement is difficult and their size is debatable (see Vickerman, 2013). As a result, when investment analyses are done, these are often treated separately from the main, well-established benefits and costs and noted as an additional benefit. Several can be identified and the borderline between is often fuzzy. The Airports Commission puts much emphasis on connectivity benefits in its assessment of options for London (Airports Commission, 2015*b*).

An important aspect to note is that, even though the term "WEBs" is the same for both surface transport and aviation, it means different things in different contexts. Estimates of WEBs are often made for surface transport evaluations, and the list of effects included is becoming fairly settled. WEBs are often listed below the traditional benefits and costs partly because of the greater uncertainty surrounding them. They are often estimated to be around 10 % of other benefits, though sometimes (less often now) rather more (for further details see Joint Study, 2012).

At this stage, the WEBs of air transport have been less researched, and discussion of them has been less systematic (see Pearce, 2013; Forsyth, 2020). Several suggestions have been made:

(i) Tourism benefits are sometimes regarded as WEBs of air transport (we have already listed them in this paper).
(ii) Frequency externality benefits have long been listed as a benefit of air transport and now might be considered as a WEB. Frequency benefits have been recognized as a benefit of other transport modes – see Mohring (1976). The Airport Commission includes them as a benefit, though not as a part of its WEI/WEBs estimates.
(iii) There can be benefits from an expanded market and more competition – as yet, we do not know of any applications of effect in air transport.
(iv) There may be benefits from air transport enabling an increase in labor supply and its productivity. It is not clear that there is any wider benefit from this, since users of air transport pay for their flights and internalize these benefits. However, passengers may not gain the full benefit from their output since they

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are taxed on it – there can be a WEB to the extent that extra output generates more tax. As yet, we do not know of any application of this in air transport.

These are some of the possible sources of WEBs in air transport. However, there is one source of WEBs which is now claimed to be a very large source of benefits – this is increased connectivity.

Connectivity is a term often used though less frequently defined (see Burghouwt & Redondi, 2013). There are benefits to travelers if an airport or city has more direct connections to other cities. For local residents, the time taken to access destinations will be less if the city is well connected. The benefits from greater connectivity are that travelers use less time and money to access their preferred destination access destinations but a greater cost of interconnection.

There have been a number of attempts to measure the impacts from increased connectivity and air transport (see Forsyth, 2020 for a review). Several of these imply very large effects from increased connectivity – see PwC (2013). The common way of estimating them is to regress GDP or productivity on an index of connectivity. There is an issue of causality present – does additional connectivity cause higher GDP, or does higher GDP lead to greater connectivity? InterVISTAS (2006) analyzed the link between additional connectivity and GDP – they found a positive link (this study recognized the causality issue)[3]. A more recent study has been that done for the London Airports Commission (2014). Most (or all) of the studies of connectivity benefits have been of impacts – they do not examine the connection between impacts and benefits. This is the difficult question, and it is not clear to what extent how much the increased connectivity creates a genuine WEB or benefit which can be used in a CBA or CGE model.

Assessment of the WEBs of air transport and its relevance to airport evaluation is in its infancy and much remains to be done in sorting out the issues and developing measures. One question is will accounting for them make a large or small difference to investment evaluations? For many suggested WEBs, the differences will be small, but a lot will depend on how large the benefits from increased connectivity are. If there are as large as some studies suggest, accounting for WEBs will have a significant impact on evaluations.

3.2 Summary

Table 2 provides a summary of how selected studies have addressed these problems.

3 See also Mukkala and Tervo (2013).

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4. An evaluation of the techniques

4.1 Cost–benefit analysis

4.1.1 Brief historical perspective

CBA is a well-established technique, and its advantages and disadvantages are well known (Jorge-Calderón, 2014). Airports have been analyzed using CBA since the 1960s. We have surveyed some important ones (see Table 2). The largest and most important study (perhaps ever) was that done by the Roskill Commission in the late 1960s/early 1970s to evaluate the options for a Third London Airport. This was a very large study which set the scene for many decades to come. It provoked much discussion, both in the popular press and in scholarly journals (Mishan, 1970; Nwaneri, 1970; Paul, 1971). It assumed that scarce capacity would be rationed by delays, not prices or, as eventually, as it happened, slots (Abelson & Flowerdew, 1972; Forsyth, 1972). The 1970s saw a number of other large studies, particularly those of the Second Sydney Airport (Mills, 1982) and Amsterdam (Central Planning Bureau, 1974).

In both the UK and Australia, CBA was the preferred technique of evaluating airports. In Europe, the European Commission (European Commission, 2014) has developed guidelines for assessing projects from cohesion funds since the 1990s. Since 2000, a CBA is mandatory for these projects which include transport projects and also airports. Some of these airports are financed through the European Investment Bank (EIB). The EIB demands a CBA for their funding decisions. The EIB approach is a standardized CBA method including externalities (European Investment Bank, 2013; Jorge-Calderón, 2014).[4] In the US, a standardized CBA is required for airport projects such as the Modernization Program for Chicago O'Hare which preserves or enhances capacity. The total Airport Improvement Program discretionary funds requested exceeds $10 million (Federal Aviation Administration, FAA, 1999).

The question of further capacity is now again an issue for Sydney and London. In both cases, the evaluation is breaking new ground in terms of technique. The Sydney study was produced in 2012 (Australian and NSW Governments, 2012). This study

4 The benefit of projects is measured using the standard transport sector framework of generalized cost of travel. The sources of the benefits of investing in landside capacity are threefold. First, to avoid traffic diversion as passengers follow alternative travel arrangements. Traffic diversion can take place in two ways: in time and in mode. The second source of benefit would be relieving congestion in terminals, reducing user throughput time. The third source of benefit is generated traffic, consisting of traffic that would not have traveled at all without the project.

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uses a conventional CBA approach. However, the study also includes a CGE study of some aspects (e.g., timing). In particular, the study estimates the impact on GDP and other variables of *not* building the additional capacity (but the CBA measured the cost of building it). The Airports Commission (2014, 2015*b*) from London is a further step in the application of a CBA and a CGE model for airport investment evaluation. The relationship of the different parts of the exercise is not very well explained – a very useful outline of some of the problems is contained in the note from Expert Advisors (Airports Commission, 2015*a*). An important exercise done during the process of the inquiry was an estimate of the wider economic impacts of the options – with the results from the traditional CBA fed into the CGE model (Airports Commission, 2014). There is an estimate of the frequency benefits, but the main change comes from an estimate of higher productivity enabled by the investment. Ultimately, this estimate uses econometric estimates, not properties of the model (this is typical of estimates of wider economic impacts with aviation and surface transport).

4.1.2 CBA in perspective

CBA is a very well-researched and accepted technique. In the airport context, it has been able to provide rigorous evaluations and address several difficult problems. However, familiarity need not blind us to its limitations shown below.

(i) It is typically a partial equilibrium technique, whereas ideally, a general equilibrium approach should be used.
(ii) It has difficulties in handling complex tax effects (including those where WEBs are being measured) accurately since it is a partial equilibrium approach which does not measure effects in markets other than the markets directly affected.
(iii) It does not handle nonlocal externalities, such as externalities which affect whole economies (or indeed the world), such as the overall climate change effect of an airport, accurately since it is a partial equilibrium approach which does not measure effects in markets other than the markets directly affected.
(iv) It is limited in evaluation when there is unemployment in the economy.
(v) It does not measure benefits or costs which are spread out throughout the economy, such as the benefits or costs of tourism, well.
(vi) It does not handle other than immediate incidence of costs and benefits well. Ultimate incidence is what required for a rigorous evaluation.
(vii) There are new types of benefits and costs which may have a role in evaluations: these include tourism benefits (which can be measured rigorously) and WEBs/impacts, which could be quite significant, though the measurement of these is in its infancy.

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This poses the question – can the other techniques, economic impact and CGE models help in gaining a better overall evaluation of an airport?

4.2 Economic impact analysis

4.2.1 Using EIA in airport evaluation

The input–output analysis describes the linkages between the production sectors in an economy (Leontief, 1987). Developed in the 1930s and 1940s, it was used to measure the amount of factor inputs required to produce a given set of outputs. By identifying these linkages, EIA, which has been developed from it, is able to provide estimates of how much factor use, or factor demand, will change throughout the economy when output is expanded. Our survey shows that EIA[5] is used for three distinct purposes (see Table 3 and Appendix).

(i) It measures economic significance;
(ii) It measures regional economies of scale and agglomeration;
(iii) It gives a criterion for investment.

We explain this in turn how EIA analyzes catalytic effects which are similar to WEBs and then criticize EIA as a tool to assess airport investment.

Measuring economic significance. The use of EIA as a tool to document the economic contribution (i.e., essentially how large in terms of key economic variables such as gross product and employment) of an airport to a regional economy can be best illustrated by the example of Vienna Airport which has a study of the economic significance of its airport in 2007 (Fritz *et al.*, 2007). The study uses an extended IO-model and estimates that the 16,031 full-time employed workers at the airport generate additional indirect and induced jobs of a magnitude of 52,500. The report does not link these results to any decision on investment or any policy issues like noise or emissions. The airport reports these results as "economic significance" and avoids any hints to policy issues. We have found similar studies at a number of European airports and US airports (see below Table 3).

Measuring regional economies of scale and agglomeration. EIA can analyze the dynamic effects of external economies in the Marshallian sense (cf. Marshall, 1920; Krugman, 1991). IO analysis can identify the locational structure of industries clustering around airports, and it can lead to a better understanding of clusters and

5 Input–Output models have been developed further to incorporate dynamic effects. However, to the best of our knowledge we are not aware of any airport study using a dynamic version of input–output model

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Table 3 Economic impact studies.

Country	Airport	Author (Year)	Purpose	Main results employment impact (additional jobs)	Catalytic effects
Austria	Vienna	Fritz *et al.* (2007)	Significance	Direct: 16,031; Indirect/induced: 52,500.	No
	Frankfurt/ Main	Hujer *et al.* (2004)	Policy criteria (Expansion)	1.77 (multiplier)	No
	Munich	Basler and Bulwien (2007): impact in 2005	Policy criteria (3rd runway)	Direct: 27,400; Indirect/induced: 30,140.	Yes (but unclear how)
	–	Basler and Bulwien (2007): impact in 2025		Direct: 8,221 Indirect/induced: 16,700	
	Hamburg	Empirica (1996)	Regional analysis	Direct: 12,000 Indirect/induced: 32,500	No
Germany	Berlin	Baum *et al.* (2005) Results for BBI 2012	Rationale for new BBI airport	Direct: 17,100; Indirect: 7,700; Induced: 3,600.	Yes (36,000 jobs by new BBI)
		Baum *et al.* (2005) BBI 2012 versus Berlin 2004		Direct: 3,700; Indirect/induced: 3,400.	
	Kassel	Klophaus (2013)	Rationale for regional airport	Direct: 725; Indirect/induced: 1,315.	Yes (389 jobs from incoming tourist)
Italy	Milano	CLAS and SACBO (2005)	Regional analysis	Direct: 3,601; Indirect: 1,116; Induced: 2,523.	No

(Continued)

Table 3 (Continued)

Country	Airport	Author (Year)	Purpose	Main results employment impact (additional jobs)	Catalytic effects
Netherlands	Shiphol	Haakfort *et al.* (2001)	Regional analysis	2.0 (multiplier)	–
Spain	Aeropuerto de Vitoria	Macho *et al.* (1999)	Regional analysis	Direct: 343; Indirect/induced: 372;	No
Switzerland	Zurich	Infras (2005)	Policy criteria (loss of hub carrier/movement cap)	Direct: 3,080; Indirect: 1,055; Induced: 6,383.	Yes (2,636 jobs from incoming tourist)
UK	Edinburgh	York Aviation (2009)	Policy criteria (Masterplan/ expansion)	Direct: 3,530; Indirect/induced: 7,680.	No
USA	Atlanta	Department of Aviation Atlanta (2009)	Significance	Direct: 237,845; Indirect/induced: 196,589.	No

provide useful information for the planner of business locations. There are a number of studies in our sample like the study on Schiphol Airport (Hakfoort *et al.*, 2001) and Hamburg Airport (Empirica, 1996) which try to identify backward and forward linkages within the region. But these studies are rather descriptive, and the studies do not use input–output tables to identify clusters (for an overview of this approach see Lublinski, 2001[6]).

As a criterion for investment. EIA has been used extensively as an investment criterion since the 1980s, in both the US and Europe. The FAA developed guidelines for the use of impact analysis in response to the airport community in 1986, which were updated in 1992 (Butler & Kiernan, 1986, 1992). The Transport Research Board evaluated the actual practice in 2008 (ACRP, 2008). The FAA guidelines reflect an ambivalent approach. On the one hand, it states that EIA should not be used as a substitute for CBA in the master planning process of US airports (Butler & Kiernan, 1986, p 1). But after evaluating more than 30 case studies in the US ACRP (2008, p. 8), we concluded that the main purpose is to justify airport expansion that is to answer the question a CBA is supposed to answer.

The FAA guidelines were adopted by ACI-Europe (the airport industry association) in the 1990s and became the official strategy for many airports such as Frankfurt Airport. Frankfurt Airport planned a new runway, although the last extension caused violent protests. To assess these plans, a mediation process was established. The objective of mediation was to find out "under which circumstances Frankfurt Airport can help to keep up permanently and enhance the competitiveness of the Rhine-Main region with respect to employment and economic structure, without neglecting the ecological costs imposed on the region" (quoted from Hujer & Kokot, 2001, p. 112). On behalf of the three mediators, studies about the economic, ecological, and social consequences were conducted. Five scenarios were defined, ranging from the status quo, a reduction of aircraft movements to a full-scale expansion. The results of the EIA (Bulwien *et al.*, 1999) were decisive for the final recommendation. The result was, while in the status quo, 142,000 jobs directly or indirectly depended on the airport in the State of Hessen, a full-scale expansion would create another 57,000 jobs. Then the mediation group weighed the different scenarios and concluded to recommend the full-scale expansion because of the economic importance of the project for the region, that is, because of the 57,000 new jobs. Due to these overwhelming economic effects, it was argued that citizens would have to accept the ecological costs.

Our survey shows that out of 32 studies in nine European countries, EIA was initially used to show the economic significance (16 %) and the regional effects of

6 Such cluster analysis is confined to input–output tables excluding induced effects.

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airports (25 %), but this purpose became less and less important. The majority of studies (59 %) serves a clear policy purpose that is to support the expansion of existing airports, building of new airports, subsidises for regional airports, and preventing stricter night curfews (see Appendix). In this respect, Europe differs from the US and Canada where the purpose of the study at least officially documents the economic significance but also serves the purpose to rationalize airports investments (ACRP, 2008, p. 8).

4.2.2 Measuring catalytic effects

Just as, in the cost–benefit literature, there has been a broadening of the list of benefits and costs, corresponding to "WEBs," EIA literature has recognized possible "catalytic effects" associated airport investment. Traditionally, impact studies did not include catalytic effects, as impact focuses entirely on the demand effects of an airport investment. However, there is a tendency to change this. This is reflected in the US literature on impact studies. The guide for impact studies from the year 1992 does not mention catalytic effects at all, but the ACRP (2008) overview recommends the "catalytic method" in Europe of the study by Cooper and Smith (2005) for Eurocontrol.

Our survey shows that there is a large variance regarding the definition and measurement of impact studies and the interpretation of catalytic effects. Most studies, though not all, agree that catalytic effects are related to the supply side of the economy. York (2004) in the study for ACI-Europe defines the catalytic impact as "employment and income generated in the economy of the study area by the wider role of the airport in improving the productivity of businesses and in attracting economic activities such as inward investment and inbound tourism" (p. 5). This is in line with traditional impact studies, which separately analyze airports as a locational factor, namely that airports offer connectivity to businesses which locate their business in the airport region, leading to regional economies of scale. Defined in this way, catalytic effects share elements of WEBs/impacts as analyzed in CBA and CGE studies.

Traditional impact studies used to analyze the catalytic effects qualitatively by undertaking surveys asking how important air transport is for locational choices. The overall result was that airports were seen as a necessary but not sufficient condition to locate a business in a region thereby strengthening regional competitiveness. The new studies try to quantify at least some parts of catalytic effects and either add the effects in terms of jobs and value-added or avoid adding up and provide the catalytic effect as an important "additional" factor.

The study of Baum *et al.* (2007) is an important example of such a new type of EIA. Baum analyzes the effects of the New Berlin Airport (BBI) by comparing economic impact and the catalytic effects of the existing Berlin Airports with the

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new centralized airport. The impact in terms of direct, indirect, and induced jobs is rather small. BBI creates just 7,000 new jobs. Baum *et al.* (2007) also quantify the catalytic effects stemming from inbound and outbound tourism, reduced travel costs, and relocation of business in the Berlin area. The catalytic effect of BBI is supposed to be of a magnitude of 32,400 new jobs. It is the decisive factor for BBI because Baum *et al.* argue that BBI has only a small impact in terms of direct, indirect, and induced jobs but a big impact in terms of catalytic effects. With this result, Baum *et al.* (2007) break new grounds because this airport project is the first project recommended just because of its catalytic impact.

4.2.3 Criticisms of the use of EIA models

If EIA is used for investment assessment, it leads to irrational decisions (see also Waters, 1976; Malina & Wollersheim, 2007).[7] Among other deficiencies, EIA makes the following six mistakes:

Confusing benefits and costs. The above argument that an investment creates a certain number of additional jobs, and that these are the benefits of a project, declares the inputs of the project as outputs, or put it differently, it redefines costs as benefits. Labor and wages are a cost of a project. Only to the extent that a project reduces involuntary unemployment, benefits are created (De Rus, 2010).

No scarcity of resources. In the model world of impact studies, resources are not scarce. Using resources for airport investment has no opportunity costs (Waters, 1976). Hence there are no price effects. This is obviously wrong in core regions where resources like land are limited and where very often labor is also scarce. Factors could be drawn from outside. This would come at a cost for the rural region as well as for the central region. It does not have to be negative. The point is that these effects are neglected.

Inefficiencies increasing the impact. Assume that there are two airport projects with the same amount of passengers and freight, but with differences in labor productivity, wages, efficiency, investment costs, and geographical distribution of suppliers. Ceteris paribus, according to EIA, the project with lower productivity and lower wages should be selected because more labor is necessary in the production of the direct and the indirect product and because low-wage workers have a higher marginal propensity to consume leading to stronger induced. If the decision were

7 Airports are not the only case in which EIA is misused to assess investment or a particular policy. In air transport, the issues of open skies and passenger ticket tax are sometimes "evaluated" by EIA. In other modes of transport CBA seems to be more dominant and EIA plays a minor role, but there might be exceptions for ports or cruise ships. Tourism events like Olympic games, and many other decisions of the government like investments in public housing might be other cases. It is beyond the scope of this paper to analyze this. There is not much literature on this misuse of EIA. See Grady and Müller (1986).

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between a new "gold-plated" traditional terminal and cost-efficient innovative terminal, EIA favors the first one because the direct and indirect effects are, ceteris paribus, higher as the production needs more resources. If the first project uses only locally produced goods, while the latter uses all the resources of a globalized world economy, its indirect effects would be greater than those of the latter. Obviously, taking IO analysis as guidance leads to unproductive and inefficient airports (Niemeier, 2001).

Ignoring substitution effects. In case of an airport extension, traffic is diverted from one airport to another airport. This substitution effect leads to further substitution effects in the vertical chain of production. Assuming a Leontief production technology implies either that the effects are relatively small or that for modeling reasons such as simplification as appropriate. While the latter might be acceptable, the former conflicts with the view that airport extensions lead to catalytic effects with the relocation of business and jobs.

Induced effects are independent of the project. The induced effects are a fifth or third of the total effects (see Table 3), but they are independent of the airport investment (Pfähler, 2001). They would also occur if income is used for on other projects (Niemeier, 2001; Thießen, 2009).

Ill-defined catalytic effects. Catalytic effects of impacts studies and WEBs of CBA/CGE have in common that they are trying to analyze the same phenomena but with different concepts and methods. The phenomena are that air transport can lead to more tourism and can create connectivity and agglomeration economies. Some of these are benefits; some are costs. Impact studies treat all effects except tourism to foreign countries as additional impact and hence benefit. In addition, the method of impact studies is so far rather descriptive and takes for granted[8] that airport investment is causing productivity gains from regional economies of scale and agglomeration economies. Adding as benefits to the direct indirect and induced effects, the catalytic effects are like adding apple and pears. Some impacts like the reduction of unemployment or time savings are real benefits; other impacts like the costs for labor are not, and the latter ones are dominating the former.

In Table 4, the difference between the concepts of catalytic effects, WEBs, and WEI are summarized.

First of all, catalytic impacts do not take account of crowding out; WEBs/WEIs do. This is because price effects are not part of the analysis. Second, catalytic impacts do not take into account general equilibrium effects; WEBs/WEIs do (e.g., tax effects, effects of imperfect competition). Again, this is due to approach to ignore price effects and rely on a rather simple model. Third, catalytic impacts provide a

8 InterVISTAS (2015) is a notable exception.

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Table 4 The relationship between catalytic effects, WEBs, and WEIs.

	Catalytic	WEB	WEI
Crowding out	No	Yes	Yes
General equilibrium effects	No	Yes	Yes
Impact on output	Yes	NA	Yes
Impact on employment	Yes	Yes	Yes
Connectivity	Yes – impact on output	Yes – impact on welfare	Yes – impact on output
Tourism inbound	Yes	Yes	Yes
Tourism outbound	No (with exceptions)	Yes	Yes
Scale economies	Yes in principle	Yes	Yes
Welfare	No	Yes	NA

Abbreviations: WEBs, wider economic benefits; WEIs, wider economic impacts.

measure of a change in output; WEIs also do, although smaller and can even be negative. Fourth, catalytic impacts provide a measure of the always positive impact on employment. Instead WEBs as well as WEIs provide a measure of the benefits, which can be either positive or negative of the change in employment. Fifth, catalytic impacts can provide a measure of connectivity effects but not of the benefits of connectivity. WEBs can provide a measure of the welfare benefits from a change in connectivity, while WEIs provide a measure of the output impacts from changed connectivity. All connectivity estimates are derived econometrically. Sixth, catalytic impacts provide a measure of the (positive) change in inbound tourism receipts; WEBs provide a measure of the welfare benefits (positive or negative) of a change in tourism; WEIs provide a measure of the smaller positive or negative change in tourism receipts because only part of the impacts are benefits or costs. Seventh, catalytic impacts very often do not provide a measure of changes in outbound tourism receipts. WEIs do not neglect these effects and provide a measure of the change in outbound tourism expenditures. WEBs provide a measure of the (positive or negative) benefits from a change in outbound tourism. Eight, catalytic impacts can, in principle, provide a measure of the output impacts arising from scale economies; WEBs can measure the benefits from reaping scale economies; WEIs can provide a measure of the output impacts from reaping scale economies. Ninth, catalytic impacts cannot measure welfare benefits; WEBs do measure welfare benefits.

It is important to note: because catalytic impacts do not take account of crowding out and general equilibrium impacts, the measured impacts on output, employment, and inbound tourism will be substantially higher than the impacts as measured using WEIs.

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4.3 Using computable general equilibrium models for evaluation

4.3.1 Brief historical perspective

In recent years, there has been the use of CGE models in the evaluation of investment generally and, in particular, airport investment. In Australia, Europe, and Japan, there has been growing use of CGE models in transport evaluation over the last 20 years, and many major projects are subjected to both CBA and CGE evaluations. Most of these studies have all used static, multisectoral, and national CGE models, without any spatial modeling, explicit specification of land use, distances, travel time, and surface transport congestion. There is now a branch of CGE modeling, which is including these spatial dimensions – these are, particularly useful in analyzing transport economics questions (see Bröcker & Mercenier, 2011). These models are useful in analyzing some airport evaluation issues.

An early study was that of Melbourne airport (Melbourne Airport, 2003). The objective was to assess the gain from the airport being curfew free – see Madden for further discussion of this study (Madden, 2004). More recent studies have included a study of the Western Sydney Region (NSW Business Chamber, 2013) and an evaluation of a second runway at Brisbane Airport (Brisbane Airport, 2007). A substantial study was that done of a new airport for Sydney, in 2012 (Australian and NSW Governments, 2012). The study included a conventional CBA of whether the airport should go ahead, and it also included a CGE analysis of the costs of not going ahead with the airport. Both approaches came to the same broad conclusion, though they were not integrated in any way. Beyond Australia, the CGE approach has been used to evaluate an airport investment in Japan (Ueda *et al.*, 2005). In the UK, the Airports Commission used a spatial CGE approach, in addition to a CBA approach, to analyze the options for additional airport capacity for London (Airports Commission, 2014, 2015*b*). In many ways, this study was a major step forward on the use of CGE model as a means of evaluating airport investments.

4.3.2 Resolving issues with the use CGE models

Just as with CBA, there are a number of issues which need to be resolved if CGE models are used in airport investment evaluation (see below Table 4). Some of the more important ones are as below.

(i) Welfare measurements
(ii) The level of disaggregation
(iii) Tourism benefits

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(iv) Externalities and nonmarket goods
(v) Exploring impacts of unemployment
(vi) Validation

Welfare measurements. CBA is a means of measuring the NSB of a project. With a CGE model, there can be several outputs (GDP, consumption, and employment), and NSB may not be one of them. Though it is straightforward to include a welfare measure equivalent to NSB within a CGE framework, most studies, especially Australian studies, do not have a welfare measure. However, it is worth mentioning that several European studies have a specific welfare measure (Bröcker & Mercenier, 2011). Alternatively, more simply, estimates of GDP or GNP can be adjusted to develop a proxy, which approximates NSB (see Dixon, 2009). Most CGE airport investment studies measure GDP, while CBAs measure NSB (e.g., the Brisbane and Sydney studies). These are very distinct measures; however, it is easy for CGE studies to report the impact on NSB and, if this is done, for the two types of studies to be quite comparable.

The level of disaggregation. CGE models are complete models of the economy but are only useful in the evaluation of investment projects if they represent a good approximation of the working of the economy concerned. One key issue in constructing a CGE model includes the nature and degree of disaggregation in terms of sectors and households. A related issue is how the introduction of the investment is to be modeled. When an aggregate model is used, or the incorporation of the investment is not explicit, results would tend to be inaccurate. If this is the case, it is common for analysis to take place at a lower level of aggregation by constructing a submodel capable of capturing the key features of the airport investment. As yet, the aggregation issue has not been explored much when CGE models are applied to airport investments.

Another aspect of disaggregation includes the level of spatial detail. Though CGE models with a spatial dimension have been applied to transportation infrastructure appraisal (e.g., Buckley, 1992; Bröcker *et al.*, 2010; Tscharaktschiew and Hirte, 2012), their application to airport investment appraisal is not widespread.

Tourism benefits. The disaggregation of branches in a CGE model makes it possible to estimate the gains from inbound tourism and the costs of outbound tourism. However, this has not been the case, as the results from most studies (e.g., Sydney Study) are highly aggregated and not broken down to specific benefits or costs. As noted before, inbound tourism benefits can be (claimed to be) around 40 % of total benefits for a large city airport and more for an airport in a leisure destination. Several CGE studies suggest that the benefits from inbound tourism or costs of outbound tourism are around 5–10 % (see Dwyer *et al.*, 2006; Blake, 2009; Dwyer *et al.*, 2013; Forsyth *et al.*, 2014; Njoya, 2020). There have been studies done on the impact of air

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Table 5 CGE studies of airports.

Airports	Type of study	Welfare measure	Externalities	Tourism	Unemployment	Level of disaggregation	Comments
Melbourne 2003	Impact of curfew	No	No	Implicit	Flexible labor market	36	Dynamic model
Brisbane 2007	New runway	No	No	Implicit	Flexible labor market	–	Limited detail
Sydney 2012	Additional airport	No	No	Limited explicit discussion	Flexible labor market	144 industry sectors in 57 regions	The Enormous Regional Model (TERM) general equilibrium model
Tokyo Haneda 2005	New runway	Yes	No	Implicit	Fixed	–	Spatial model
London 2014	Multiple investments a several airports	No	Yes	Some explicit discussion	Fixed?	11	Spatial model
Airports in Australian regions 2007	Study of benefits and impacts of subsidies	Yes	No	Explicit Tourism Model	Fixed and Variable	50+	–
Western Sydney 2013	Study of impacts on Western Sydney and rest of Sydney	No	No- capability of model not used	Implicit	Flexible labor market	13	Dynamic multi-regional CGE

Abbreviation: CGE, computable general equilibrium.

taxes on the UK economy, which, among other things, have a measure of tourism benefits (PwC, 2013). Using the results of CGE models, it is possible to gain rigorous estimates of tourism benefits which can be incorporated in a CBA of an airport investment.

Externalities and nonmarket goods. It is straightforward to include nonmarket goods such as leisure time in a CGE evaluation – the valuation can be handled in the same way as it is in CBA. Leisure time is a large proportion of the costs and benefits of airport investment, affecting airport delay costs and access transport costs. Again, however, the correct evaluation of leisure time may not be as simple as invariably assumed in CBA (Forsyth, 1980). This is an aspect which has yet to be explored (these aspects have been examined in the context of measuring the WEBs of surface transport – see Venables, 2007).

Exploring the impacts on unemployment. If there is unemployment in the economy, an airport project may not reduce labor available to other industries much or at all. In CBA, this is reflected in a shadow wage being less than the market wage. The principle is easy to enunciate, but measuring the shadow wage is very difficult, given the general equilibrium nature of the problem. A CGE approach to investigating labor force impacts can be helpful, though there are practical limitations to its contribution – neither technique can measure the shadow wage. Many CGE models have very simple labor markets and do not investigate the sensitivity of their results to different labor market assumptions. It may be possible to come up with a range of possible values and the impacts on the investment's NSB.

Validation. Validation is an important step in the analysis of results of a CGE model. Essentially, the model must be tested to ensure that it is a correct representation of reality. While there are some CGE models of airports, which have now been used, it is not clear how robust the validation of these models has been.

As with CBA, ex-post studies are of value, even though rare. In the case of a CGE modeling study, it is possible to compare forecasts as against actuals, and if they are different, resimulate the shock, to estimate results based on actual data, not just forecast data. As yet, this has not been done in the case of airport evaluations.

4.3.3 CGE modeling studies in perspective

CBAs have been applied to airports for around 50 years. In contrast, CGE models have been applied to airport investment evaluation for only 15 years or so. As a result, there are still major problems to be resolved – for example, the issue of model results and welfare measures, the treatment of externalities and nonmarket goods, the use of the CGE approach in the measurement of difficult-to-value costs and benefits such as

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tourism, and the contribution of CGE models in measuring the full general equilibrium rather than the partial equilibrium results as provided by a CBA.

Capturing general equilibrium effects. A CGE model can measure GE effects, though a typical CBA cannot, though often some indirect effects are measured. The magnitude of the indirect effects will depend on the presence and extent of distortions in the market. GE effects of a CGE model can be compared with the results of a CBA study – this would be instructive to do, and it would be easy to do, but as yet, this has not been done. The Sydney and recent London studies include both a CBA and a CGE study, but there is no attempt to compare results to determine how big a difference measuring GE aspects makes, other than for specific evaluation issues such as nonlocal externalities or widely spread benefits such as tourism benefits.

Two other aspects which a CGE model can evaluate but which a CBA cannot are economy-wide (as distinct from local) externalities (such as the impact on and costs of) greenhouse gas emissions and distribution. CGE models can allow for externalities and nonmarket goods, such as noise, carbon dioxide emissions, and climate change effects. Currently, there are several models which have greenhouse gas emissions as one of the "outputs" of the model (these are calculated by multiplying the emissions intensity of each industry by its output). An example is that of Adams *et al.* (2000). This makes it possible to estimate the overall emissions from Australia as a result of a change, such as the expansion of an airport.

In a small number of cases, there has been an attempt to assess distributional impacts of airport investments (Nwaneri, 1970; the MANS study of Sydney Airport in the 1970s – see Mills, 1982). The problem with CBA is that it can only handle immediate incidence effects – determining ultimate incidence is quintessentially a general equilibrium problem. As a result, most airport studies do not take distributional impacts into account. If a CGE model allows for different income classes (or other groups of consumers, such as urban and rural), it can be used to determine ultimate incidence.

Analyzing the impacts of employment assumptions. In investment evaluation, one of the most important assumptions is that of determining how the labor market works. Moreover, the results of the model are a reflection of the assumptions made about the market, such as the extent of wage flexibility and mobility of labor. A CGE model is very useful in examining the implications of different labor market assumptions. Although few studies comparing CBA and CGE estimates have been reported in the literature, doing this would have at least two distinct advantages. Firstly, evaluations using the two techniques can be compared like-for-like, and secondly, doing so would provide a conservative estimate of the NSB of the project – one not dependent upon on questionable labor force assumptions. Despite this, we have not yet seen examples of this being done.

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Sensitivity analysis. Good CBA and CGE studies include sensitivity analyses to illustrate how sensitive the results are to alternative parameter values (e.g., values of time) and assumptions (full employment or not). With CGE evaluations, this is easy, since it simply involves doing more simulations of the model, which is both cheap and quick. The problem with a CGE evaluation is how to present the results in a way, which makes effective use of the large amount of information, which a CGE study can produce.

Measuring WEBs using CGE models. CGE models can be useful in measuring WEBs (or WEIs) of air transport, though not all aspects of WEBs can be estimated using a CGE model. For example, effects on productivity in the economy need to be estimated by other means, such as econometrically. One aspect of WEBs comes about as a result of market power and taxes in the economy – CGE models are useful ways of estimating these effects (see, e.g., Venables, 2007; Forsyth, 2020). Thus, a CBA could use an estimate of WEBs of air transport derived in part from a CGE study. The CGE study of London airport options done for the Airports Commission (2014) especially saw the CGE model as a means of measuring WEIs.

5. Concluding comments

We have analyzed three techniques for evaluating an investment in airports.

(i) CBA, which is based on a strong theoretical foundation, is practical and easy to interpret.
(ii) EIA, which has become quite popular, but which is not rigorous and is misleading.
(iii) CGE modeling, which has only recently been used for airport evaluation, but which is strongly based on theory and can handle evaluation issues which CBA cannot.

For the reasons given in the paper, we strongly discourage the use of EIA. This recommendation is not new. Waters (1976) criticized the use of EIA convincingly in the 1970s when he was confronted with impact studies in almost any public project. Impact studies cannot evaluate effects was his message. Unfortunately, this message got lost, at least for airports. In the 1980s, the airport industry developed the strategy to rationalize airport expansion with the direct, indirect, and induced jobs airports supposed to create. The values generated by EIA have been large and got even larger as from about 2005 onwards, with the airport industry claiming to create even more jobs through catalytic effects. We argue that this strategy is misleading and does not lead to a rational dialogue if an airport investment makes the region and/or the country better off.

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This leaves the choice between CBA and CGE. It may be a matter of choosing one over the other, or it may be a matter of using both in some way which makes effective use of their different capabilities.

A CBA evaluation is easier to create, but there are several requirements for a CGE evaluation. To start with, there needs to be a suitable model available. With CGE models proliferating in most developed, and many less-developed, countries, this is usually not much of a problem. The next question is cost. These days CGE model simulations are cheap once a model is available. There is a cost in terms of labor time in adapting the chosen model to analyze the specific investment evaluation question. There is some cost in terms of the intellectual property of the model when using a research center or consultant. Finally, there is a question of the degree of disaggregation of the model – many models are quite aggregated and not capable of handling the detail necessary for accurate analysis. However, details can be handled by the use of submodels of the chosen model (though there is a cost in terms of about time to develop these submodels). Just as with CBA, additional details can be achieved at a cost. However, with medium to large projects, the cost of the evaluation is small compared to the cost of the investment.

CBA is a long-established technique, but the application of CGE models to investment evaluation, and in particular the evaluation of airport investments, is quite new. As a result, there are issues to be used as to how best to use them. Some of these concern how to simulate the investment in the model. Several CGE studies have not used the full potential of the technique. For example, they have concentrated on measuring the more macroimpacts, such as those on output and employment, and left the core question of whether the economy is better or worse off as a result of the investment to a CBA study. There is still confusion as to whether a CGE model can assess welfare in the same way as CBA does (it can). CGE models can be used to assess the NSB from an investment in the same way that CBA do.

Once the practical problems as discussed above are addressed, there are several ways in which a CGE approach can lead to a more accurate measure of the benefits and costs of an airport project. Below are six of the more important ways it can contribute.

(i) A CGE approach can evaluate the general equilibrium aspects of an investment, which CBA cannot. These could be significant – we do not know, but we can only find out using a CGE model. This is an important question which needs to be answered.
(ii) CGE can provide a general equilibrium measure of nonlocal externalities, such as greenhouse gas emissions, though CBA is limited to a partial equilibrium measure.

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(iii) CGE models can analyze distributional aspects in terms of ultimate incidence of benefits and costs of an investment, which CBA cannot.
(iv) There are practical evaluation problems which can be handled, at least in part, by a CGE approach, including measuring some of the WEBs of aviation.
(v) CGE examines widely spread benefits and costs, such as the benefits or costs of tourism, which CBA cannot handle.
(vi) CGE models can be used to estimate the effects of an airport on unemployment, though they cannot be used to estimate the benefits of reducing unemployment without further information on shadow wages.

While CBA is a rigorous way of measuring many of the benefits and costs of airport investments, it is incomplete. The CGE approach can give us a more accurate evaluation of the costs and benefits of airport projects and is thus highly relevant, especially when it comes to the evaluation of larger projects. In practice, the economist should avoid EIA and use CBA and CGE as tools to evaluate airport investment rigorously.[9]

Supplementary Materials

To view online supplementary materials for this article, please visit https://doi.org/10.1017/bca.2020.31

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9 We like to caution the reader that we have provided evidence that, in general, one of the two rigorous methods should be used for airports and, in general, for transport. We think that the decision between CBA and CGE is less a question of theory (which is more general?), but a practical one.

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