CAPACITY UTILISATION AND PROFITABILITY: A DECOMPOSITION OF SHORT RUN PROFIT EFFICIENCY

by

Tim Coelli

CEPA, School of Economics, University of New England, and

CORE, Université Catholique de Louvain

Emili Grifell-Tatje

Departament d'Economia de l'Empresa, Universitat Autònoma de Barcelona

and Sergio Perelman

CREPP, Department of Economics, Université de Liège

ABSTRACT

The principal aim of this paper is to measure the amount by which the profit of a multi-input, multi-output firm deviates from maximum short-run profit, and then to decompose this profit gap into components that are of practical use to managers. In particular, our interest is in the measurement of the contribution of unused capacity, along with measures of technical inefficiency, and allocative inefficiency, in this profit gap. We survey existing definitions of capacity and, after discussing their shortcomings, we propose a new *ray economic capacity* measure that involves short-run profit maximisation, with the output mix held constant. We go on to describe how the gap between observed profit and maximum profit can be calculated and decomposed using linear programming methods. The paper concludes with an empirical illustration, involving data on 28 international airline companies. The empirical results indicate that these airline companies achieve profit levels which are on average US$815m below potential levels, and that 70% of the gap may be attributed to unused capacity.

Keyword: capacity utilisation, profit decomposition, technical efficiency, allocative efficiency,

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1. Introduction

The principal aims of this paper are to measure the amount by which the profit of a multi-input, multi-output firm deviates from maximum short-run profit, and then to decompose this profit gap into components that are of practical use to managers. In particular, our interest is in the measurement of the contribution of unused capacity, along with measures of technical inefficiency, and allocative inefficiency, in this profit gap.

We are particularly interested in ensuring that the methods we propose provide information that is meaningful to managers. In particular, when we tell a manager that his/her observed short-run profit is $Q below the maximum possible, given the available quantity of fixed inputs, and that R% of this is due to unused capacity, we want to be sure that our measure of capacity is meaningful. As we shall illustrate in this paper, a number of existing capacity definitions do not provide meaningful information in this situation.

This study is by no means the first to attempt to decompose firm performance measures into that part due to unused capacity and other factors. A number of authors (Gold, 1955, 1973, 1985; Eilon and Teague, 1973; Eilon, 1975, 1984, 1985; and Eilon, Gold and Soesan, 1975) have made substantial advances in this regard. However, in these studies the authors grapple with a number of problems. Such as, how to define capacity and output in a multi-output firm, and how to remove the effects of price differences from the input costs and output revenues. In this paper we show that one can solve all of these problems. First, we propose a new ray economic capacity measure that involves short-run profit maximisation, with the output mix held constant. Second, by making use of adjusted versions of the production frontier methods championed by Farrell (1957), Färe, Grosskopf and Lovell (1994) and others, we show how this measure can be estimated and decomposed

This paper is organised into sections. In the next section we review some existing definitions of capacity. In section 3 we illustrate why physical definitions of capacity are not terribly useful in profit efficiency decompositions. We go on to define a new profit-based definition of capacity and show how it can be used (as one component) in a decomposition of short-run profit efficiency. In section 4 we outline the linear programs which we use to measure and decompose capacity and short-run profit efficiency. In section 5 we illustrate our methods using data on international airline companies. Finally, in section 6 we make some brief concluding comments.

2. Capacity definitions

A number of analysts in the economics and business literature have looked at the issue of capacity measurement in recent decades. These studies can be roughly divided into two groups, those that consider only physical information and those that also include price information in deriving their measure. We discuss each of these groups in turn.

Physical definitions of capacity

One of the earliest discussions of capacity measurement is provided by Gold (1955, p103) who states that "productive capacity estimates may take two forms: as an estimate of the total amount which can be produced of any given product, assuming some specified allocation of plant facilities to such output; and as an estimate of the composite productive capacity covering some specified range of products. The former of these may be expressed in purely physical terms and may be used to measure the absolute volume of capacity as well as relative changes in it." This is made under the assumption that, "sufficient labor, materials and other inputs are available to service the full utilization of present capital facilities" Gold (1955, p102).

Johansen (1968), utilizing the concept of the production function, defines the capacity of existing plant and equipment (for a single output production technology) in a similar way to Gold (1955). He defines it as: "the maximum amount that can be produced per unit of time with existing plant and equipment, provided that the availability of variable factors of production are not limited". Färe (1984) labels this definition of capacity as a strong definition of capacity. He goes on to define a weak definition of capacity which only requires that output be bounded, as opposed to insisting on the existence of a maximum, which the Johansen definition requires. The strong definition implies the weak definition, but not vice versa.

The methods we propose in this paper involve production technologies which have a well-defined maximum. Thus we can safely use the strong definition of Johansen. However, note that in the case of a decreasing returns to scale Cobb-Douglas short-run production function, a production function that is regularly used in economic analysis, the weak definition of capacity must be used, because the maximum of this function occurs when the amount of variable input approaches infinity.[1]

[1] Note that the economic definitions of capacity, which we discuss shortly and which we argue for in this paper, generally avoid such problems.

The above single-output physical definition of capacity has been generalised to multi-output situations by some authors. For example, see Gold (1955, 1976) who suggests the use of output prices as weights in the multi-output case. That is, capacity is defined as the price-weighted sum of actual production levels over the price-weighted sum of the maximum possible levels of each output. Alternatively, Eilon and Soesan (1976) suggest the construction of a full capacity envelope curve, which defines the maximum possible output levels for each output mix. They then suggest measuring capacity utilisation as the ratio of observed output to maximum output, holding the output mix constant. This concept is closely related to the radial (output-orientated) technical efficiency measures proposed by Farrell (1957) and the distance function measures proposed by Shephard (1970), that we utilise in this paper. However, they are not identical to these concepts, because the capacity measure allows the variable inputs to be unbounded while the efficiency/distance measures are calculated with all inputs held fixed.

Furthermore, it is interesting to note that Eilon and Soesan (1976) suggest that one could use linear programming methods to construct this curve, but do not expand on this idea. However, Färe, Grosskopf and Valdmanis (1989) and Färe, Grosskopf and Kokkelenberg (1989) do look at this possibility. They use a variant of the data envelopment analysis (DEA) linear programming method to construct a maximum capacity envelope curve using observed data on a sample of firms.

Economic definitions of capacity

As we illustrate later in this paper, the above physical definitions of capacity can provide quite strange information when used in the decomposition of short run profit inefficiency. In fact, they can suggest operation of the firm at a point where the short run profit is substantially below other (less than full capacity) alternatives. This has lead many economists to search for more economically meaningful measures of capacity. Klein (1960) and Berndt and Morrison (1981) turned to the short-run cost function for guidance. Klein (1960) suggested the output level associated with optimal capacity was the point at which the short-run (SRAC) and long-run average cost (LRAC) functions were at a tangency. Berndt and Morrison (1981) suggested the minimum point of the short-run average cost function, and noted that their measure will coincide with the Klein (1960) measure when there is long-run constant returns to scale, which they assume in their paper.

In this study we note that these cost-based definitions of capacity are clear improvements over the physical measures. However, we also note that when the output price is not equal to the minimum average cost, we will have price (P=Marginal Revenue) not equal to marginal cost (SRMC), and hence the firm will not be operating at the point of short-run maximum profit. The Klein (1960), Berndt and Morrison (1981) and Johansen (1968) capacity measures are illustrated in Figure 2.1. This figure provides a clear indication of a situation in which all three proposed capacity measures suggest operation at a point that foregoes short-run profit.

In this paper we suggest the use of the point of short-run profit maximisation as the preferred measure of capacity, in the single-output case. We also suggest a multi-output generalisation of this measure, where the point of maximum capacity is obtained by proportionally expanding (or contracting) the output vector until the short-run profit is maximised (subject to the constraint that the output mix remains unchanged). We discuss this measure in more detail in the following section.

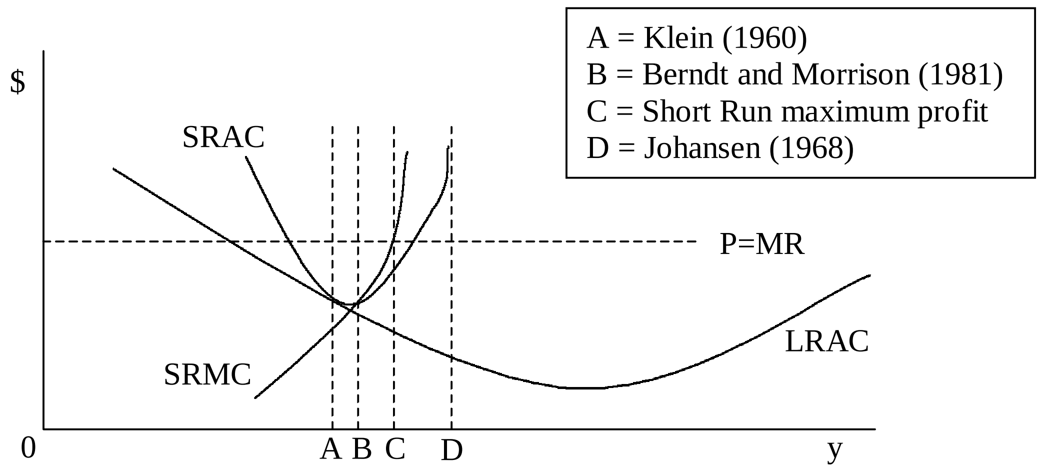

Figure 2.1: Measurement of Capacity

However, before continuing, we should quickly make note of two additional types of capacity measures, which are often used. First, there are engineering definitions of capacity, such as the name-plate rating on an electric power generator, which define theoretical maxima rather than real-world practical maxima. These are generally of limited use to managers, because they tend to not account for the need for down-time for maintenance and repairs and they do not allow for any unexpected fluctuations in demand and/or input supply. Second, there are a number of regularly quoted macro economic capacity measures, such as the Wharton index, which reports the ratio of actual US output over potential output, where the later is derived from information on previous peaks in the output/capital ratio and subsequent net investment levels. This macro information is of limited interest in this paper, given our interest in firm-level information.

3. Methodology

Before we describe our methodology we must first provide a description of the underlying production technology. Since we wish to be able to account for multi-output production, we do not use the standard single-output production function which has been so widely used over the past 70 years. We instead follow Shephard (1970) and use set constructs to define the production technology and use distance functions to provide a functional representation of the outer boundary of the production sets.

The technology

A multi-input, multi-output production technology can be described using the technology set, S. Following Färe and Primont (1995), we use the notation x and y to denote a non-negative $K\times1$ input vector and a non-negative $M\times1$ output vector, respectively. The technology set is then defined as:

$$S = \{(x,y) : x \text{ can produce } y\}. \tag{3.1}$$

That is, the set of all input-output vectors (x,y), such that x can produce y.

The production technology defined by the set, S, may be equivalently defined using output sets, P(x), which represents the set of all output vectors, y, which can be produced using the input vector, x. That is,

$$P(x) = \{y : x \text{ can produce } y\}. \tag{3.2}$$

These sets are assumed to satisfy the usual properties. That is they are assumed to be closed, bounded, and convex, and are assumed to exhibit strong disposability in outputs and inputs. See Färe and Primont (1995) for discussion of these properties.

To measure and decompose short run profit efficiency we require a functional representation of the technology. An output distance function is used for this purpose. The output distance function is defined on the output set, P(x), as:

$$d_o(x,y) = \inf\{\delta : (y/\delta)\in P(x)\}. \tag{3.3}$$

The properties of this distance function follow directly from those of the technology set.

Namely, $d_o(x,y)$ is non-decreasing in y and increasing in x, and linearly homogeneous in y. We note that if y belongs to the production possibility set of x (i.e., $y \in P(x)$), then $d_o(x,y) \leq 1$; and that the distance is equal to unity (ie. $d_o(x,y) = 1$) if y belongs to the "frontier" of the production possibility set.

The output distance function can be illustrated using an example where two outputs, y_1 and y_2, are produced using the input vector, x. Now for a given input vector we can represent the production technology on the two dimensional diagram in Figure 3.1. Here the production possibility set, P(x), is the area bounded by the production possibility frontier (or isoquant), isoq-P(x), and the vertical and horizontal axes. The value of the distance function for the firm using input level x to produce the outputs defined by the point A is equal to the ratio δ=0A/0B.

This distance measure is the inverse of the factor by which the production of all output quantities could be increased while still remaining within the feasible production possibility set for the given input level.[2] We also observe that the points B and C are on the production possibility surface, denoted by isoq-P(x), and hence would have distance function values equal to 1.

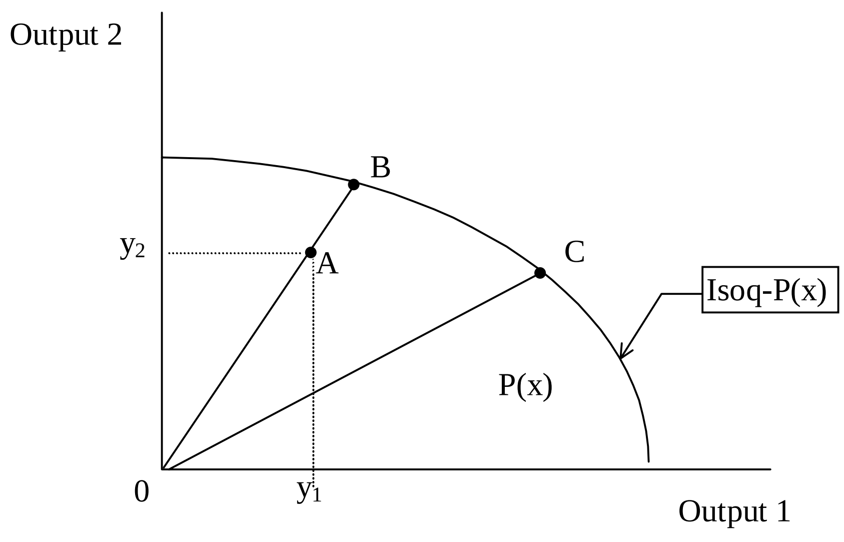

Figure 3.1: Output Distance Function and Production Possibility Set

[2] Note that this distance measure is the inverse of the Farrell-type output-orientated measure of technical

Short-run profit maximisation

To facilitate the discussion of short run profit maximisation, we divide the $K\times1$ input vector, x, into a $K_v\times1$ vector of variable inputs, x_v, and a $K_f\times1$ vector of fixed inputs, x_f, such that $x=(x_v,x_f)$. We assume that the manager is able to vary quantities of the variable inputs (eg. labour and materials) in the short run, but is unable to vary quantities of the fixed inputs (eg. capital). In the long run all inputs are variable. The length of the short run will vary between different industries. For example, it may be only a few months in the case of small clothing factories, while it may be three years or more in the case of electricity generation.

We assume that the firm faces exogenously determined output and input prices: an $M\times1$ vector of output prices, p; a $K_v\times1$ vector of variable input prices, w_v; and a $K_f\times1$ vector of fixed input prices, w_f. We denote the $K\times1$ vector of all input prices by $w=(w_v,w_f)$. The observed short run profits, π, is defined as,

$$\pi = p.y - w_v.x_v. \tag{3.4}$$

The maximum profit than can be achieved by the firm, given the current technology, S, the fixed input vector, x_f, of the firm, and the output and variable input prices, p and w_v, faced by the firm, is denoted by

$$\pi^* = p.y^* - w_v.x_v^*, \tag{3.5}$$

where y^* and x_v^* are the output and variable input vectors which provide maximum short run profit. Note that, in the case of a sample of N firms, we assume that the quantities of fixed inputs and prices may vary from firm to firm, but that the technology, S, is common to all firms.

As noted in the introduction, our primary interest in this study is to propose a way to measure the amount by which the observed profit of a firm deviates from the maximum possible short run profit, given the fixed inputs it owns, and then to decompose this profit gap into components which are of use to managers. In particular, we wish to identify that portion of forgone profit that is the result of under utilisation of capacity. Before this can be done we must first agree upon an appropriate definition of capacity.

Definitions of capacity

Some possible definitions of capacity were briefly discussed in the previous section. In this

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efficiency, described in Färe, Grosskopf and Lovell (1994).

section we provide precise definitions. We define two types of measures: those which only rely on physical information, and those which also involve price information.

Following Johansen (1968), for the case of a single-output technology, we define capacity as follows.

> **Definition 3.1:** The *capacity* of a plant, y^c, is the maximum output that can be produced using the given technology, S, and the fixed input vector, x_f; when the variable input vector, x_v, may take any non-negative value.

Hence we define capacity utilisation as follows.

> **Definition 3.2:** *Capacity utilisation,* θ, is equal to the ratio of observed output, y, to the capacity of the plant, y^c. That is, $\theta = y/y^c$.

This measure of capacity utilisation will take a value between zero and one. A value of one indicates that the plant is operating at full capacity.

The above definitions apply to the case of a single output technology. In this paper we are interested in short run profit decomposition in the case of M outputs and K inputs. Hence, we need to define M-output generalisations of Definitions 3.1 and 3.2. In this direction, we follow Eilon and Soesan (1976), and consider a measure involving the radial expansion of the output vector. That is, by how much can the output vector be proportionally expanded, given the current technology and the fixed input vector? More formally, we can state the following definition.

> **Definition 3.3:** The *ray capacity* of a plant, y^c, is equal to y/θ, where $1/\theta$ is the largest scalar amount by which the output vector, y, can be radially expanded, using the given technology, S, and the fixed input vector, x_f; when the variable input vector, x_v, may take any non-negative value.

Hence we define an M-output definition of capacity utilisation as follows.

> **Definition 3.4:** *Ray capacity utilisation*, θ, is equal to the inverse of the largest scalar amount by which the output vector, y, can be radially expanded using the given technology, S, and the fixed input vector, x_f; when the variable input vector, x_v, may take any non-negative value.

It is easy to see that Definitions 3.3 and 3.4 are equivalent to Definitions 3.1 and 3.2, respectively, when M=1. We now provide a simple illustration of Definition 3.1.

A Single-output Example

In this simple example we have a production technology where one output is produced using one fixed input and one variable input. For example, this could be an agricultural example and these could be kilograms of wheat, hectares of land and kilograms of fertiliser, respectively. The example is depicted in Figure 3.2, where the short run production technology is defined by the area between the short run production function, f(.), and the horizontal axis; HH′ is an isoprofit line (with slope w_v/p); and all other notation is as previously defined. On this figure we have marked the original production point, (y,x_v), the full capacity production point, (y^c,x_v^c), and the profit maximising production point, (y^*,x_v^*).

Some observations can be made with regard to Figure 3.2. First, the current production point is drawn such that there is no technical inefficiency. That is, it is on the production frontier, f(.). This need not be the case. In our next example we will introduce technical efficiency. Second, the observed production point is situated below the profit maximising point. It could alternatively be situated above this point, if the farmer was using excess fertiliser. Third, the profit maximising point and the maximum scale point will only coincide if the slope of the isoprofit curve, HH′, is zero. This implies a zero variable input price, w_v. Thus, it is unlikely that the point of optimal scale and the short run profit maximising point will ever coincide.

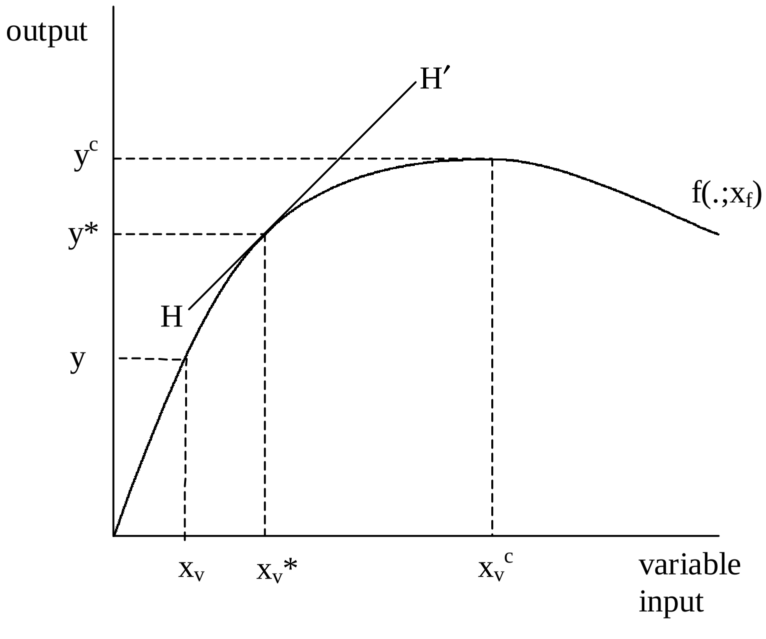

Figure 3.2: A single-output example

If we now introduce some numbers into our example we note some interesting things. First, we define some units of measurement: wheat production in tonnes per hectare, fertiliser in kgs per hectare, area in hectares, wheat price in dollars per tonne and fertiliser price in dollars per hectare. Assume that $x_f = 1$, $(p, w_v) = (100, 2)$ and that $(y,x_v) = (3, 40)$, $(y^c,x_v^c) = (6, 200)$, and $(y^*,x_v^*) = (5, 80)$. Hence, using the definition of profit defined in equation 3.4, we obtain $\pi=220$, $\pi^c=200$ and $\pi^*=340$. Thus we observe that movement from the original data point to the point of short run profit maximisation will result in \$120 extra profit. However, the contribution of unused capacity in this profit difference is unclear, since operation at full capacity will actually result in a \$20 *decrease* in profit relative to the original point. This suggests that the maximum physical output capacity measure is not very meaningful. It is not sensible to suggest that the firm operating at (y^*,x_v^*) is not operating at full capacity, because any increase in output will result in lost profit. From an economic point of view, the firm doesn't have any incentive to increase the amount of output over y^*. As we discuss below, we propose to link the definition of capacity of a plant to this point of maximum short run profits.

A two-output example

We now extend our discussion to the multiple-output and multiple-input situation. A two-output representation is depicted in Figure 3.3. We will illustrate our approach using this figure, although it is not restricted to this situation and can be straightforward extended to M outputs case. In Figure 3.3, GG´ is an isorevenue line (with slope $-p_1/p_2$), y^e is the level of output produced by the firm if it was technically efficient, x_v^{rec} and y^{rec} relate to our new concept of *ray economic capacity*, which will be defined shortly, and all other notation is as previously defined.

In this new situation we have depicted a firm which is technically inefficient. The Farrell measure of output-orientated technical efficiency is equal to the inverse of the output distance function defined in equation 3.3. On Figure 3.3, the technical inefficiency is represented by the distance between the observed point, y, and the technically efficient point, y^e. The measure of technical efficiency equals $0y^o/0y^e$, which will take a value between zero and one. The point y^* is the short run profit maximising point and the point y^c is the point of maximum *ray capacity*, according to Definition 3.3. The measure of capacity utilisation, according to Definition 3.4, is equal to $0y/0y^c$.

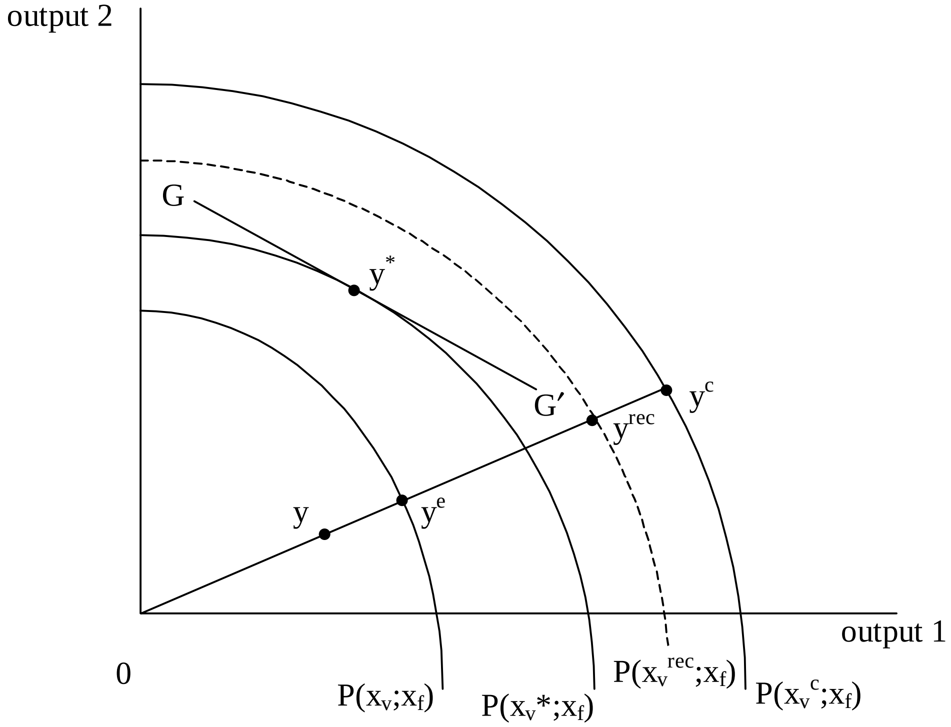

Figure 3.3: A two-output example

As we noted in the case of one output, it is not possible for the profit at y^c to be larger than that at y^*, and it is possible (and in many cases quite likely) that the profit at y^c will be lower than the observed profit level. This is because y^c is the short run profit maximising point when the variable input prices, w_v, are all assumed to be zero. Thus, we seek a more useful definition of capacity for use in our short run profit analysis. In the one output case we observed that the short run profit maximising level of output may be a sensible choice. One natural M-output extension of this idea is one that maximises short run profits while preserving the original output mix. This is defined below.

> **Definition 3.5:** The *ray economic capacity* of a plant, y^{rec}, is equal to y/ϕ, where ϕ is a positive scalar. This quantity of ray economic capacity is the vector of output at the point of maximum short run profit, using the given technology, S, and the fixed input vector, x_f; when the variable input vector, x_v, may take any non-negative value and the output mix (but not the level) of the original production point must be preserved.

This definition has a number of attractive properties. First, it preserves the output mix, and hence produces a scalar measure of capacity utilisation, ϕ (see Definition 3.6 below). Second, the contribution of unused capacity in the profit decomposition (defined below in equation 3.8) cannot be negative. Third, we avoid complications associated with the notions of weak and strong capacity measures, as long as no input price is zero. Fourth, we avoid possibly serious empirical problems associated with the accurate estimation of the frontier surface in the area of y^c, when there are no firms operating in that part of the frontier.[3] One economic characteristic of this measure is that it depends on the output and variable input prices. When these change, the measure of capacity may change.

The capacity definition in Definition 3.5 leads us to the following measure of capacity utilisation.

> **Definition 3.6:** The *ray economic capacity utilisation* of a plant is equal to the scalar ϕ, where y/ϕ is the output vector at the point of short run profit maximisation on the ray from the origin through y. This is conditional on the given technology, S, and the fixed input vector, x_f; while allowing the variable input vector, x_v, to take any non-negative value.

It is of interest to link our measure of ray economic capacity utilization to the measure of capacity utilization given by Definition 3.4. This can be done via the following decomposition analysis.

Capacity utilization decomposition

The measure of capacity utilization given in Definition 3.4 ($\theta=y/y^c$), can be decomposed into

$$\frac{y}{y^c} = \frac{y}{y^{rec}} \; \frac{y^{rec}}{y^c}, \qquad (3.6)$$

where $\phi=y/y^{rec}$ is the ray economic capacity utilization of a plant, given in Definition 3.6, and y^{rec}/ y^c could be viewed as a measure of the *optimal amount of capacity idleness*, which will depend upon the prices of outputs and variable inputs. When an increase in capacity utilization will produce a decrease in the level of short run profits, the optimal behavior of the manager of the firm is to have an idleness. From this point of view the idleness of the

[3] Recall that it is only rational to operate at this point if all input prices are zero. Hence, if one is using parametric methods to estimate the frontier one is likely to need to extrapolate a long way away from the observed data points to identify this point. Alternatively, if one is using variable returns to scale data envelopment analysis to estimate the frontier, the location of y^c will be determined by the largest firms in the

capacity utilization is an economic variable.[4] Note that it is equal to the ratio θ/ϕ. In other words, the ratio of the *ray capacity utilization* (Definition 3.4) over *ray economic capacity utilization* (Definition 3.6). The ratio y^{rec}/y^{c} takes a value between zero and one. A value of one indicates that the firm maximises short run profit by producing at the point of ray capacity, y^{c}. However, when profits are maximized by a completely idle plant (ie. a closed plant), the ratio y^{rec}/y^{c} takes a value equal to zero.

The ray economic capacity utilization measure, y/y^{rec}, can be additionally decomposed as

$$\frac{y}{y^{rec}} = \frac{y}{y^{e}} \frac{y^{e}}{y^{rec}} \tag{3.7}$$

where y/y^{e} is the measure of technical efficiency and y^{e}/y^{rec} a measure of ray economic capacity utilization that is *net* of technical inefficiency of the plant. Färe *et al.* (1989a) have proposed a measure of capacity utilization where technical efficiency is not included in the measure. They suggest using y^{e}/y^{c} as a measure of capacity. We prefer to define a capacity measure that includes technical inefficiency. The reasons for this are explained shortly hereafter.

Profit decomposition

Now, our desire is to decompose the profit difference between y and y^{*} into meaningful components. In particular, we wish to identify the contribution of unused capacity in this profit difference. Using the definition of ray economic capacity, we propose the following decomposition of short run profit:

$$\begin{aligned}(\pi^{*} - \pi) &= (\pi^{*} - \pi^{rec}) + (\pi^{rec} - \pi) \\ &= [p.(y^{*} - y^{rec}) - w_{v}(x_{v}^{*} - x_{v}^{rec})] + [p.(y^{rec} - y) - w_{v}(x_{v}^{rec} - x_{v})].\end{aligned} \tag{3.8}$$

From Figure 3.3 we observe that the first component in this decomposition is primarily an output mix effect, while the second component is the component due to unused capacity. We can further decompose the component of profit due to unused capacity into two parts. One part due to technical inefficiency (movement from y^{o} to y^{e}) and a remaining part which we

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sample, and hence is likely to systematically underestimate this point.

[4] See Winston (1974) for further discussion of this concept.

could label an input mix effect [5] (movement from y^e to y^{rec}). Thus we obtain:

$$
\begin{aligned}
(\pi^{rec} - \pi) &= (\pi^{rec} - \pi^e) + (\pi^e - \pi) \\
&= [p.(y^{rec} - y^e) - w_v(x_v^{rec} - x_v^e)] + [p.(y^e - y) - w_v(x_v^e - x_v)].
\end{aligned}
\tag{3.9}
$$

Note that we include technical efficiency in our measure of unused capacity. This approach differs from that used by Färe *et al* (1989a) and others, who treat technical inefficiency and unused capacity as two mutually exclusive components. We believe that their approach can lead to some unusual results. The best way to make our point is to use a simple diagram. In Figure 3.4 we plot a short run production function for the case of one output, one variable input and one fixed input. The plotted production surface is associated with a particular level of fixed input. We have two firms, A and B, which are identical, except that A is technically efficient, while B uses excess amounts of the variable input, and hence is inefficient. Now, the capacity measure (see Definition 3.4)[6] will conclude that both firms have the same amount of unused capacity. That is, (y^c-y). However, the capacity measure used by Färe *et al* (1989a) will indicate that the unused capacity in firm B is much less. Namely, (y^c-y^e). Given that firms A and B produce the same level of output and have the same potential capacity (y^c), this calculation of different capacity measures seems rather unintuitive. Hence, in this paper, our unused capacity measures include technical inefficiency. That is, technical inefficiency is a component of unused capacity.

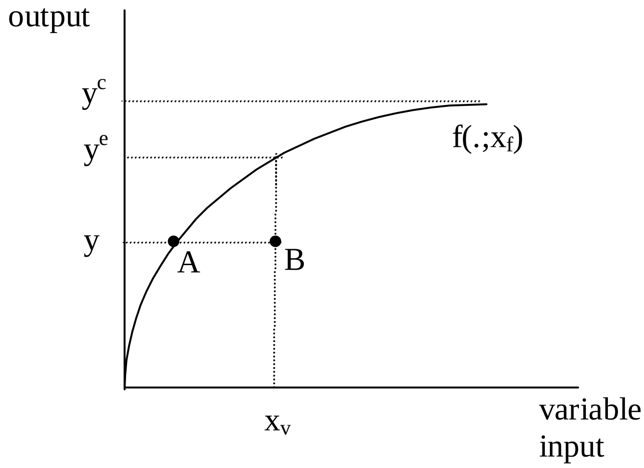

Figure 3.4: Measures of capacity and technical efficiency

We define the profit efficiency of a firm using profit difference measures in this paper.

5 Another possibility is to name it "volume change efficiency" see, Shank and Churchill (1977).

6 The discussion here applies equally to our ray economic capacity measure. However, the illustration of our

However, one could alternatively use ratio measures, as is sometimes done in the efficiency measurement literature. That is, one could calculate π/π^* instead of $\pi^*-\pi$. This ratio measure will vary between zero and one, when π is non-negative and π^* is strictly positive. A value of one would indicate full short run profit efficiency. However, negative values of π and non-positive values of π^* will provide ratio profit efficiency values that may be negative, positive or undefined, and hence ambiguous. The difference measure of profit efficiency will always provide a non-negative efficiency measure, where a value of zero indicates full short run profit efficiency. However, one problem with the difference measure is that the size of the measure can be influenced by the scale of operations, hence it does not produce an unambiguous ranking of firms, in terms of their profit performance. In this study we use the difference measures as our preferred measures. Furthermore, in an attempt to reduce the impact of firm size upon our difference measures, we present a second set of measures where we divide the various profit measures by the book value of the firm's assets. This provides measures that are closely related to the "return on assets" measure, which is commonly found in business performance reports.

4. Linear Programs

To be able to implement the above concepts, we require an estimate of the unknown production technology. Given the availability of sample data on the input and output quantities of N firms, we can construct an estimate of the technology using a range of parametric or non-parametric methods.[7] In this paper we use variants of the non-parametric linear programming method to construct an estimate of the technology. At least we can follow two approaches to implement the short-run profit decomposition. The first one is to build an LP frontier using the information from the same industrial sector. The second one is to use only information from the own firm. In this case the frontier is defined using accumulative information from the firm, see Tulkens and Vanden Eeckaut (1995). In this paper we follow the former approach but the later is straightforward. We also use these methods to identify the various optimal points that are used to measure the profit of each firm, and to decompose the profit into meaningful components.

We need to solve four linear programs (LP's) for each firm in our sample. Firstly, to obtain the ray capacity measure in Definition 3.4, we follow Färe, Grosskopf and Kokkelenberg

point is much simpler in the case of the ray capacity measure.

[7] See Coelli, Rao and Battese (1998) for an introduction to these methods.

(1989a) and specify the following LP for the i-th firm.

$$\max_{\alpha_i, \lambda_i} \ \alpha_i$$

$$\begin{aligned} \text{st} \quad & Y\lambda_i \geq \alpha_i y_i \\ & X_f\lambda_i \leq x_{fi} \\ & N1'\lambda_i = 1, \end{aligned} \tag{4.1}$$

where y_i is the M×1 vector of outputs of the i-th firm, Y is the M×N matrix of outputs of all N firms, x_{fi} is the K_f×1 vector of fixed inputs of the i-th firm, X_f is the K_f×N matrix of fixed inputs of all N firms, λ_i is a N×1 vector of weights, N1 is a N×1 vector of ones, and $\theta_i=1/\alpha_i$ is the measure of ray capacity utilisation, which takes a value between zero and one.[8] A value of one indicates that the firm is operating at full capacity. Essentially, this LP seeks the maximum feasible expansion (α_i) in the output vector of the i-th firm (y_i), subject to the constraint that the optimal point must lie within the piece-wise linear *capacity envelope*, or *capacity possibility frontier*, defined by the data on the other firms. In terms of Figure 3.3. the product θ.y defines the vector y^c. The decision variables in this LP are α_i and λ_i. This LP is almost identical to the standard output-orientated data envelopment analysis (DEA) LP (see below), except that it excludes the variable input constraints.

The application of the above LP, N times, once for each firm in the sample, will build up a piece-wise linear capacity possibility frontier. For each firm, it will identify the maximum possible capacity, given the level of fixed inputs (and allowing unlimited variable inputs). The associated level of variable inputs can be obtained after solving each LP, via the λ weights, as $x_{vi} = X_v\lambda_i$, where x_{vi} is the K_v×1 vector of variable inputs of the i-th firm, X_v is the K_v×N matrix of variable inputs of all N firms.

Färe et al (1989a) describe these variable input levels the "optimal level of variable inputs". We believe this term is potentially misleading, given that these values are derived on the assumption that the price of these variable inputs are zero. Hence, when one looks at the short-run profit implications of these "optimal points" one will often find that they are far from optimal in this sense. This is clearly illustrated in our application in the following section.

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[8] Note that we were required to use the parameter $\alpha=1/\theta$ in our mathematical program to ensure that the problem was in linear form. Otherwise we would have been required to solve a non-linear problem, which involves more complex mathematical optimization methods.

The above LP was used to obtain a measure of ray capacity. This measure is not used in the preferred profit decomposition, but it is used in the capacity decomposition analysis and is also used for comparative purposes in our illustration.

We now outline the three LP's that need to be solved to obtain our preferred capacity measure and profit decomposition. First we calculate the short run maximum profit of each firm.[9]

$$\max_{x^*_{vi},\, y^*_i,\, \lambda_i} \quad p_i y_i^* - w_{vi} x_{vi}^*$$

$$\begin{aligned} \text{st} \quad & Y\lambda_i \geq y_i^* \\ & X_v\lambda_i \leq x_{vi}^* \\ & X_f\lambda_i \leq x_{fi} \\ & N1'\lambda_i = 1, \end{aligned} \tag{4.2}$$

where p_i is the M×1 vector of output prices faced by the i-th firm, and w_{vi} is the K_v×1 vector of variable input prices faced by the i-th firm.[10] This is LP is a slight variant of the long-run profit LP presented in Färe, Grosskopf and Lovell (1994). The only difference here is that the prices and quantities of the fixed inputs are not included in the objective function. Hence, the decision variables are the outputs and the variable inputs (and the λ weights), y^* and x^* in Figure 3.3.

The output-orientated technical efficiency of the i-th firm is calculated using the standard DEA LP found, for example, in Färe *et al* (1994).

$$\max_{\mu_i,\, \lambda_i} \ \mu_i$$

$$\begin{aligned} \text{st} \quad & Y\lambda_i \geq \mu_i y_i \\ & X_v\lambda_i \leq x_{vi} \\ & X_f\lambda_i \leq x_{fi} \\ & N1'\lambda_i = 1, \end{aligned} \tag{4.3}$$

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[9] Note that the LP required to obtain the minimum point on the short run average cost curve, required for the Berndt and Morrison (1981) capacity measure could be obtained by removing the py term from the objective function in this LP. However, we do not look at this measure in the empirical illustration in this paper.

[10] Note that the λ values obtained in the four LP's, considered in this section, are likely to differ, because they are used to identify different types of optimal points.

where $\psi_i=1/\mu_i$ is the technical efficiency score of the i-th firm, which takes a value between zero and one. A value of one indicates that the firm is fully efficient. However, a value of 0.85 would indicate that the firm is producing only 85% of the potential output that could be produced by the firm, given its (fixed and variable) input levels.

In our fourth and final LP we specify a way in which one can measure the ray economic capacity measure presented in Definition 3.6

$$\max_{x_{vi}^{rec},\beta_i,\lambda_i} \quad p_i\beta_i y_i - w_{vi}x_{vi}^{rec}$$

$$\begin{aligned} \text{st} \quad & Y\lambda_i \geq \beta_i y_i \\ & X_v\lambda_i \leq x_{vi}^{rec} \\ & X_f\lambda_i \leq x_{fi} \\ & N1'\lambda_i = 1. \end{aligned} \tag{4.4}$$

This LP can be viewed as a hybrid of the LP's in equations (4.1) and (4.2), in that it seeks to maximise short-run profits, but it is constrained to not alter its original output mix. This is achieved by insisting that the optimal output vector is a proportional scaling of the observed output vector (ie. $\beta_i y_i$). This prevents the firm from suggesting "optimal" capacity levels that result in a reduction in short-run profits. The scalar, $\phi_i=1/\beta_i$, is the ray economic capacity utilisation measure. It reflects the amount by which the i-th firm can radially expand (or contract) its output vector to achieve higher (constrained) short-run profits. In terms of Figure 3.3, LP (4.3) allows us to calculate y^e as the product $\mu.y$ and LP (4.4) the vector y^{rec} as the product $\beta.y$.

The above four LP's, defined in equations (4.1) to (4.4), need to be solved for each firm in the sample. Thus, if there are N firms in the sample, one must solve 4N LP's. We now provide an illustration of these methods using data on international airline companies.

5. Application to International Airlines

The purpose of this section is to provide an illustration of the above-proposed methods. Our intention is not to provide a detailed discussion of the profitability of these companies, but to provide an indication of how useful these methods could be in such an analysis. Airlines produce two distinct output categories: passenger and freight services, using a range of inputs, including aircraft, labour (pilots, crew, maintenance staff, etc.), fuel and other assorted inputs (eg. various office and maintenance materials and services). Aircraft are the principal capital expenditure in these companies. Orders for the purchase (or long term lease) of aircraft must usually be placed a number of years in advance. Thus, in the short run the quantity of aircraft is a fixed input. The other input categories, on the other hand, can generally be altered fairly easily in the short run. Capacity utilization is a big issue in airline companies. Poor demand forecasts can result in a significant number of empty seats (and half-full cargo holds), which will quickly erode profits.

Data

In this empirical study we have collected data on 28 companies in 1990. These data are derived from three annual digests: *Traffic*, *Fleet-Personnel* and *Financial Data*, published by the International Civil Aviation Organization (ICAO, 1992, a, b, c). The data used in this study are listed in Table 1. The sample is composed of carriers which activity is concentrated in domestic and international scheduled services. It was selected to represent three main regions of the world: Asia/Oceania, Europe and North America, but essentially the availability of data determined its final composition. Passenger and freight services are measured using passenger-kilometres and tonne-kilometres of freight (ICAO, 1992a). Average fares were obtained by dividing revenues by these quantity measures (ICAO, 1992c).

We distinguish three variable inputs: staff, fuel and "other". The staff corresponds to the total number of personnel at the middle of the year, as reported by ICAO (1992,b). It includes other that pilots, co-pilots and cockpit staff, all the personnel involved in maintenance, ticketing and general administration. Annual average wages were obtained by dividing total personnel expenses by the labour quantity (ICAO, 1992, c). Data on quantity of fuel consumed is not directly available from ICAO statistics. Thus we estimate the fuel quantity by dividing total fuel expenditures by average fuel prices.[11] The expenses on "other" inputs is calculated by subtracting personnel and fuel expenses from total operating expenses (ICAO, 1992c).[12] This input includes, among other things: maintenance, ticketing and general administration costs (net of any personnel expenses involved). We do not have access to a specific price index for this "other" inputs category. Hence we use international PPP (purchasing power parity) indexes as a proxy for this price index. The implicit quantity of

[11] The Bureau of Transportation Statistics (BTS, 2000) estimates the average price per gallon paid by US carriers (0.78 USD in 1990). We use this price for all North American carriers. Another information available from the BTS is the average price per gallon paid by US carriers in international services (0.84 USD in 1990). We assume that this is the average fuel price paid by all the companies operating from outside North America.

[12] Total operating expenses are redefined to exclude current capital costs like rental of flight equipment and

“other” inputs is then derived by dividing the “other” expenses figure by this price index.

The fixed capital measure is a key variable for this particular study. Its definition and measurement is always a difficult problem in any empirical study. Some studies use physical measures while others use monetary measures. We have reported a physical and a monetary measure of capital in Table 1. The physical capital variable was computed using information provided by ICAO’s *Fleet-Personnel* digest (ICAO, 1992b). For each company, this measure corresponds to the sum of the maximum take-off weights of all aircraft multiplied by the number of days the planes have been able to operate during the year.[13] Our financial measure of capital comes from the balance sheets of companies as reported in the *Financial Data* digest (ICAO, 1992c). It corresponds to the book value of flight equipment assets before depreciation. Our physical and monetary measures of capital are likely to be quite highly correlated in the situation in which the airline companies have similar age profiles of aircraft in their fleets. However, since these companies have fleets with differing average aircraft ages, we find that this monetary capital measure is not always a good measure of the quantity of aircraft available for service, because of the effects of inflation upon aircraft values. The monetary measure will tend to overstate the capital quantity in those companies that have newer fleets, and understate the capital quantity in those companies that have older fleets. We have hence decided to use our physical measure of capital in the calculations in this study. However, we have also reported the monetary measure of capital because we use this value to deflate our profit difference measures so as to attempt to reduce the impact of firm size from these measures.

A number of points can be made about the data presented in Table 1. First, we observe a great variability in company sizes. For instance, the Austrian airline (AUA) is nearly twenty times smaller, in terms of staff members and capital investment, compared with major U.S. carriers like American, United or Delta. Second, it appears that European companies charged higher fares than North American and Asia/Oceania companies (with the exception of Japanese airlines). This can be partially explained by network characteristics like shorter average stage length, but also because the airlines deregulation process was always in process in Europe in 1990. Finally, Table 1 also illustrates a wide range of variation in factor prices, especially in wages and within Asian countries. Three companies, Garuda, Malaysia Airlines

depreciation of owned capital.

[13] The same definition of physical capital was used in Coelli et al. (1999). The multiplication by the number of days available is primarily to account for cases in which a plane was only available for a fraction of the year because it was bought or sold during the year.

and SIA paid annual wages of around ten thousand U.S dollars to their employees in 1990, whereas a company like JAL paid salaries eight times higher.

Results

The various measures of technical efficiency and capacity utilisation are reported in Table 2. Before we begin with a discussion of these results we must stress a very important point. The production frontiers and capacity frontiers constructed using LP in this study (and in any other study) reflect the outer boundary of *observed best practice in the sample*. Thus, even though we may observe results such as: "JAL is technically efficient" and "American Airlines is operating at full capacity", these results are only relative to other firms in the sample. It is possible that if we added new sample observations to our data set (from other airlines or from different years) we may find that these firms are no longer located on the frontier. Having said this, we now discuss the results.

The average level of technical efficiency (y/y^e) for these 28 firms is 0.937. This indicates that the average firm is producing 6.3% less output than is technically feasible, given the inputs it possesses. This technical efficiency is one component of unused capacity. The average level of *ray economic capacity* utilisation (y/y^{rec}) is found to be 0.867. This suggests that, on average, firms are operating at a point that is 13.3% below the optimal level of capacity utilisation. The profit consequences of this are discussed shortly.

It is interesting to note that when we use the alternative *ray capacity* measure (ie. which does not consider profit issues) we find that the average level of *ray capacity* utilisation (y/y^c) is lower at 0.831, or 16.9% unused capacity. The ratio of these two capacity measures provides a measure of the *optimal amount of capacity idleness* (y^{rec}/y^c), which is equal to 0.958. This figure suggests that, on average, it is optimal to leave 4.2% of the *ray capacity* idle, because an increase in capacity utilisation above the *ray economic capacity* level will result in a loss of profit.

The final column in Table 2 contains the ratio of the technically efficient output level to the ray economic capacity output level. The average value of this ratio is 0.925. It indicates that once technical efficiency is removed, there still remains a 7.5% gap between the technically efficient level of output and that level of output associated with full (ray economic) capacity.

The results for individual firms in Table 2 provide quite interesting reading. For example, we note that some companies are operating well below ray economic capacity. In particular, Saudia is operating at more than 60% below capacity. On the other hand, we note that a few firms are operating above the optimal ray economic capacity level. For example, United has a ray economic capacity utilisation measure of 1.096, indicating that it is overusing its fleet by 9.6%. This suggests that United can increase short run profits by reducing output. We will now look at our profit decomposition analysis to investigate the magnitude of these profit differences.[14]

In Table 3 we present profit levels and decompositions (in US dollars). Note that profit levels are reported in the first seven columns in this table, while ratio measures (profits divided by capital stock) are listed in the final seven columns. From the information on observed profits (π), we see that these 28 airline companies achieve average operating profits of US$391m. In terms of the ratio measure, we see that this equates to an average of 11.4% return on the capital stock.[15] The firm by firm results differ substantially, from Garuda and TAP, with ratios over 30.0%, to those firms that make loses, such as Northwest (-19.0%) and Qantas (-8.1%).

The second column in Table 3 reports the differences between observed profit and the maximum short run profit (π-π*). Note that the estimated levels of maximum short run profit are conditional on the capital quantity and price levels, which vary from firm to firm. These figures indicate that the average firm is missing out on US$815m in (short run) profit. This ranges from $0 for American Airlines to a not insignificant $2,842 for British Airways.

This gap between observed and maximum profits can be decomposed into various components. In particular, we observe that (for the average firm) US$566m, or 70%, of this gap can be attributed to unused capacity (π^{rec}-π), while the other 30% (US$249m) is due to a type of output-mix allocative inefficiency (π^*-π^{rec}).[16] This 70% due to unused capacity can be further decomposed into two components, that part due to technical inefficiency (π^e-π), which contributes US$198m, or 24%, and that part due to a type of input mix allocative efficiency effect (π^{rec}-π^e),[17]which contributes the other US$368m, or 46% of the total profit

[14] One possible explanation for this apparent overuse of capacity, could be that United wished to retain market share, and hence was willing to accept loss of profit in the short run, with the intention of making more profit in the longer term.

[15] Note that the capital measure here is undepreciated nominal capital stock, which differs from the measure of depreciated capital stock which is usually used in reporting measures of "return on assets" in financial reports.

[16] This is not pure output-mix allocative efficiency because the variable input quantities can also vary between these two points. However, we have decided to label this profit difference as "output-mix" allocative efficiency because it reflects the extra profit that can be achieved when we relax the restriction that the original output mix must be maintained.

[17] Again, this is not pure input-mix allocative inefficiency because the scale of output vector can also change

gap.

In the seventh column in Table 3 we present an additional profit difference measure which is not actually utilised in our decomposition. This is a measure of the effect on profits of moving from the point of *ray economic capacity*, proposed in this study, to the point of *ray capacity*, used in some previous studies. The resulting average profit difference (π^c-π^{rec}) is equal to minus US$186m. This clearly illustrates that the use of the ray capacity measure is not very sensible when one considers the profit implications.

We conclude this brief discussion of our results by repeating the warning that we gave at the beginning of this results section. Namely, that the production frontiers and capacity frontiers constructed using LP in this empirical study reflect the outer boundary of the *observed best practice in the sample*. Now, given that the world economy was on a down-cycle in 1990, we have perhaps overestimated the degree of capacity utilisation and underestimated the amount of forgone profit. In future work, we plan to obtain additional data on these airline companies for a number of years, including years at the top of the macro cycle.[18] We will then use this panel data to re-estimate our frontiers to see if this has the effect of changing our conclusions regarding the degree of foregone profit, and the contribution of unused capacity to this profit gap.

6. Conclusions

The main aim of this study was to develop a methodology which would allow us to measure the gap between observed short-run profit and maximum short-run profit, and to decompose this gap into meaningful components, with particular interest in the contribution of capacity utilisation. We began by reviewing a number of previously proposed capacity measures, and concluded that these measures did not provide meaningful information when one attempted to use them in a profit decomposition analysis.

As a result of the problems with the existing capacity measures, we proposed a new measure of *ray economic capacity*, which involves finding the largest radial expansion (or contraction) of the output vector, coinciding with the largest possible short run profit. We then use this

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between these two points. However, we have decided to label this effect this profit difference as “input-mix” allocative efficiency because it reflects the extra profit that can be achieved when we relax the restriction that the original variable input mix must be maintained.

[18] The collection and analysis of this extra data will be a very large amount of work. It was beyond the scope of this study, which focuses primarily upon the development of the methodology, to consider this additional empirical work.

capacity measure to decompose the gap between observed short-run profit and maximum short-run profit into components due to unused capacity, technical inefficiency, input mix allocative efficiency and output-mix allocative inefficiency. We then devise a series of DEA-like LP problems which allow us to measure and decompose the short-run profit inefficiency of a group of firms into these various components.

Following this, we have provided an empirical illustration of these methods using data on 28 international airline companies. Our empirical model has two outputs (passengers and freight), one fixed input (aircraft) and three variable inputs (labour, fuel and “other”). Our empirical results indicate that the average (short-run) profit of these 28 firms was US$391m, which equates to an 11.4% return relative to the (undepreciated) capital stock. After calculating the maximum levels of short-run profit, we observe that the average profit gap is US$815m. The decomposition analysis then attributes 70% of this gap to unused capacity and 30% to output-mix allocative inefficiency. A further decomposition of the 70% profit gap due to unused capacity, indicates that 24% is due to technical inefficiency and 46% is due to a type of input mix allocative efficiency inefficiency effect. The firm-level results indicate substantial differences in profit gaps and decompositions among the firms, and clearly demonstrate the rich quantity of information that can be generated using these methods.

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Table 1
Data on international airline companies, 1990 [a]

Airlines and regions	Outputs: Passenger pass-km 10^6	Passenger price	Freight tones-km 10^6	Freight price	Variable inputs: Staff units	Staff wages 10^3	Fuel gallons 10^6	Fuel price	Other expenses quantity 10^6	Other expenses PPP	Fixed capital: Aircraft take-off tones-days 10^6	Replacement value 10^6
Asia/Oceania												
All Nippon Airways	35,261	0.137	614	0.608	12,222	67.5	860	0.84	2,008	1.347	6,074	6,408
Cathay Pacific (Hong-Kong)	23,388	0.087	1,580	0.278	12,214	33.5	456	0.84	1,492	0.721	4,174	2,362
Garuda (Indonesia)	14,074	0.090	539	0.393	10,428	8.2	304	0.84	3,171	0.256	3,305	929
JAL (Japan)	57,290	0.106	3,781	0.372	21,430	79.9	1,351	0.84	2,536	1.347	17,932	8,643
Malaysia Airlines	12,891	0.072	599	0.265	15,156	10.8	279	0.84	1,246	0.401	2,258	1,232
Quantas (Australia)	28,991	0.064	1,330	0.239	17,997	30.7	393	0.84	1,474	0.993	4,784	2,233
Saudia (Saudi Arabia)	18,969	0.095	760	0.318	24,078	29.2	235	0.84	806	1.235	6,819	3,489
SIA (Singapore)	32,404	0.064	1,902	0.263	10,864	13.3	523	0.84	1,512	0.898	4,479	3,933
Europe												
AUA (Austria)	2,943	0.192	65	0.641	4,067	47.9	62	0.84	241	1.320	587	387
British Airways	67,364	0.113	2,618	0.264	51,802	35.6	1,294	0.84	4,276	1.080	12,161	6,788
Finnair (Finland)	9,925	0.098	157	0.411	8,630	31.5	185	0.84	303	1.581	1,482	1,084
Iberia (Spain)	23,312	0.122	845	0.412	30,140	39.9	499	0.84	1,238	1.073	3,771	3,188
Lufthansa (Germany)	50,989	0.132	5,346	0.300	45,514	48.6	1,078	0.84	3,314	1.302	9,004	7,997
SAS (Scandinavia)	20,799	0.168	619	0.462	22,180	52.8	377	0.84	1,234	1.489	3,119	2,221
Swissair	20,092	0.144	1,375	0.324	19,985	57.8	392	0.84	964	1.626	2,929	3,287
TAP Air Portugal	8,961	0.100	234	0.444	10,520	23.5	121	0.84	831	0.671	1,117	252
North America												
Air Canada	27,676	0.089	998	0.306	22,766	38.5	626	0.78	1,197	1.035	4,829	1,869
America West	18,378	0.069	169	0.263	11,914	21.8	309	0.78	611	1.000	2,124	831
American	133,796	0.079	1,838	0.252	80,627	35.0	2,381	0.78	5,149	1.000	18,624	7,945
Canadian	24,372	0.081	625	0.319	16,613	31.9	513	0.78	1,051	1.035	3,358	1,214
Continental	69,050	0.072	1,090	0.240	35,661	27.4	1,285	0.78	2,835	1.000	9,960	2,147
Delta	96,540	0.086	1,300	0.339	61,675	42.4	1,997	0.78	3,972	1.000	14,063	6,263
Eastern	29,050	0.073	245	0.261	21,350	23.9	580	0.78	1,498	1.000	4,459	1,428
Northwest	85,744	0.077	2,513	0.273	42,989	41.5	1,762	0.78	3,678	1.000	13,698	4,833
Pan American	54,054	0.068	1,382	0.193	28,638	32.1	991	0.78	2,193	1.000	7,131	1,466
TWA	62,345	0.070	1,119	0.223	35,783	32.5	1,118	0.78	2,389	1.000	8,704	3,221
United	131,905	0.078	2,326	0.274	73,902	35.5	2,246	0.78	5,678	1.000	18,204	6,346
Usair	59,001	0.100	392	0.413	53,557	36.4	1,252	0.78	3,030	1.000	8,952	4,049

[a] All prices and capital replacement value are in 1990's U.S. dollars. Source: ICAO (1992, a, b, c).

Table 2
Technical efficiency and capacity utilization [a]

Airlines and regions	Efficiency y/y^e	Capacity utilization y/y^c	y/y^{rec}	y^{rec}/y^c	y^e/y^{rec}
Asia/Oceania					
All Nippon Airways	0.993	0.758	0.805	0.942	0.810
Cathay Pacific (Hong Kong)	0.905	0.815	0.827	0.985	0.914
Garuda (Indonesia)	0.706	0.551	0.551	1.000	0.780
JAL (Japan)	1.000	0.816	1.000	0.816	1.000
Malaysia Airlines	0.760	0.760	0.796	0.955	1.047
Qantas (Australia)	1.000	0.819	0.831	0.985	0.831
Saudia (Saudi Arabia)	1.000	0.384	0.395	0.972	0.395
SIA (Singapore)	1.000	1.000	1.000	1.000	1.000
Europe					
AUA (Austria)	1.000	1.000	1.000	1.000	1.000
British Airways	0.907	0.808	0.820	0.985	0.904
Finnair (Finland)	1.000	0.803	1.000	0.803	1.000
Iberia (Spain)	0.805	0.805	0.805	1.000	1.000
Lufthansa (Germany)	1.000	1.000	1.000	1.000	1.000
SAS (Scandinavian)	0.882	0.842	0.842	1.000	0.955
Swissair	1.000	1.000	1.054	0.949	1.054
TAP Air Portugal	1.000	1.000	1.170	0.855	1.170
North America					
Air Canada	0.930	0.759	0.771	0.984	0.829
America West	1.000	1.000	1.000	1.000	1.000
American	1.000	1.000	1.000	1.000	1.000
Canadian	0.914	0.914	0.923	0.990	1.010
Continental	1.000	0.934	0.960	0.973	0.960
Delta	0.945	0.939	0.955	0.983	1.011
Eastern	0.842	0.830	0.837	0.992	0.994
Northwest	1.000	0.889	1.068	0.832	1.068
Pan American	1.000	1.000	1.054	0.949	1.054
TWA	1.000	0.958	1.000	0.958	1.000
United	1.000	1.000	1.096	0.912	1.096
Usair	0.883	0.883	0.892	0.989	1.011
Mean	0.937	0.831	0.867	0.958	0.925

[a] Definitions of efficiency and capacity utilization are given in Section 3 (see Figure 3.3). Namely, y: actual production; y^e: technical efficient production; y^{rec}: ray economic capacity; y^c: ray capacity.

Table 3
Profit decomposition and ratios over capital investment [a]

Airlines and regions	Profit decomposition (million USD)							Ratios over capital stock (%)						
	π	$\pi^*-\pi$	$\pi^*-\pi^{rec}$	$\pi^{rec}-\pi$	$\pi^{rec}-\pi^{e}$	$\pi^{e}-\pi$	$\pi^{c}-\pi^{rec}$	π	$\pi^*-\pi$	$\pi^*-\pi^{rec}$	$\pi^{rec}-\pi$	$\pi^{rec}-\pi^{e}$	$\pi^{e}-\pi$	$\pi^{c}-\pi^{rec}$
Asia/Oceania														
All Nippon Airways	940	1734	687	1047	1010	36	-47	14.7	27.1	10.7	16.3	15.8	0.6	-0.7
Cathay Pacific (Hong Kong)	599	730	252	477	218	260	-76	25.4	30.9	10.7	20.2	9.2	11.0	-3.2
Garuda (Indonesia)	327	1656	17	1639	1023	616	0	35.2	178.2	1.8	176.4	110.1	66.3	0.0
JAL (Japan)	1226	0	0	0	0	0	-2585	14.2	0.0	0.0	0.0	0.0	0.0	-29.9
Malaysia Airlines	189	599	40	559	216	344	-73	15.4	48.6	3.3	45.4	17.5	27.9	-5.9
Qantas (Australia)	-181	426	87	340	340	0	-13	-8.1	19.1	3.9	15.2	15.2	0.0	-0.6
Saudia (Saudi Arabia)	156	1173	13	1160	1160	0	-44	4.5	33.6	0.4	33.3	33.3	0.0	-1.2
SIA (Singapore)	648	0	0	0	0	0	0	16.5	0.0	0.0	0.0	0.0	0.0	0.0
Europe														
AUA (Austria)	43	0	0	0	0	0	0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
British Airways	785	2842	670	2172	1312	860	-3	11.6	41.9	9.9	32.0	19.3	12.7	0.0
Finnair (Finland)	134	0	0	0	0	0	-531	12.3	0.0	0.0	0.0	0.0	0.0	-49.0
Iberia (Spain)	237	1601	120	1481	708	774	0	7.4	50.2	3.8	46.5	22.2	24.3	0.0
Lufthansa (Germany)	896	2187	2187	0	0	0	0	11.2	27.3	27.3	0.0	0.0	0.0	0.0
SAS (Scandinavian)	462	1627	57	1570	1064	506	0	20.8	73.2	2.6	70.7	47.9	22.8	0.0
Swissair	282	812	538	274	274	0	-274	8.6	24.7	16.4	8.3	8.3	0.0	-8.3
TAP Air Portugal	92	248	3	246	246	0	-246	36.6	98.7	1.0	97.6	97.6	0.0	-97.6
North America														
Air Canada	170	939	186	753	545	209	-6	9.1	50.2	9.9	40.3	29.1	11.2	-0.3
America West	210	0	0	0	0	0	0	25.2	0.0	0.0	0.0	0.0	0.0	0.0
American	1178	0	0	0	0	0	0	14.8	0.0	0.0	0.0	0.0	0.0	0.0
Canadian	162	460	114	346	141	204	-5	13.4	37.9	9.4	28.5	11.6	16.8	-0.4
Continental	389	280	156	124	124	0	-149	18.1	13.0	7.3	5.8	5.8	0.0	-6.9
Delta	599	921	193	728	221	507	-193	9.6	14.7	3.1	11.6	3.5	8.1	-3.1
Eastern	-279	954	308	646	236	410	-46	-19.5	66.8	21.6	45.2	16.5	28.7	-3.3
Northwest	419	426	229	197	197	0	-474	8.7	8.8	4.7	4.1	4.1	0.0	-9.8
Pan American	45	258	191	67	67	0	-67	3.1	17.6	13.0	4.6	4.6	0.0	-4.6
TWA	182	278	278	0	0	0	-112	5.7	8.6	8.6	0.0	0.0	0.0	-3.5
United	900	268	66	201	201	0	-201	14.2	4.2	1.0	3.2	3.2	0.0	-3.2
Usair	126	2394	569	1825	1016	810	-73	3.1	59.1	14.0	45.1	25.1	20.0	-1.8
Mean	391	815	249	566	368	198	-186	11.4	23.8	7.2	16.5	10.7	5.8	-5.4

[a] Definitions of profit decomposition are given in Section 3, equations 3.8 and 3.9. Ratio measures were calculated using the value of capital as the denominator (Table 1). Operating profits are calculated net of capital expenses (rental of flight equipment and depreciation on owned capital).