Productivity Commission's draft report on price regulation of airport services

Comments on land valuation and congestion issues

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1 Overview

The purpose of this report is to comment on certain aspects of the draft report issued by the Productivity Commission (the "PC") entitled *Price Regulation of Airport Services* and dated August 2001 (the "Draft Report").

The key issues addressed in this report are:

- land valuation; and
- the welfare consequences of inappropriate airport charging more generally.

This report begins with a discussion on the effectiveness of price-oriented approaches to the management of congestion externalities and reviews some of the issues raised by such approaches.

In essence, the PC assumes that there is a congestion problem at Kingsford Smith Airport ("Sydney Airport") and on that basis argues that a scheme of congestion pricing ought to be adopted. It then argues that the valuation of the land used by Sydney Airport at its opportunity cost is required for this pricing arrangement, and will contribute to overall efficiency. Moreover, it asserts that the congestion rents collected under this arrangement should flow to Sydney Airport's owner. The PC recognises that airports might use any monopoly power they have to increase charges, but it suggests that the welfare costs of the excess pricing would be low.

This report examines each of these arguments and concludes that the PC's analysis of the issues of present concern, as reflected in the Draft Report, is flawed in a number of important respects:

- for example, congestion is, by definition, an externality. However, this well-studied concept is relatively little used in the relevant sections of the Draft Report. Instead, the PC evaluates the issues in very general terms, proposing regulatory arrangements as if they were obvious, when this is far from being the case; and
- as a result, important options are not analysed fully or even at all and, at times, it is by no means clear quite what assumptions the Draft Report is making. Little empirical evidence is presented on the matters being considered, even though some of the Draft Report's conclusions rest on what are ultimately empirical issues. Given

the relatively high stakes involved, it would seem desirable to proceed to a more systematic and comprehensive analysis in the PC's final report.

The major conclusions of this report are reached on the following bases:

- accepting that there is congestion at Sydney Airport, it may be the case that some form of regulation is needed to deal with the inefficiencies that stem from the external, and not privately accounted for, effects of individual usage decisions. However, the PC's reliance on a market-like pricing system is at least questionable. The imposition of congestion-related landing and take-off fees may be a solution (if better analysed), but alternative regulation is possible and it is not clearly self-evident that there is a need to rely solely on a price coordination approach;

- even if a congestion charging system provided the optimal coordination approach, it is far from established that land is the binding constraint on the service potential of Sydney Airport. Other constraints like those imposed to deal with noise disamenities seem more binding. As a consequence, land valuation may have little, if any, role in determining efficient congestion charges;

- furthermore, even if the acquisition of additional land was a possible solution to the congestion problem, it is not clear whether it would be the most efficient. Alternative remedies, notably in terms of demand side considerations, need to be explored before it can be concluded that the equilibrium congestion charge is determined by the long run marginal cost of altering Sydney Airport's land surface;

- even if the long run marginal cost of altering Sydney Airport's land surface were the relevant factor in efficient congestion charges, the land valuation methodology used by the PC is, at best, unexplained and, at worst, incorrect. The correct approach to land valuation would necessitate considering alternative solutions, such as a transfer of traffic to another airport or the development of a second (major) airport in Sydney. The PC's approach could well yield the least efficient solution;

- the approach taken by the PC does not seem to pay any regard to the industrial structure of the downstream markets that use airport services, and most specifically commercial aviation. Specifically, the PC's arguments seem based on assumptions that do not accurately reflect competitive conditions in the markets at issue. That this is dangerous becomes clear once it is recognised that, in the presence of imperfect competition in a downstream market, simple congestion charging upstream can lower welfare; and

- finally, not only does the proposed policy represent a considerable transfer of wealth from consumers to the owners of Sydney Airport without a proper analysis – or simply an incorrect one – but the policy of vesting congestion rents in Sydney Airport's owner is criticisable on the grounds that it is likely to increase the incentives to create congestion.

Prior to addressing the PC's analysis in detail, it is relevant to note that, while the PC has presented its arguments as a critique of the decision made by the Australian Competition and Consumer Commission (the "Commission") in its May 2001 decision on the aeronautical pricing proposal put forward by the Sydney Airports Corporation Limited ("SACL"):[1]

- the PC's argument for using a different approach to land valuation from that adopted by the Commission is entirely based on a consideration of congestion; and

- SACL expressly noted that it was "not advocating an explicit congestion pricing approach" at the time of issuing its pricing proposal.[2]

As a result, while it may be that consideration of congestion would lead to a view that differed from that adopted by the Commission, this is not relevant to SACL's pricing proposal as that proposal was not intended to set out SACL's position in respect of, or proposals with respect to, explicit congestion charging issues.

Having said that, it emerges that a consideration of congestion does not lead to a different position from that adopted by the Commission, at least on the basis of the facts as they stand at the time of writing.

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1 Australian Competition and Consumer Commission, *Sydney Airports Corporation Limited: Aeronautical Pricing Proposal – Decision*, May 2001 (available at: http://www.accc.gov.au/airport/fs-air.htm).

2 Sydney Airports Corporation Limited, *Sydney Airport Revised Draft Aeronautical Pricing Proposal*, September 2000 (available at: http://www.accc.gov.au/airport/sydney/SACL_Rev_Draft_Prop_sep.pdf), page 132.

2 The PC's argument—an economic assessment

2.1 Background

The PC recommends that land used at Sydney Airport be valued on the basis of its value in alternative use. It argues that such a valuation is likely to yield welfare gains mainly for three reasons, namely that it:

- is likely to result in higher charges than would otherwise prevail, and hence help signal and limit congestion;
- will provide better incentives for allocation of the land as between competing uses; and
- through the privatisation process, will result in the transfer of congestion rents to the Commonwealth.

The argument put by the PC relies upon a number of assumptions, namely:

- there is a congestion problem which should be dealt with by congestion charging;
- the main feature of such a congestion charging solution is that efficient prices at the congested times would be substantially higher than they are now; and
- finally, valuing airport land on the basis of "value in alternative use" is the best way of moving prices towards these levels.

Accepting the relatively uncontroversial proposition that there is congestion at Sydney Airport, the question arises whether the PC's approach to dealing with that problem is indeed efficient. This requires a somewhat more general characterisation of the congestion problem and of the ways in which any inefficiencies caused by congestion may be addressed. This is discussed here as a preliminary matter prior to considering in more detail the assumptions on which the PC's approach rests.

By definition, congestion is the impedance users impose on each other due to the speed-flow relationship in the provision of a service, in conditions where the use of the system by means of which the service is provided approaches its capacity limits. The resulting congestion (which arises because the short-term arrival rate of demand exceeds the airport's service rate) – reflects a negative externality, namely that the attempted consumption of an

additional unit will lower the utility derived from total realised consumption.[3] A similar result occurs, for example, with traffic jams where the total benefits from using a car are lower when additional drivers turn out on a crowded road. As the congestion externality is virtually always marginal[4] (indeed, in most systems subject to congestion, the marginal cost of additional arrivals rises sharply as congestion sets in), decentralised decision-making in situations where the risk of congestion arises can lead to inefficiency.

As with other externalities, the inefficiency can typically be overcome by one of two means.

The first involves internalisation of the externality. This occurs when property rights are structured such that each party captures both the costs and the benefits of the relevant behaviour and hence has incentives to act efficiently. This can be referred to as the Coasian solution.

The second is by relying on a central planner to engage in some process of resource management. This planner may rely on a price- or quantity-based auction mechanism to allocate the scarce resource.[5] Equivalently, the planner may impose taxes (and perhaps subsidies) that guide users to the efficient production and consumption decisions. The ultimate equivalence of this approach to an "externality offsetting" tax/subsidy scheme makes it natural to refer to the approach as Pigouvian.

Seen in these terms, the PC's approach is Pigouvian. It seeks to price the externality, and to do so on the basis of the cost of acquiring and putting to use additional land.

However, it is hasty to assume that this must be the correct approach. As Buchanan and Tullock explain:

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3 Note the difference with respect to diminishing marginal utility - what is at issue here is a reduction in the total realised value of consumption.

4 Externalities can and often do arise that are purely infra-marginal, and hence do not lead to failure in decentralised decision-making.

5 The close parallel here is the Lange-Taylor central planner. See Lange O, (1936) "On the Economic Theory of Socialism: Part One" *Review of Economic Studies*, 53-71; and Taylor F M, (1929) "The Guidance of Production in a Socialist State", *American Economic Review*, 1-8.

> "The choice between voluntary action, individual or co-operative, and political action, which must be collective, rests on the relative costs of organizing decisions, on the relative costs of social interdependence. The costs of organizing voluntary contractual arrangements sufficient to remove an externality or to reduce the externality to reasonable proportions may be higher than the costs of organizing collective action sufficient to accomplish the same purpose. Or, both of these costs may be higher than the costs of bearing the externality, the spillover costs that purely individual behaviour is expected to impose."[6]

It follows that an appropriate and detailed economic analysis needs to be conducted before the PC's approach can be adopted. In particular, it is important to critically assess the key premises that underlie the PC's approach. These key premises, arranged in a cascade in which each premise relies on those prior to it (if any), are that:

1. the proper approach to managing congestion is to rely on the "tax/subsidy" method, rather than on direct allocation by quantities;

2. in implementing the "tax/subsidy" method, the crucial parameter is the value of acquiring and putting to use additional land, because it is this which constrains capacity at Sydney Airport;

3. given that it is land that constrains capacity at Sydney Airport, the price users face for aeronautical services should, in an efficient equilibrium, be no less than the price that factors in the value of that land in alternative uses;

4. in calculating the value of that land in alternative uses, the relevant cost should be determined on the basis of the price the land could secure in residential or light industrial use, with that price then being used as a part of a Depreciated Optimised Replacement Cost valuation of the aggregate revenue requirement for the airport as a whole;

5. even if this leads to prices that in some periods are too high, the resulting social costs (that is, the loss in social welfare caused by the excess pricing) will be low; and

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[6] Buchanan J and Tullock G, *The Calculus of Consent: Logical Foundations of Constitutional Democracy*, Ann Arbor, MI: University of Michigan Press, 1962.

6. it is not problematic to allocate any congestion rents that are collected through these prices to the airport owner.

Each of these premises is questionable and made without appropriate analytical support. We consider each premise in turn.

2.2 Externalities and how they should be managed

> *Premise 1:* The economic problems caused by congestion are best managed by relying on congestion prices, rather than on direct allocation of the scarce resource(s).

From an economic point of view, congestion is a type of externality. Externalities are pervasive in virtually every area of economic activity. For example, a chemical factory emits wastage as a by-product into nearby rivers and into the atmosphere. This creates negative externalities, which impose higher social costs on other firms and consumers in the form of clean up costs and health costs. Another example of higher social costs comes from the problems caused by traffic congestion in towns, cities and on major roads and motorways.[7] However, it is important to stress that the use of cars can also generate external benefits to society, as straightforward as individual mobility, and hence a cost-benefit analysis can be useful in valuing both the social costs and the social benefits of production. The need to take account both of social costs and of social benefits is of crucial relevance when considering airport congestion.[8]

When negative production externalities exist, marginal social cost is higher than private marginal cost. If we assume that producers are interested in maximising profits, then they will only take into account the private costs and private benefits arising from their supply of the product. However, the socially efficient level of production would consider the external

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[7] See, for example, Vickrey W, (1969), "Congestion theory and transport investment" *American Economic Review*, 59:251-261.

[8] Urban economics may be the area where this trade-off between positive and negative externality is most commonly found. See, for example, Combes P P and Duranton G, (2000): "Labor Pooling, Labor Poaching, and Spatial Clustering", Paris: CERAS, mimeo.

costs as well. Failure to consider these leads to the private optimum output being greater than the social optimum level of production. Equivalently, consumers can also create externalities when they purchase and consume goods and services, like pollution from cars and motorbikes, litter on streets and in public places, noise pollution or congestion when using public transport. In these situations, the marginal social benefit of consumption will be less than the marginal private benefit of consumption. This leads to the good or service being over-consumed relative to the social optimum. Without external intervention, the good or service will be socially under-priced and the negative externalities will not be taken into account.[9] This is the classical issue of market failure, which has been well set out in the following terms:

> "What is it we mean by "market failure"? Typically, at least in allocation theory, we mean the failure of a more or less idealized system of price-market institutions to sustain "desirable" activities or to estop "undesirable" activities. The desirability of an activity, in turn, is evaluated relative to the solution values of some explicit or implied maximum-welfare problem."[10]

One device often suggested to resolve market failures associated with negative externalities is the levying of a tax on the performance of the externality-generating activity - a tax that is equated to the external costs per unit that the activity imposes.[11] Equality between marginal

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9 Examples of positive externalities range from research into new technologies, which can then be disseminated for use by other producers, to flood protection systems and spending on improved fire protection in schools and public arenas. Where substantial positive externalities exist, the good or service may be under-consumed or under-provided since the market working by itself may fail to take into account these effects. This is because the marginal social benefits of consuming the good are higher than private marginal benefits. In the case of external benefits from production, the marginal social cost would be lower than private marginal costs. Regarding externalities associated with airports specifically, see Blum U, (1998), "Positive Externalities and the Public Provision of Transportation Infrastructure: An Evolutionary Perspective" *Journal of Transportation and Statistics* 1:81-88.

10 Bator F, (1958), "The Anatomy of Market Failure" *Quarterly Journal of Economics*, 72:351-79.

11 Pigou A C, *The economics of welfare*, London 1920.

private cost and marginal social cost is the allocative criterion of Pigouvian welfare economics, and the principle remains acceptable to most modern welfare economists. In this view, corrective taxes and subsidies are deemed to be required in order to satisfy the necessary conditions for optimality when external effects are present.

The PC adopts this perspective, and indeed, seems to take it for granted that congestion charging is the only or best way of dealing with congestion externalities. In other words, faced with a problem of coordination of resource use, the PC focuses on price, as against quantity, coordination only.

In a variety of situations, however, governments do regulate undesirable activities by controlling quantities rather than by directly changing prices. Examples include anti-smoking and antitrust laws (which restrict rather than tax particular conduct) and pollution controls to limit greenhouse gas emissions, and fishing and hunting rules that limit activity during certain periods rather than taxing the catch.

As a general matter, it is difficult to show that such schemes of quantity allocation are necessarily inferior to reliance on a price system. There are, in effect, many reasons why a price system may be supplanted by quantity goals as a coordinating mechanism.

A first reason for this is that the "efficient" prices can be very difficult to determine, and decentralised schemes for discovering them may not prove to be very effective. In many situations that involve congestion, the lumpy nature of both supply and demand introduces non-convexities[12] into the allocation process. In the presence of non-convexities, allocation processes based on quantities can converge more efficiently than those based on prices.[13] As a result, a quantity-oriented allocation scheme may allow better use to be made of the scarce resource.

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12 This property refers to nothing more than the fact that producing one unit of output costs more than the average of separately producing zero unit and two units. The relationship between non-convexity and externalities is discussed at some length by Starret D, (1972) "Fundamental Nonconvexities in the Theory of Externalities" *Journal of Economic Theory* 4:180-199.

13 See Heal G, *The Theory of Economic Planning* (1973) at 147 and following.

The intuition behind this result is discussed further in Appendix A. However, perhaps the simplest way to understand the issue is to note that, with a non-convex production function, a firm has a discontinuous demand (or supply) curve for its input. Therefore, there are certain demand (or supply) levels that it will never choose, no matter what prices it faces: the curve will jump over these because of the non-convexity. The use of quantitative targets solves this problem because each possible quantity corresponds to a single price.

A second reason why price-like responses to congestion may not be optimal is that, even if it is possible to find the "efficient" tax, the process involves a cost. This "cost of using the price mechanism"[14] is the consequence of searching, negotiating and enforcing price-based contracts. These transactions costs must be significant: for if this were not the case, it is obvious from the Coase theorem that private bargaining would have solved the congestion problem at issue. This is obviously not intended to imply that quantity allocation is costless; rather, the point is that a price-like scheme cannot be recommended independently of a consideration of the transactions costs it entails as compared to possible alternative approaches to congestion management.

The premise underpinning the PC's approach – which is that some price-like signal of congestion is needed – should not therefore be accepted uncritically. In reality, making proper use of price-like signals is complex in the presence of non-convexities and, in any practical circumstance, entails the specification of an enormous amount of detail. Whether the benefits that can be obtained from relying on price signals exceeds the costs, is an empirical issue that the PC does not appear to address.

2.3 Is land the binding constraint on the airport's service potential?

Premise 2: The availability of land at Sydney Airport is the binding constraint that results in slot scarcity. As a result, land scarcity determines the relevant capacity cost, and the long run marginal cost of acquiring and putting to use additional land is relevant for congestion pricing.

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[14] Coase R, (1937), "The Nature of the Firm", *Economica* 4:386-405.

Even assuming that it was indeed appropriate to use a price-like system of congestion charges to allocate the scarce resource, would land values play a role in setting these charges? The PC assumes that they would, and it bases this on the premise that land is ultimately the cause of constraints on service potential at Sydney Airport.

As a starting point for assessing this premise, it is useful to note that two states can characterise an airport that has to set landing and takeoff fees for the use of slots: in a first state, the welfare maximising decision is constrained by existing capacity; in a second, it is not. In other words, in certain conditions, the price choice (and its derived demand) is ***not*** constrained by the limited possibilities to take-off and land – this is the case at off-peak hours – while in other conditions, the derived demand from a first-best choice ***is*** constrained by the capacity restriction.[15]

The relevant costs differ as between these alternative states. If and when the capacity constraint is ***not*** binding, only operating costs are relevant for socially efficient pricing. As a result, the PC is incorrect in assuming that land valuation ought to have any impact on charging in conditions where the capacity constraint is not binding. Yet its approach to determining the allowed revenue ceiling for at least Sydney Airport would allow land values to so influence charges.[16]

However, the greater interest here is in the situation in which the capacity constraint is indeed binding, with the question then being that of the economic valuation of this constraint.

In economics, the "cost" of a constraint is generally determined by reference to the concept of a shadow price. Shadow prices are used in valuing any item that is rationed in some way;

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15 The unconstrained maximisation problem and the optimisation with inequality constraints (and the related sufficiency of the Kuhn-Tucker conditions) are analysed, for example, in Lancaster K, (1987) *Mathematical Economics*, Dover Publications New York, at page 23.

16 The PC does not discuss efficient charging when the capacity constraint does not bind. However, its approach seems to be one in which the land value is being used to determine an aggregate revenue requirement, with the airport then being free to recoup that requirement as it sees fit. There would, in the scheme, seem to be no restraint on the airport increasing off-peak charges in line with the higher valuation the PC's approach would set.

these prices can be derived using programming techniques. By definition, the shadow price is the amount by which the value of the objective function (in this case, social welfare) would change if the constraint at issue were relaxed by one unit. If a constraint is binding, the shadow price is strictly positive. If a constraint is not binding, its shadow price is zero (since the value of the objective function does not change when an inactive constraint is relaxed).

The concept of a shadow price is the proper basis for understanding the role of land valuation in congestion pricing.[17] The starting point is that, if it were the case that the total land holding was the limiting factor for landing and taking-off, then the long run marginal cost of acquiring land and putting it into use would be the relevant value for estimating the shadow price. However, this is not quite so.

In effect, the marginal cost of land acquisition is only relevant if acquiring land is the most cost-effective means of relaxing the constraint. There are two reasons why this may not be the case.

The first reason is related to one of the negative externalities caused by an airport, namely, noise. In the Sydney Airport context, so as to manage this externality, an hourly cap has been

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17 See Ricardo D, (1815), *An Essay on the Influence of a Low Price of Corn on the Profits of Stock*, London, John Murray; which contains the first formulation of the marginal theory of rent. Ricardo's law of rent is expressed as: the rent of land is determined by the excess of its produce over that which the same application can secure from the least productive land in use. This law, which of course applies to land used for purposes other than agriculture, has been exhaustively explained and illustrated by all the leading economists since Ricardo. But its mere statement has all the force of a self-evident proposition, for it is clear that the effect of competition (or regulation) is to make the lowest reward for which labour and capital will engage in production, the highest that they can claim. This then enables the owner of more productive land to appropriate in rent all the return above that required to recompense labour and capital at the ordinary rate – that is to say, what can be obtained upon the least productive land in use, or at the least productive point, where, of course, no rent is paid. In terms of land valuation for an airport, the ***same*** land is analysed as being ***different*** depending upon the time period and the congestion level. Therefore, the least productive land can be thought of as the land during off-peak period, where no rent is paid. The land value is then based on the congestion rent during the peak period.

imposed of 80 landings or take-offs.[18] As a result, even if capacity at Sydney Airport were increased (as a result, for example, of further investment in land), this would not change the airport's ***effective*** capacity, that is its service potential. In effect, the constraint on service potential is not one of physical capacity; rather, it results from a political choice about how to deal with an externality issue. To the extent to which this is the case, land valuation is simply not relevant. To use the technical vocabulary introduced above, the shadow price of the land constraint is zero (since it is not binding), and the positive shadow price is attached to the political constraint, which cannot be (easily) relaxed.[19]

The second reason relates to the use of Sydney Airport by regional airlines. Basic management of congestion, well before pricing solutions are usually envisaged, generally includes effective management of the scarce resource.[20] It is sound practice in this respect to give a degree of priority (in terms of access to slots) to larger aircraft, as this will usually, though not always, allocate the scarce resource to more productive processes. In the case of Sydney Airport, however, the regulator does exactly the opposite (apparently so as to take account of regional development concerns: a percentage of slots is reserved to regional links, with those links typically using smaller aircraft). This, in turn, constrains the potential the airport has to service larger planes.

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18 Section 6 of the Sydney Airport Demand Management Act 1997 (Cth). Note that this is obviously an example of a quantity, rather than price, control. There is, however, an additional tax payable for travel to and from Sydney Airport, which is used to fund compensation payments to residents in the areas affected by noise pollution.

19 For a recent analysis of the consequences of political group interests on regulatory constraints, see Finkelshtain I and Kislev Y, (1997) "Prices versus Quantities: The Political Perspective" *Journal of Political Economy* 105-1:83-100.

20 Drucker P, (1966), *The Effective Executive*, New York: Harper & Row, offers a helpful and simple distinction. He emphasises the difference between "do things right" or "do the right things". "Doing things right" means efficiency – getting the most from resources. "Doing the right things" means effectiveness – setting the right goals and objectives and then making sure they are accomplished.

Now, it may be the case that this constraint could be relaxed by increasing the land surface at Sydney Airport; however, from an economic point of view, what matters is whether this is the most efficient means of relaxing the constraint. In effect, it may be cheaper, from society's point of view, to relax the constraint either by reducing the number of regional flights in total or by shifting some regional flights to another airport in the Sydney region. If this were indeed the case, then the shadow price would be the net cost of transferring usage away from Sydney Airport. Whether this condition is or is not met depends on a cost-benefit analysis that the PC has not carried out. As a result, the PC is not in a position to say that the cost of land acquisition is an appropriate basis for charging.

In short, the assumption by the PC that land is the binding constraint is unlikely to be valid.

2.4 Should the capacity constraint be relaxed?

> *Premise 3:* Assuming that land is indeed the binding constraint on the airport's service potential, the value of the constraint will in equilibrium equal the long run marginal cost of land.

Establishing that land acquisition is the most cost-effective means of relaxing the constraint on Sydney Airport's service potential is a *necessary* but not *sufficient* condition for land values to be a determining factor in congestion prices. In effect, land values are only relevant if the willingness to pay for the marginal, constrained flight is no less than the long run marginal cost of the additional land – otherwise the constraint should not be relaxed, and its shadow price is simply the social value of the lost load.

To see this, it is important to understand how congestion pricing is intended to work. Consider two travel periods, differentiated by the level of congestion.[21] Congestion in this context can be interpreted as meaning a low speed of traffic, implying that the time cost incurred by each user is high. Assume there are travellers whose benefits differ. For example, business users will place a high value on peak hour travel relative to the value of travel at the off-peak times (for instance, because they would need to forego business opportunities to

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[21] The classic reference is Boiteux M, (1949) "*La tarification des demandes en pointe: Application de la théorie de la vente au coût marginal*" *Revue générale de l'électricité*, 321-40; translated in (1960) as "Peak-load pricing" *Journal of Business*, 157-79.

travel in the off-peak period). On the other hand, holiday-goers may receive relatively little benefit from peak travel. It is useful to imagine each of these types of travellers as being part of a continuum of agents along a line that characterises the value for peak travel.

Individuals will base their decision on the net benefit of travel, which equals gross travel benefit minus time costs. By definition, the time cost will be higher during congested periods. Since the peak yields low gross benefits for tourists along with high time costs, net benefits for this group will be higher in the off-peak period. Conversely, for a businessperson, net benefits will be higher in the peak even with high time costs. In between these extreme cases and along the continuum of agents, as long as net travel benefit is higher in the peak, the would-be traveller will choose the peak period. But as additional travellers make this choice, time costs rise, depressing the net benefit of peak travel. The equilibrium traffic allocation is reached when it satisfies travellers in that no traveller wishes to alter the timing of his or her trip. A standard result is to consider a particular traveller, called the marginal traveller, who is indifferent between peak and off-peak travel. Logically, the marginal traveller will define the allocation between periods – those valuing more the peak travel will actually choose the peak travel, and *vice versa*.

If the process is left to its own devices, the equilibrium choice derived above will not be socially desirable. The reason is that, since external costs are ignored, too many travellers choose the peak period relative to the social optimum. This conclusion can be understood in terms of the difference between the private and social costs of travel. The social benefit of travel is the net private benefit for an individual minus the external costs generated by his or her use of airport facilities. By definition, the net social benefit is lower than the net private benefit during rush hours, while the two coincide in the off-peak period (where external cost is zero).

From society's point of view, an additional individual should travel during peak period as long as the net social benefit of travel is larger in the peak. However, more travel during peak hours causes higher congestion. Eventually, net social benefits become equal between the two periods for the social marginal traveller, who is defined by society being indifferent as to when this individual travels. When this social optimality condition is satisfied, the aggregate net benefits of travel are as high as possible.

The inefficiency of the equilibrium is caused by the failure of users to consider the external costs of the congestion they create. In a simple model, this failure can be corrected if *somebody* levies a "tax" that explicitly captures the external costs. This tax, referred to as a "congestion toll", is set equal to the value of external costs imposed by each traveller.[22] Because external costs are sensitive to the traffic level, they should vary as conditions change. The system thus generates a zero toll in the off-peak period and a positive toll during the peak period, the magnitude of which depends on the volume of peak traffic.

With a toll capturing external costs, the marginal traveller in the no-tax situation, who was previously indifferent between peak and off-peak travel, now finds that peak travel is too expensive. This individual switches to off-peak travel and, in the new equilibrium, a new marginal traveller emerges. For this individual, net private benefits, modified by subtraction of the toll, are equated between periods. Since the toll exactly captures external costs, net social benefits are equated between periods for the new marginal individual. As a result, the new equilibrium coincides with the socially optimal traffic allocation.

The important point to draw from this discussion is that, when dealing with congestion, an alternative to relaxing the constraint is to manage demand, *given* the capacity constraint. The cost of this, in equilibrium, is the net social value of the peak travel foregone – that is, the value taking account of the ability to shift from the peak to the off-peak period.[23] Now, as a general principle of economic policy, when there are alternative ways of dealing with a problem, it is the least costly of these that should be used. Relaxing the capacity constraint involves (if the PC's underlying assumption is accepted) incurring the likely substantial cost of acquiring additional land. Plainly, this should only be done if it is less costly than managing demand, *given* the capacity constraint. As a result, the land value is relevant to congestion pricing ***only*** if it is known that relaxing the space constraint is the least cost approach to the congestion problem.

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22 For an application of this economic tool, see Varian H, (1994) "A Solution to the Problem of Externalities when Agents are Well-Informed" *American Economic Review* 1278-93.

23 Mishan, E J, (1981), *Economic Efficiency and Social Welfare* argues, at pages 209-218, that this social cost should be very low, and possibly close to zero.

There is no *a priori* reason to assume that in fact the marginal cost of land is less than the equilibrium value of lost load, and the PC provides no empirical evidence to support its contention. As a result, the PC appears to be speculating when it says that land values are relevant to efficient charging for Sydney Airport's services.

2.5 The opportunity cost valuation

> *Premise 4:* In determining the long run marginal cost of land acquisition at Sydney Airport for the purposes of congestion pricing, the appropriate benchmark is the value of Sydney Airport's land were it sold for residential or/and industrial usage.

Assuming that the PC's premises were indeed correct (notwithstanding the above considerations), how should the cost of land be determined for the purposes of congestion pricing? The PC essentially adopts a Depreciated Optimum Replacement Cost ("DORC") approach to this issue, in which the value of land is computed by reference to its value in the best alternative use. This value is then used to calculate an aggregate revenue requirement, which is presumably then unitised by volumes of output to derive unit prices.[24]

Given the geographical location of Sydney Airport, it is quite obvious that this approach results in a high aggregate revenue requirement, as the land at issue would have a substantial value if sold for residential and/or industrial and commercial purposes. As a matter of fact, estimates of the annual holding cost for the 652.85 hectares of total land holding for aeronautical purposes range up to A$705 million.

There are at least two problems with this approach.

The first problem is that it seems to confuse ***marginal*** with ***average*** valuations. Even assuming the PC's premises were correct, these premises would determine price at the margin; but unless it is assumed that marginal and average prices must be identical (which seems inconsistent with the PC's own emphasis on the ability of airports to price discriminate), it is unclear why the marginal price should determine the price earned on

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[24] The Draft Report itself is silent on the issue of how the aggregate revenue requirement would be translated into unit charges. The discussion in the Draft Report, however, suggests a fairly straightforward unitisation.

average across all units of output. Rather, the same price at the margin of consumption is consistent with a broad range of average prices, without any loss of efficiency.

Put slightly differently, a given congestion charge can be associated with almost any aggregate revenue requirement, so long as that aggregate revenue requirement is sufficient to fund the airport's continuing operations at the efficient scale. If the charge, when consistently applied, generates revenues in excess of the aggregate revenue requirement, then the excess (or at least that component of it which is purely a congestion rent) can be removed from the airport without any adverse effect on efficiency. Conversely, if the price at peak is less than is needed to fund the airport's continuing operations, and these operations are indeed worth continuing, then the deficiency can be made up through a tax on infra-marginal units.

The assumption the PC makes that the marginal price ought to be simply grossed up into an aggregate revenue requirement for the Sydney Airport's overall aeronautical income is consequently at best unexplained and at worst incorrect.

The second problem is that, even if one wanted to carry out such a DORC-like grossing-up, the PC's approach to it seems difficult to defend. In effect, the PC's approach (which is that previously adopted by SACL), simply asks what the land would sell for were it sold for residential or light industrial use. This makes absolutely no sense.

This is because the approach seems to be based on the assumption that Sydney Airport is shut down. This raises two obvious problems. The first is simply a question of realism; it is difficult to imagine a city like Sydney without an airport able to handle the traffic that Sydney Airport does. Notwithstanding this, even if it were assumed that Sydney could do without such an airport, it cannot be assumed that the value of land in Sydney would be unchanged in the event that the Sydney Airport were in fact indefinitely shut. Rather, it is obvious that the effect of eliminating airport facilities in Sydney would be to lower the price of land in the Sydney region, including that at Sydney Airport. The A$705 million would melt down a great deal. Furthermore, the resulting capital loss suffered by every Sydneysider (and the wider social cost to Australia of the premature stranding of productive

potential at Sydney) would have to be to taken into account in determining the valuation set.[25]

Given this, the approach adopted by the PC (and originally proposed to the Commission by SACL) is in error. Even in terms of a DORC valuation, its vice lies in not being clear as to the alternative being considered. A proper application of the principles underlying the DORC approach would necessitate the estimation of the value under clearly set out alternative assumptions.

For instance, one might consider a scenario in which land use at Sydney Airport was reduced by transferring regional traffic to say, Bankstown Airport. In this case, the costs (and hence the basis for the Sydney Airport valuation) would include:

- the necessary investment in Bankstown Airport to handle more traffic;
- the investment in infrastructure to match the level of services travellers could reasonably expect (for example, roads and public transport from Bankstown to Sydney and to Sydney Airport); and
- finally, the disutility travellers on connecting flights would suffer from a transit between Sydney Airport and Bankstown Airport.

Another possibility would be to develop and maintain a second (major) airport in Sydney. This would indeed ease the congestion constraint at Sydney Airport and allow some sale of land, but it would obviously require substantial investment and impose a broad range of social and private costs. These would be the true cost of relaxing the capacity constraint, and hence would have to form the appropriate basis for the valuation.

Which alternative is the most efficient remains unclear. However, two comments may be made. First, a more rigorous analysis is needed since the "right" result is not straightforward. Secondly, it is not unlikely that simply selling the current land for

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25 For a recent comment and analysis based on the link between land value and infrastructure, see Brittan S, "How land taxes could pay for urban renewal: A levy on windfall gains in land and property values would be a good way to tackle transport congestion", *Financial Times*, 30 August 2001.

residential/industrial use will prove to be the least economical of the alternatives that can be considered. Regardless, the result will differ from that which the PC assumes, which is both implausible and very likely inefficient.

2.6 The welfare costs of excessive charging

> *Premise 5*: Even if the aggregate revenue requirement calculated on the basis of the value of land in alternative use results in prices that are too high, the social costs associated with these prices are not likely to be high.

The PC seems to recognise that calculating the aggregate revenue requirement on the basis of the value of land in alternative use can result in prices that are too high. However, the PC seems to suggest, as a more general theme in its Draft Report, that the social costs of the excess pricing will be low.

The PC's argument is largely based on the assumption that both airports and airlines are efficient price discriminators. However, what is unclear is quite how Sydney Airport would, as a practical matter, structure the new, higher prices so that they fall effectively on infra-marginal demand. Indeed, the aeronautical charges most recently approved for SACL are not infra-marginal in any sense; rather, they seem to fall on passengers and capacity, and hence can affect usage in all periods.

Some, possibly significant, effect on usage is all the more likely if the downstream market (in particular, that for air transport) is non-competitive. In that case, prices in the downstream market are already likely to be set at the point at which demand is elastic, so that charges that are not purely lump-sum will alter output significantly. Indeed, when the downstream market is non-competitive, it can be shown that the imposition of a congestion charge may not increase, and may well reduce, social welfare.

For example, assume that the congested service is a monopsony – that is, that there is only one purchaser (or more properly, direct consumer) of the service that is subject to congestion. In that case, the congestion effect is internalised: when the monopsony is considering the use of the service, it will take complete account of the displacement that any one use causes for others. At the times when the service is approaching its capacity limits, the monopsonist, in taking its consumption decisions, will take account of the fact that each additional use displaces some other use; acting rationally, it will give priority to the most highly valued uses. If the value of the most highly valued displaced use exceeds the marginal cost of expanding capacity, the monopsonist will contract with the facility owner for additional

investment to occur. Conversely, if the marginal cost of capacity expansion is no less than the value of the most highly valued displaced use, then an efficient level of use of the congested capacity will have been secured.[26]

Assume that, in these circumstances, the facility owner imposes a Pigouvian congestion tax. Can social welfare rise? It is difficult to see how it could. At best, the tax, if purely lump sum in character, could redistribute rents from the monopsonist to the monopolist; at worst, however, a tax that was not lump sum in incidence would distort the downstream monopsonist's output decisions. Indeed, the monopsony by definition is a monopoly in the provision of airline services and hence tends naturally to reduce its output – even if it is not *directly* linked to a goal of managing congestion. The introduction of a congestion charge that is not purely lump sum will simply result in its reducing its output further.

This can be put succinctly by saying noting that Coase plus Pigou is "too much of a good thing".[27] This result is further explained in Appendix B to this report.

To understand this result,[28] consider a situation where the airport is entirely dominated by a monopoly airline. Thanks to market power, the airline is a price-setter, as opposed to a price-taker in the competitive environment. Its profit maximisation will lead to the determination of two fares: one for peak travel and another for off-peak travel. Travellers will choose their travel time by considering net travel benefits, which now take fares into account. The net travel benefits for an individual are now equal to gross benefits minus time cost minus the fare paid. As before, individuals choose the travel period yielding the larger value.

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26 This is not to say that the costs of monopoly have been overcome, but there are no additional inefficiencies due to the presence of a congestible resource.

27 Friedman D G, (2000) *Law's Order: What Economics Has to Do with Law and Why It Matters*, Princeton University Press at 57. Buchanan refers to this as an "elementary point": Buchanan J, (1969), *Cost and Choice: An Inquiry in Economic Theory*, Chicago: Markham Publishing Co, at page 68.

28 Daniel J I, (1995), "Congestion Pricing and Capacity of Large Hub Airports: A Bottleneck Model with Stochastic Queues", *Econometrica*, 63:327-70 sets out a formalisation of the concept that is now widely accepted.

When setting fares, the monopoly airline automatically internalises the externality: reducing the peak fare encourages travel in the peak period, while raising the fare discourages it. The off-peak fare is set at a level that makes the individual with the lowest off-peak benefits indifferent between travelling and not travelling. As a result, this fare is not really relevant to the problem at hand since it is not used to adjust the allocation of traffic between periods. The monopoly airline's calculations on whether to shift some traffic to the peak period are based on the following. If it decides to move a flight from off-peak to the peak period, it earns more revenue because the higher peak fare is charged. But the latter must be cut slightly below its previous value in order to compensate the previously marginal passengers for the higher time costs. In addition to this fare reduction, the airline experiences another negative effect: higher operating costs for all existing peak flights as a consequence of the higher congestion caused by the additional flight.

The usual marginal calculus applies: the airline's profit will be as high as possible when the gains and losses from shifting a flight to the peak exactly cancel out, leaving profit unchanged. For this balance to occur, the revenue gain from charging the higher peak fare to previous off-peak passengers must equal the loss from higher passenger time costs (captured by the required peak fare reduction) plus the loss from higher operating costs for existing peak flights.

When this equilibrium condition is satisfied, the allocation of traffic between periods is also socially optimal: the difference between the peak and off-peak fares, which generates the revenue effect discussed above, exactly mirrors the difference in travel benefits, less time costs, between the two periods. As result, satisfaction of the equilibrium condition means that individual travel benefits minus time costs, net of the external cost of congestion, are equated between the peak and off-peak periods. As seen in the standard analysis of congestion, satisfaction of this condition guarantees that the allocation of traffic between the periods is socially optimal.

To summarise, the monopoly airline internalises the congestion. This conclusion is obvious with respect to the higher operating costs caused by congestion. However, the internalisation of passenger time costs, which occurs because these costs affect the peak fare, is subtler. Because the monopolist controls the peak fare and must reduce it as higher congestion

pushes up time costs of the traveller, these costs are ultimately taken into account in the pursuit of profit.[29]

The internalisation of externality by a monopoly airline yields an important conclusion regarding congestion pricing. In particular, it implies that congestion tolls are not needed. Moreover, imposing congestion tolls in this situation would be counterproductive, leading to under-use of the peak period.

Relaxing the assumption that the user of the congestible service is a monopsonist obviously changes matters. But important complexities remain so long as the market structure of the using activity is significantly less than competitive. More specifically, if the using activity is imperfectly competitive, then any Pigouvian taxes must take the nature of price setting in the downstream market into account.

Now, consider the oligopoly case, where several large airlines serve the airport. In contrast to the competitive case, each carrier is large enough to exert market power, but each faces competition from the other carriers. The behaviour of airlines in this setting is similar to that in the monopoly case. In particular, if one of the oligopoly carriers wishes to shift a flight from the off-peak to the peak period, it must accept a lower peak fare, which encourages some passengers to switch to the peak. Once again, the fare reduction must offset the increase in time cost per passenger caused by the extra peak flight. While the lower fare applies to peak passengers on all carriers, the revenue loss for the carrier at issue arises only because its own passengers are paying less. As a result, the carrier internalises only the increase in time costs experienced by its own passengers. The increase in time costs for passengers using other carriers is ignored. Similarly, the carrier takes account of the increase in operating costs for its own existing peak flights when it adds a new flight to the peak. But it ignores the increase in peak operating costs for other carriers.

The conclusion is that an oligopolistic carrier internalises only a portion of the congestion created when it operates an extra peak flight. Because congestion is only partially internalised, the solution is again to levy a congestion tax in the peak period. But the toll has a different magnitude than in the competitive case discussed above, where no congestion

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[29] In the tradition of the pure theory of externality, all of this is completely consistent with the allocation of a property right over the scarcity to solve the problem.

was internalised. Now, the toll should capture only the portion of external cost that is not internalised, being equal to the external congestion cost generated by an extra peak flight times one minus each carrier's airport flight share. Additionally, the efficient toll must take account of double marginalisation in the downstream market. Under a wide range of conditions, the optimal toll will then be below that charged in a market characterised by perfect competition.

The PC's analysis ignores these complications – which nonetheless seem highly relevant to the current situation at Sydney Airport (where Qantas now accounts for an extremely high share of passenger movements).

2.7 Allocation of congestion rents

> *Premise 6*: It is appropriate to allocate any congestion rents collected through the congestion price to the owner of the airport.

As a result of the analysis of the efficient pricing and investment policy related to the management of congestion, it is clear that two alternative devices can be used: either the airport should add a mark-up to its price to signal scarcity and thereby "flatten the peak and raise the troughs"; or the airport ought to invest capital to expand its capacity and relax the scarcity constraint. Clearly, the choice between these ought to be driven by relative social cost. If it is socially costlier to expand capacity than to displace some traffic load, the latter option is preferable, and *vice versa*. Technically, for each unit of traffic in the peak period, the choice is based on the *minimum* of, first, the value of the displaced load, and secondly, the increase in capacity cost.

At least two important conclusions can be drawn from this analysis. First, efficient pricing and investment are inextricably linked.[30] Each is viewed as an alternative solution to the same issue with its own costs. However, under very general conditions, an efficient situation is only reached when the marginal costs of using these instruments are equal. Achieving this equalisation is a necessary condition for social optimality.

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30 See Dreze J, (1964) "Some Postwar Contributions of French Economists to Theory and Public Policy" *American Economic Review*, 54:1-64.

Secondly, under very general conditions, this equality will be reached at a point where congestion still occurs. Since there is a trade-off between the alternative instruments, it makes sense to assume that the optimal capacity investment will not be at such a level that the constraint is never binding. This is no different from a standard result in the extensively-analysed issue of environmental externalities - generally, the optimal level of pollution is not zero; rather, there is a point where the social benefits from reducing pollution any further is equal to its social costs and the efficient trade-off has been achieved.

As a result, one would not expect a social-welfare maximising airport to set charges in such a way that no congestion rents were being collected. However, it is not easy for an outside observer to determine that the level of congestion actually being observed is socially efficient. There is consequently a principal-agent problem involved in delegating the setting of congestion charges to the airport when it is the airport itself that will own the resulting rents. This is because there will be an incentive for the airport to save on capacity costs in order to earn the resulting congestion rents. In other words, the airport owner will not test investments against the social shadow price of congestion; rather, it will test them against its private shadow price, which will differ from the social rate unless the airport is a perfect price discriminator (which, in the case of Sydney Airport, SACL clearly is not).

Does the fact of impending privatisation in any way alter this analysis? The PC claims that it does, largely because the obvious wealth transfer from air travellers to Sydney Airport will be capitalised into bids made for the airport and will result in a correspondingly higher valuation.

To the extent to which a scarcity rent will be earned in any event, and its magnitude is essentially unaffected by the allocation decision, taxing it to the Commonwealth ***may*** improve the distribution of income. However, for reasons set out above, these premises do not hold in the case at hand: rather, it seems reasonable to assume that the approach the PC recommends will result in at least some welfare losses and not merely in income transfers. The PC's argument must then involve a comparison of two parameters. The first is the welfare cost of the rents being allowed to the airport owner (and which it is presumed will be capitalised into the sale price of the asset); the second is the social gain from relaxing the Commonwealth's fiscal constraint by the amount of the additional funds, taking account of the fact that a similar amount could have been raised by other means (that is, by increasing other taxes or by reducing outlays). Since the PC estimates neither of these, it is by no means clear how it can reach the conclusion it sets out.

Moreover, it needs to be pointed out that the PC's argument could be read as a general argument in favour of creating and privatising monopolies. Even if this is not the PC's

intention, the fact that welfare gains to consumers are being traded off against a (purely illusory[31]) income gain to the Commonwealth, highlights the risk of misinterpretation.

Finally, it seems difficult to believe that the privatisation argument could be used to limit to SACL, and SACL alone, the right to receive congestion rents; rather, the likelihood is that, eventually, other airports too will seek to receive congestion payments. At that point, competitive neutrality will dictate that they be treated equivalently to SACL. As a result, the wealth transfers will be generalised, with gains to the owners of the already privatised airports. It is difficult to believe that these gains amount to an improvement in the income distribution.

3 Conclusion

In summary, our view is that the PC's Draft Report and its conclusions about the issues analysed here are flawed in a number of important respects.

For example, congestion is, by definition, an externality. However, this well-studied concept is relatively little used in the relevant sections of the Draft Report. Instead, the PC evaluates the issues in very general terms, proposing regulatory arrangements as if they were obvious. This is far from being the case.

As a result, important options are not analysed fully or even at all and, at times, it is by no means clear quite what assumptions the Draft Report is making. Little empirical evidence is presented on the matters being considered, even though some of the Draft Report's conclusions rest on what are ultimately empirical issues. Given the relatively high stakes involved, it would seem desirable to proceed to a more systematic and comprehensive analysis in the PC's final report.

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[31] Unless there are differences between the rate of welfare loss from the taxation and the social cost of government funds, with the second being less than the first, then the alleged gain disappears. If the first is less than the second, then there is a net social loss; if the two are equal, then any redistribution is merely an instance of fiscal illusion.

Appendix A: Non-convexities

This Appendix A considers the results of the planning literature that relate to the non-existence of equilibria in the presence of non-convexities, and to the possible solutions in terms of quantitative targets.

The intuition is based on the fact that, when an agent receives a quantity (instead of a price) signal, the scale of production is given. In other words, the quantity level is exogenously fixed and does not result from the firm's own choice. Therefore, it is not subject to the problem of the jumps in the demand or supply functions and hence, non-convexities are not a problem. Indeed, from a more general point of view, it is the quantity-coordination mechanism (and not that functioning through prices) that is *de facto* the dual to the market mechanism in terms of information flows.[32] When the central planner (that is, the entity allocating rights of access to the scarce resource) uses a market-like price system, it sends one signal only. The information flow is based on the planner sending a price message, and receiving a response in the form of quantitative targets. The market mechanism is such that all agents will respond, no matter how heterogenous they are. Each of them will send a quantity as a response, that will be such as "since you tell me $X, I tell you Y units of output". In contrast, in a system oriented around the allocation of quantities, the central planner sends a tailored signal to each unit, which responds with its own characteristic. In the purest systems of this kind, the central planner sends out quantitative targets and receives marginal productivities (that is, prices) as a response. The central planner's signal would be "produce Y units", with the response being of the form "I will do it for $X". In the context of airports, the price system is based on landing/take-off fees, which airlines receive as a signal of slot scarcity. The quantity system is the complete, coordinated allocation of slots to individual airlines.

Although the two approaches seem identical, they are in fact profoundly different. The informational load is undoubtedly greater in quantity coordination but, first, this burden is

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32 Heal's paper (1969), "Planning without prices" *Review of Economic Studies* 36:346--362, reverses the types of signal used in the Arrow-Hurwicz model, which is the solution to the problem related to equilibrium and non-convex production sets, first noted by Guesnerie R, (1975) "Pareto Optimality in Non-Convex Economies" *Econometrica* 43-1:1-29.

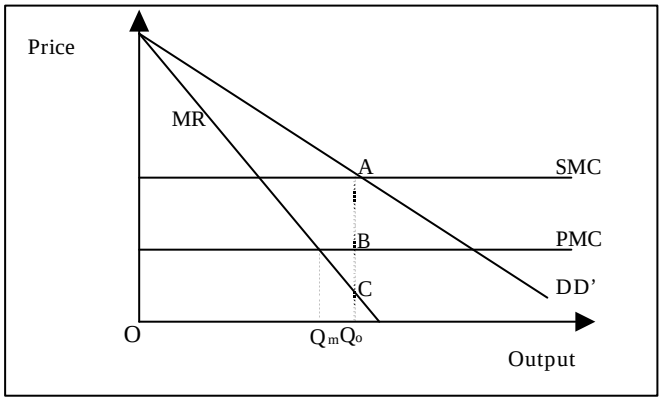
necessary if individual plans are to be compatible in the context of non-convexities and, secondly, even if more numerous, the relevant decisions are easier to make. Indeed, each decision will involve a single business unit and not the entire economy and, hence, will involve less uncertainty.

In short, where there are non-convexities, as is typically the case in transport systems subject to congestion, it cannot properly be assumed that coordination of resource use through price-like signals will be efficient. Rather, processes of quantity allocation seem more likely to yield efficient solutions, at least from the perspective of economic theory.

Appendix B: Implications of "Coase plus Pigou"

The purpose of this Appendix B is to explain the problems that arise when Pigouvian taxes are imposed in a context in which some Coasian internalisation of an externality may already have occurred. These problems are often referred to by noting that "Coase plus Pigou is too much of a good thing".

Consider the situation of a monopolist that imposes an external effect that it does not take into account in its economic decisions. Assume the firm at issue has a monopoly over airline services.



In the figure above, let DD' represent the airline demand curve and MR the corresponding marginal revenue curve. Assume a constant (private) marginal cost PMC. The (congestion) externality is accounted for by a social marginal cost SMC greater than PMC.

The profit maximising behaviour of the monopoly leads to an output OQ_m.

Following the simple Pigouvian precept, imagine the central planner (or the regulator or the airport) subjects the monopoly airline to a congestion fee. Social welfare is maximised when the social marginal cost and private marginal cost (including the tax) are equal. As said in the

main text, the tax t is such that PMC+t=SMC. In the figure, t=AB.[33] From the figure, we see that the optimal output is OQ_o.

Barnett explains this outcome in the following terms:

> "Two sources of misallocation can occur with imperfectly competitive polluters. One is the distortion due to the externality, and the other is the underproduction of final products generally associated with the exercise of monopoly power. A tax on pollutants will reduce the generation of external damages, but it may also cause firms to reduce further their production of final products. Thus there may be tradeoffs between the two distortions, one due to monopolistic underproduction and the other due to external diseconomies. A tax based only on marginal external damages ignores the social cost of further output contraction by a producer whose output already is below an optimal level.
>
> An ideal solution to this problem would incorporate the two policy actions: a device to increase production of final products together with a tax to control the external diseconomy. It is assumed, however, that the product market distortion cannot be directly corrected, and so the pollution tax must achieve an optimal second best tradeoff of distortions."[34]

In our framework, the optimum would require two policy actions: a Pigouvian tax AB and a subsidy on production equal to BC (the difference between marginal cost and marginal revenue).

In the realistic case where subsidies are not possible, the solution is to set the tax equal to the standard Pigouvian tax *minus* the hypothetical subsidy. Three results with respect to this analysis are interesting. First, the optimal tax under a monopoly is *always* lower than the standard Pigouvian tax. Since a monopolist already restricts output below the optimal level, a (full) additional restriction induced by a Pigouvian tax is welfare reducing. Secondly, the tax varies directly with the monopolist's price elasticity of demand: the more price elastic is

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33 This level would be consistent for a competitive firm pricing at (private) marginal cost PMC.

34 Barnett A H, (1980), "The Pigouvian Tax Rule Under Monopoly" *American Economic Review* 70:1037-1041.

demand, the smaller is the departure from the optimal marginal pricing[35] and hence the smaller is the welfare loss associated with any reduction in output. Therefore, if the price elasticity is low, as is the case for the demand for aeronautical services, the tax ought to be small. Thirdly, and this is the corollary of the second result, if the price elasticity of demand tends to infinity, the optimal tax under monopoly does ***not*** differ from the standard Pigouvian tax. As a matter of fact, this is entirely consistent with intuition, since an infinite price elasticity of demand makes the monopolist act as if it were in a competitive environment.

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35 See Baumol W and Bradford D, (1970), "Optimal Departure's from Marginal Cost Pricing" *American Economic Review* 265-283.