

Public Goods *and* Pigouvian Taxes

Agnar Sandmo

Abstract.

This paper consists of the text of two articles prepared for the second edition of the *New Palgrave Dictionary of Economics*. The first article provides a mathematical and diagrammatic exposition of the theory of public goods as originally formulated by Samuelson. It describes the extension of the model to take account of the costs of distortionary taxation, and discusses the concept of the marginal cost of public funds. Different types of public goods (such as mixed goods and local and global public goods) are discussed before turning to a survey of the incentive problems related to preference revelation. The second article considers the use of taxes designed to correct for negative external effects. It sets out the basic theoretical argument and considers the modifications that have to be made when these taxes are seen in the context of an otherwise distortionary tax system. It also briefly considers the issue of the 'double dividend' from a green tax reform.

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Public Goods.

The development by Paul Samuelson (1954, 1955) of the modern theory of public goods must be counted as one of the major breakthroughs in the theory of public finance. In two very short papers Samuelson posed and partly solved the central problems in the normative theory of public expenditure:

(1) How can one define analytically goods that are consumed collectively, that is for which there is no meaningful distinction between individual and collective consumption?

(2) How can one characterize an optimal allocation of resources to the production of such goods?

(3) What can be said about the design of an efficient and just tax system which will finance the expenditures of the public sector?

None of these questions was entirely new to the literature of public finance. Indeed, more than 250 years ago David Hume (1739) noted that there were tasks which, although unprofitable to perform for any single individual, would yet be profitable for society as a whole, and which could therefore only be performed through collective action. The theme was later taken up by Hume's friend Adam Smith, who maintained that one of the duties of the state consisted in

'erecting and maintaining certain publick works and certain publick institutions, which it can never be for the interest of any individual or small number of individuals, to erect and maintain; because the profit would never repay the expense to any individual or small number of individuals, though it may frequently do much more than repay it to a great society.' (Smith 1776; 1976, 687-688.)

Apart from this insight, however, the progress made over the next centuries, certainly with regard to problems (1) and (2), was rather modest. From the point of view of the history of ideas, this is hardly surprising. What is required is a satisfactory theory of market failure. But this presupposes a clear understanding of the optimality properties of the market allocation of resources, and this was not established until the modern development of Paretian welfare

economics which started in the late 1930s. More was undoubtedly achieved with respect to problem (3), reflecting the fact that problems of tax incidence had been a central area of theoretical analysis ever since the time of the classical economists, and that criteria of just taxation had developed independently of any analysis of the expenditure side of the public budget. Still, Samuelson's formulation was in every respect a great leap forward, presenting an integrated solution to all three problems, and determining the research agenda for the years to come. It is therefore natural to begin by setting out the basic elements of his model.

In a short essay it is of course impossible to do justice to the large literature in this field. For more comprehensive surveys the reader is referred to the textbooks by Atkinson and Stiglitz (1980, lectures 16–17) and Myles (1995, chapter 9), and the article by Oakland (1987).

The Samuelson model.

The aim of the model is to derive conditions for optimal resource allocation in an economy in which there are two types of goods, private and public. It is worth emphasizing that these terms do not prejudge the respective tasks of the private and public sectors; the analysis at this stage is institution-free and can best be considered as representing the problems of a planner who knows the production possibilities of the economy, the preferences of the consumers and his own ethical values. The definition of the two types of goods is technological, not institutional.

The nature of the two types of goods is defined by the equations which give the relationship between individual and aggregate consumption. For private goods the total quantity consumed is equal to the sum of the quantities consumed by the individuals, so that

$$x_j = \sum_{i=1}^I x_j^i, \quad (j = 0, \dots, J) \quad (1)$$

where the superscript refers to individuals and the subscript to commodities. For public goods the corresponding relationship is one of *equality* between individual and total consumption, namely

$$x_k = x_k^i, \quad (i = 1, \dots, I; k = J + 1, \dots, J + K). \quad (2)$$

Individual preferences, represented by utility functions, are then defined over the quantities consumed of private and public goods, so that we can write the utility of individual i as

$$\begin{aligned}
U^i &= U^i(x_0^i, \dots, x_J^i, x_{J+1}^i, \dots, x_{J+K}^i) \\
&= U^i(x_0^i, \dots, x_J^i, x_{J+1}^i, \dots, x_{J+K}^i), \quad (i = 1, \dots, I)
\end{aligned} \tag{3}$$

The definition (2) has given rise to some confusion and controversy. Are there actually any goods which can be described by this definition? The usual answer is that there are some cases of ‘pure’ public goods, like national defense, which can indeed be so described; in such cases consumer benefits are directly related to the total availability of the good in question, and the consumption benefits of any one individual do not depend on the benefits enjoyed by others. This property of public goods is usually referred to as non-rivalry in consumption; given the supply of the good in question, the consumption possibilities of one individual do not depend on the quantities consumed by others as they do in the case of private goods. However, many goods which it is natural to think of as public, turn out on closer inspection to have elements of rivalry. A road may satisfy the definition of a public good as long as the traffic is low, but with higher density and consequent congestion this will no longer be the case. Accordingly, several studies have been devoted to the analysis of ‘impure’ public goods, combining in some way the properties of private and public goods in the original Samuelson definition; we shall return to this below. It should be observed, however, that the Samuelson formulation does not assume that the *benefits* derived from the supply of the public good are the same for all, even though *availabilities* are the same. Neither does it assume that the benefits from public goods are independent of the quantities consumed of private goods. And the elements of rivalry in the road congestion example may be captured by introducing externalities in the consumption of a private good – car use – whose benefits depend on the supply of a public good – the road. Thus, the original Samuelson formulation offers great flexibility of interpretation, and we have been provided with an answer to the first of the main problems noted above.

We now turn to the problem of optimality of resource allocation and begin by characterizing a Pareto optimum for this kind of economy. Since the interesting special features of the model are on the consumption side only, we assume that the conditions for efficient production are satisfied, so that the production possibilities for the economy can be summarized in the transformation or production possibility equation

$$F(x_0, \dots, x_J, x_{J+1}, \dots, x_{J+K}) = 0 \tag{4}$$

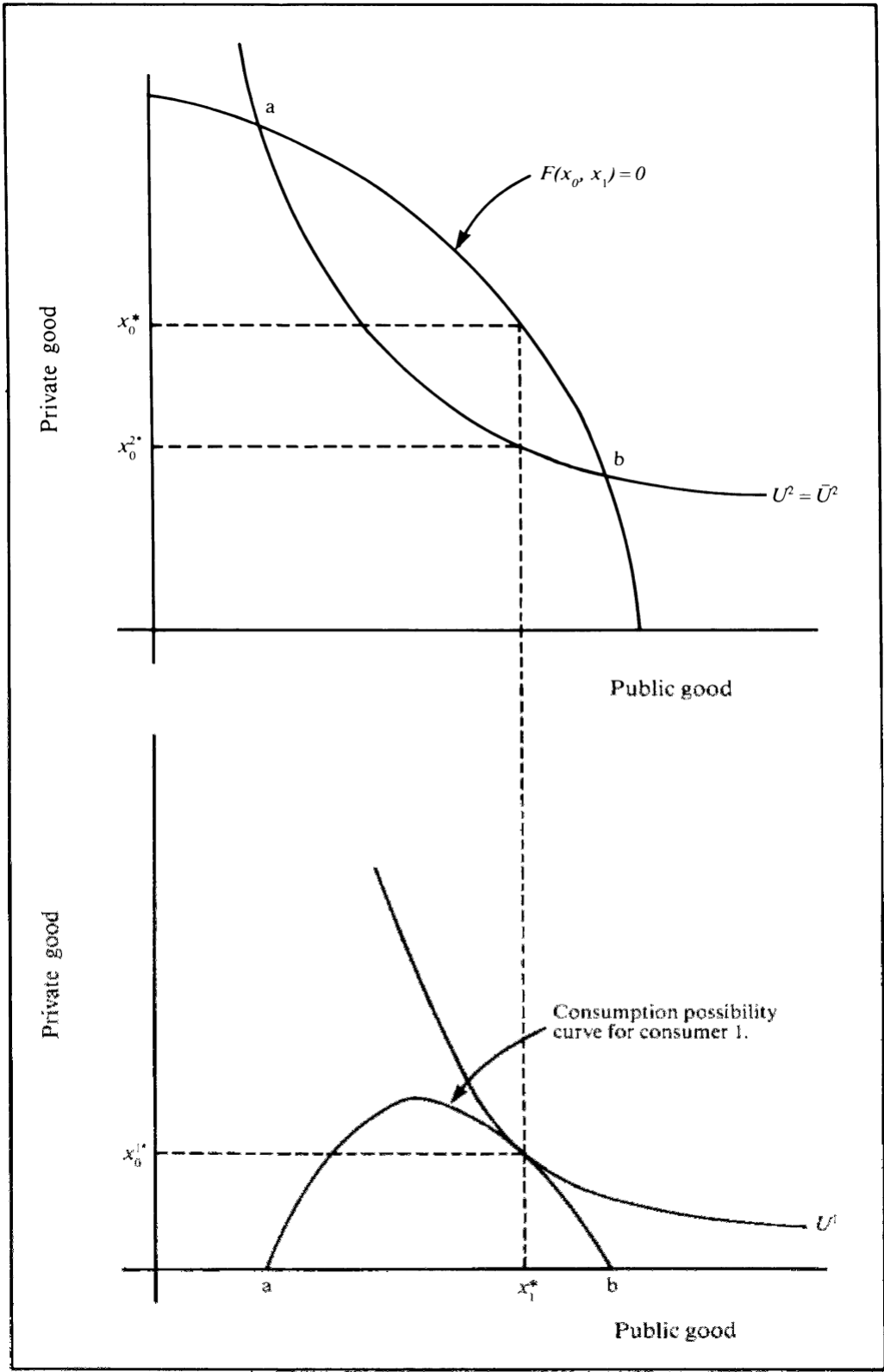


Figure 1 Pareto optimality with one private and one public good.

The problem of Pareto optimality may now be formulated as follows: of all allocations satisfying equation (4), find the allocation which maximizes utility for consumer 1, given arbitrary but feasible utility levels for all other consumers. As shown by Samuelson (1955),

the solution can be given an instructive graphical solution in the two-dimensional case. We therefore begin with the case where there are two consumers and one private and one public good. In the upper panel of Figure 1 we have drawn the production possibility curve as well as an indifference curve corresponding to the fixed level of utility for consumer 2; since the two curves intersect, there are obviously a number of allocations which satisfy these two constraints. In the lower panel the curve ab shows the consumption possibilities for consumer 1, the points a and b corresponding to the points of intersection in the upper panel. For any point on U^2 between a and b, it must be the case that the two individuals consume the same amount of the public good, while consumer 1's private good consumption is equal to the vertical difference between the production possibility curve and consumer 2's indifference curve. The best allocation from 1's point of view is then given by the tangency between his indifference curve and the consumption possibility curve in the lower panel. This determines the optimum supply of the public good (x_1^*) and consumer 1's consumption of the private good (x_0^{1*}) as well as the consumption of consumer 2 (x_0^{2*}).

The slope of the consumption possibility curve must of course be equal to the difference of the slopes of the two curves from which it is derived. The tangency point can therefore be characterized in terms of marginal rates of substitution and transformation as

$$MRS^1 = MRT - MRS^2, \quad \text{or } MRS^1 + MRS^2 = MRT.$$

In more precise mathematical terms this condition can be rewritten (letting subscripts denote partial derivatives) as

$$\frac{U_1^1}{U_0^1} + \frac{U_1^2}{U_0^2} = \frac{F_1}{F_0}. \quad (5)$$

In words: the sum of the marginal rates of substitution should be equal to the marginal rate of transformation between the public and the private good. Or, since the private good may be taken as a numéraire commodity, the sum of the marginal willingness to pay for the public good should be equal to the marginal cost of production. The intuition should be clear: an extra unit of supply benefits both consumers simultaneously; to find the total marginal benefit we have to take the sum of the marginal benefits accruing to all consumers. Problem (2) has been solved.

The mathematical derivation of the corresponding condition in the general case need not occupy us here. To extend the analysis to more than two consumers, we have only to add more terms on the left-hand side of (5). An increase in the number of public goods simply requires us to introduce similar conditions for every such good. To generalize to an arbitrary number of private goods, we note that for any given allocation of public goods, the allocation of private goods should be a Pareto optimum relative to this, so that the usual marginal conditions must hold. This gives us two sets of first order conditions for Pareto optimality, namely.

$$\frac{U_j^i}{U_0^i} = \frac{F_j}{F_0}, \quad (i = 1, \dots, I, j = 1, \dots, J) \quad (6)$$

$$\sum_{i=1}^I \frac{U_k^i}{U_0^i} = \frac{F_k}{F_0}, \quad (k = J + 1, \dots, J + K). \quad (7)$$

In the two-dimensional case the first order conditions could be taken to describe a true maximum because the diagrams introduced the required convexity–concavity conditions. In the more general case one has to assume quasi-concavity of the utility functions as well as convexity of the transformation surface for the second order conditions to be satisfied.

There is of course an element of arbitrariness in the concept of Pareto optimality, corresponding to the arbitrary location of consumer 2's indifference curve in Figure 1. The model can be closed by assuming the existence of a social welfare function, and the usual assumption is that this is of the Bergson–Samuelson type, where the arguments of the function are the individual utility levels. Maximizing the welfare function $W(U^1, \dots, U^I)$ gives as the optimality conditions first (6) and (7)—since a welfare optimum must be a Pareto optimum — and then a set of conditions for optimal distribution of consumption between individuals.

These can be written as

$$W_i U_0^i = W_h U_0^h, \quad (i, h = 1, \dots, I). \quad (8)$$

The marginal social utility of consumption should be the same for all. (Note that although the conditions as stated here refer to the consumption of private good 0, they can be converted, by using conditions (6), to express the equality of the marginal social utility of consumption in terms of any private good.)

Suppose now that private goods are allocated through a system of perfectly competitive markets, and that the allocation of resources to public goods also satisfies the efficiency conditions (7) as the result of some decision procedure which is yet to be specified. Imagine further that at least part of the provision of public goods is undertaken by the public sector, and that taxes are needed to finance this. What is the ideal tax system for this purpose? We wish the tax system to satisfy conditions (8), but these are conditional on the remaining first order conditions being satisfied. Under competitive conditions the marginal rates of substitution will be equal to consumer prices, taking commodity 0 to be the *numéraire* good, while marginal rates of transformation will correspond to producer prices. Thus, conditions (6) will be satisfied in a competitive economy provided that consumer prices are equal to producer prices. But this means that there must be no distortionary taxation; the only taxes which are consistent with a fully optimal solution are lump sum taxes in amounts which are independent of all components of demand and supply for consumers and firms. This is of course an insight which is well known from the standard competitive model with private goods only, but it is worth restating in the present context as the answer to problem (3).

This exposition of the basic elements of the Samuelson model can be used to put his contribution into historical perspective. Earlier writers on public finance, for example Mazzola (1890), Sax (1924) and Pigou (1928), did in fact apply marginal utility theory to the problem of the optimal supply of public goods, emphasizing the optimality rule that marginal benefit at the optimum should be equal to marginal cost. They failed, however, to develop a definition of public goods which could be used to characterize the difference between such goods and private goods. For the same reason they were also vague about the nature of the marginal benefit and how to measure it in the absence of market prices. Finally, although there is much interesting discussion by the older writers of the ability to pay and benefit theories of taxation, the efficiency aspect of taxation played a very minor part in their writings, and so they were unable to face the basic problem of how to reconcile the objectives of a just distribution and economic efficiency. With the Samuelson formulation all these issues had been clarified, and the foundation had been laid for further progress.

Distortionary Taxation

The above optimality rules hold for the case where taxation is non-distortionary, that is where taxes are imposed to raise revenue and to redistribute incomes without disturbing the efficiency properties of the price mechanism. For a variety of reasons such taxes are hardly feasible, and it is interesting to consider the modifications that will have to be made if taxes are distortionary. Pigou (1928) argued that the cost of tax distortions should be taken into account in balancing the costs and benefits of public goods supply:

‘Where there is indirect damage, it ought to be added to the direct loss of satisfaction involved in the withdrawal of the marginal unit of resources by taxation, before this is balanced against the satisfaction yielded by the marginal expenditure.’ (Pigou 1928; 1947, 34.)

As pointed out by Atkinson and Stern (1974), however, this argument is not necessarily correct. Their analysis is an interesting exercise in the theory of the second best.

To abstract from problems of redistribution, consider the case where all individuals are identical. There are two private goods, numbered 0 and 1, and one public good, identified as commodity 2. The representative consumer maximizes his utility function $U(x_0, x_1, x_2)$ subject to the budget constraint

$$x_0 + P_1 x_1 = 0. \quad (9)$$

Thus, there is no lump sum income, and commodity 0 serves as the *numéraire*. Given the optimum of the consumer, the government maximizes the sum of the utility functions (a special case of the welfare function in the previous section) subject to the constraint that the resource cost of public goods supply equals the tax revenue. Thus, the government maximizes $IU(x_0, x_1, x_2)$ subject to

$$It_1 x_1 = p_2 x_2. \quad (10)$$

Here I is as before the number of consumers, t_1 is the tax per unit of commodity 1 such that $P_1 = p_1 + t_1$. The small p s denote producer prices, which for convenience are taken to be constant, corresponding to constant unit costs of production in terms of the *numéraire*. The government determines t_1 and x_2 simultaneously.

The analytical details of the model need not concern us here. To understand the result, one should note that from the formulation of the consumer's problem it follows that demand for the taxed good depends on the supply of the public good, so that the demand function can be written as $x_I = x_I(P_I, x_2)$. Thus, when the supply of the public good is increased, there will be two effects on the demand for private goods. One is the effect via increased availability of the public good, another is the price effect via increased taxation. It can be shown that the condition corresponding to the Samuelson equation (7) in this case becomes

$$\sum_i MRS^i = \frac{p_2 - t_1 I (\partial x_1 / \partial x_2)}{1 + (t_1 / x_1) (\partial x_1 / \partial t_1)}. \quad (11)$$

If there is no distortionary taxation, the right-hand side becomes simply p_2 , which is the marginal rate of transformation, and we are back to the original Samuelson case. An increase in the tax rate lowers the demand for the taxed good, and the corresponding term in the denominator shows that this 'blows up' the cost of the public good; this is the effect alluded to by Pigou. On the other hand, the additional term in the numerator can in principle be of either sign and may therefore reverse Pigou's conclusions. Suppose that $\partial x_1 / \partial x_2$ is positive, meaning that increased supply of the public good increases the demand for the taxed good. Then the relevant social marginal cost of the public good may in fact be lower than the pure resource cost. The point is that in this case the effect of the public good on the demand for the private good serves to counteract the tax effect. The commodity tax is distortionary because it lowers consumption and production of the taxed good. If an increase of the amount of the public good serves to push the quantity of the taxed good back towards its first best optimal level, this could lower the economic cost of production.

This analysis has inspired a considerable literature about the concept of the *marginal cost of public funds* (MCF). Starting from the insight provided by the formula (11), it has been suggested that practical calculations of the optimal amount of public expenditure should be based on the formula

$$? MRS^i = MCF \cdot MC,$$

where MC corresponds to p_2 and the presumption is that $MCF > 1$. The use of the MCF for practical cost-benefit analysis of public goods provision - one of the more important

applications of the pure theory of public goods - would therefore tend to depress the provision of public goods below the level indicated by the Samuelson rule.

This conclusion may be disputed, however. First, it is not clear that equation (11) supports the hypothesis that the marginal cost of public funds exceeds one. Even if we assume, which seems reasonable, that the tax elasticity is negative, complementarity between private and public goods ($\partial x_1 / \partial x_2 > 0$) might lead the right-hand side of (11) to become less than p_2 . However, since the sign and magnitude of the complementarity term must be expected to differ between different types of public sector projects, there is a good case for considering this term to be project specific and therefore not to include it in a general measure of the cost of distortionary tax finance. In this view, it is the tax elasticity of demand that is important for the *MCF*.

Second, there is one feature of the Atkinson-Stern analysis which calls for particular caution in practical application. This is the assumption that the government optimizes both with respect to public goods supply and the tax rate. In principle, therefore, their results are valid only for an optimal tax system, although it can be shown that the formal expression for the *MCF* is the same also for a non-optimal tax system (see e.g. Sandmo 1998). More importantly, however, in the more realistic case where there are many tax rates which have not been chosen optimally, there is no reason to expect that the *MCF* will be the same for all sources of tax finance. It will therefore be misleading to speak about *the* marginal cost of public funds, as if it were a general characteristic of the whole complex system of direct and indirect tax rates.

Third, in order to focus on the efficiency aspects of the problem, Atkinson and Stern made the assumption that all consumers are identical. But one of the reasons why we have distortionary taxation is the fact that they are not, and that governments try to achieve some measure of redistribution through the design of the tax system. As shown by Sandmo (1998), an explicit modeling that takes account of the redistributive objective leads to a measure of the marginal cost of public funds where the efficiency loss from taxation may, depending on the distributional preferences embedded in the government's policies, be partly or wholly offset by distributive gains.

Types of Public Goods

In line with the original Samuelson formulation we have so far limited the discussion to pure public consumption goods. Various alternative formulations have been discussed in the literature, and we shall briefly discuss some of these.

We have already observed that many consumption goods which may be classified as public turn out also to have important elements of 'privateness'. This has two aspects. In the first case it may be argued that a public good like a national park cannot really be enjoyed by the individual without expenditure on private goods like hiking equipment etc., and that even such an apparently clear case of a public good should be analyzed as a mixed case of a private and a public good. To some extent this argument is based on a misunderstanding of the theory. There is no presumption that the benefit that an individual derives from the availability of a public good be independent of his consumption of private goods. Still, it may sometimes be useful to model the interaction between private and public goods consumption in a more explicit manner than is done in the standard formulation. One way in which this can be done takes as its point of departure the consumption technology approach and assumes that there are some final goods like road trips and nature hikes which are intrinsically private, but which are produced by the individual consumer by means of private and public goods inputs. The second aspect of mixed goods is that the benefits enjoyed by any one individual may depend on the consumption of others as in the cases of a crowded road or a congested national park. This aspect too may be handled by the consumption technology approach by letting other people's consumption of complementary private goods enter every individual's production function for the final good in question. This would be a special case of the Samuelson formulation when in addition it is assumed that some private goods create externalities in consumption. Thus, the advantage of the consumption technology approach to the theory of public goods lies not in greater generality, but in a formulation which captures in a more intuitive fashion a natural way of thinking about public goods. An additional advantage is that the theory becomes more closely related to the practice of cost-benefit analysis, where willingness to pay is typically computed not by observing preferences directly, but by calculating the private cost reductions that would follow from an increase in the provision of a public good. The theory is further elaborated in Sandmo (1973); for an alternative formulation of similar ideas see Bradford and Hildebrandt (1977).

Not all public goods are naturally analyzed as consumption goods. One of the classical examples, the lighthouse, is more easily interpreted as a producer good or a factor of production. Public factors of production were first introduced in the theoretical literature by Kaizuka (1965), who derives the efficiency conditions analogous to Samuelson's for the production case. Sandmo (1972) shows how the formulation can be used to derive shadow prices for such goods when the private sector is competitive.

The Samuelson formulation implies that the availability of any public good is the same for all individuals and independent of their decisions about private goods consumption – although, as we have noted, the benefit is not. This ignores the fact that many public goods are only available to individuals residing in a particular location, and that an individual may therefore select the amount available of the public good by changing his place of residence. This was first pointed out by Tiebout (1956) in a paper which has since given rise to a rich literature on the important topic of local public goods and, more generally, local public finance. We shall return below to the demand-revealing aspects of mobility between communities. But it is worth noting here that although the original application of the basic idea was to individual choice among residential communities, there are possibilities of application to other interesting areas as well. In the labour market, workers' choice among firms might be affected by public good aspects of the working environment which are specific to the individual firm. Following Buchanan (1965), 'clubs' has become the generic term for voluntary associations of individuals whose purpose is to provide the members with a public good. Internationally, public goods which are country-specific might influence the pattern of international migration; in this perspective, almost all public goods would be local, and the original formulation becomes a special case characterized by geographical immobility of the population. For surveys of the theory of clubs and local public goods the reader is referred to Rubinfeld (1987) and Scotchmer (2002).

At the other end of the scale from local public goods are global public goods, goods that provide benefits to the whole of the world's population. Examples of such goods are international security, global environmental quality, and scientific knowledge. One might perhaps think that in this case the theory is directly applicable, since the complications associated with geographical mobility are ruled out by assumption. On the other hand, additional problems arise because the world is not one jurisdiction but composed of a number of independent nation states. In the original Samuelson formulation, the economy is at its

production possibility frontier; this is evidently a strong assumption even for a national economy, and it becomes even more unrealistic when applied to the world as a whole. Moreover, Samuelson assumed redistribution in the form of individualized lump-sum taxes and transfers; this also is an assumption which is much farther from reality when considered in a global context. Even the assumption of redistribution via progressive taxation, which is a more realistic description of national redistribution policy, is far from the economic realities of the international community of countries.

It can be shown that the problems of global production efficiency and redistribution are in fact interrelated, as one would in fact expect on the basis of the theory of the second best; see Sandmo (2003). If one takes the viewpoint of global welfare maximization and assumes that there are perfect lump sum transfers both within and between countries, the Samuelson optimality conditions must hold for the world as a whole. In particular, there will be global production efficiency, and the social marginal utility of income must be the same for all individuals. However, if for some reason the international transfers are not made, then production efficiency is in general not desirable. If one assumes that the global welfare function displays inequality aversion, poor countries should not be required to contribute as much to the production of global public goods as their comparative advantage would otherwise call for. But the model also points to a serious problem of incentives, because each country, in deciding how much to contribute to the production of global public goods, finds itself in a strategic situation similar to that of the single individual in the nation state, who has an incentive to be a free rider on the contributions of others (see below). At least if one assumes that national governments are motivated by a fairly narrow concept of national self-interest, there is likely to be an under-supply of global public goods.

Equilibria With Public Goods

We have concentrated on the theory of public goods as an extension of welfare economics; the central question has been how to characterize optimal or efficient allocations in economies with public goods. But just as in the case of private goods it is interesting to go on from there to consider the equilibrium allocations that would follow from particular institutional arrangements in the economy and to compare these with the optimality conditions. Thus, the theory of public goods ought to be positive as well as normative, a view emphasized strongly in the influential contributions by Buchanan (e.g., 1968).

The first clear formulation of a theory of public expenditure which can be given a positive interpretation was presented by Erik Lindahl (1919), who in turn was inspired by Wicksell (1896); an important modern exposition is that of Johansen (1963). In this formulation, individuals bargain over the level of public goods supply simultaneously with the distribution of the cost between them. The bargaining equilibrium is Pareto optimal, implying that the efficiency conditions (7) are satisfied. In addition, each individual pays a price in terms of private goods which is equal to his marginal willingness to pay. Formally, let p_{J+k}^i be the price which individual i pays for public good k , and let p_{J+k} be the producer price or marginal cost. Then the Lindahl equilibrium will be characterized by the condition

$$\sum_i p_{J+k}^i = p_{J+k}, \quad (k = 1, \dots, K) \quad (12)$$

Thus, at first glance the concept of a Lindahl equilibrium seems to establish an analogue to competitive markets for private goods with the interesting difference that prices should differ from one individual to another, depending on his marginal willingness to pay. This also ties in with older notions of the benefit theory of taxation, according to which taxes were seen as payments for public goods, to be levied in accordance with the benefits which each individual derived from them.

At the technical level it may be noted that there is an interesting ‘duality’ between the definitions of private and public goods on the one hand and the properties of equilibrium prices on the other. In terms of quantities, for private goods the sum of individual quantities consumed *add up* to the quantity produced, while for public goods individual consumption *equals* aggregate production. In terms of prices, on the other hand, for private goods each consumer price *equals* the producer price, while for public goods individualized consumer prices *add up* to the producer price.

There is, however, one crucial difference between a Lindahl equilibrium and a competitive equilibrium for private goods. With private goods, individuals facing given prices have clear incentives to reveal their true preferences by equating their marginal rates of substitution to relative prices. Without paying, the individual is excluded from enjoying the benefits of consumption. With public goods this no longer holds. Because an individual has the same quantity of public goods available to him whether he pays or not, he has an incentive to

misrepresent his preferences and to be a free-rider on the supply paid for by others. Moreover, this problem is likely to be particularly severe when the number of individuals is large, since an individual contribution will then make little difference to the total supply. The connection between Lindahl equilibria and the game theoretic concept of the core was discussed by Foley (1970); see also the survey by Milleron (1972).

The equilibrium of the Lindahl model is not compatible with individual incentives to reveal preferences truthfully; for this reason Samuelson (1969) has referred to the individual Lindahl prices as pseudo-prices and to the equilibrium as a pseudo-equilibrium. In this case one would conjecture that because all individuals have the same incentives to understate their true marginal willingness to pay, the Lindahl mechanism would result in equilibrium levels of public goods supply which would be too low relative to the optimum. But there is really no need to associate the problem of preference revelation with this procedure alone; as another extreme, one might think of the case where individuals are asked to state their preferences on the assumption that the cost to them is completely independent of their stated willingness to pay, but there is a positive association between this and the quantity supplied. Then there will be incentives to exaggerate the willingness to pay and a consequent tendency towards oversupply. Thus, the general problem which arises is how to design a mechanism that will allow the decision maker to implement the efficiency condition.

Various solutions to this problem have been discussed in the literature. The most practically oriented solution is that of cost-benefit analysis, which takes as its point of departure that people's preferences for public goods are revealed in the market through their demands for complementary private goods (see above). But in theoretical terms it has been shown that this will only be true on certain rather restrictive assumptions about technology and preferences. Another solution is represented in the literature on local public goods, where it has been suggested that people reveal their preferences for public goods by moving to the community offering them their most preferred combination of taxes and public goods. But whether this process will result in an optimum satisfying the efficiency conditions must clearly depend first on how the supply of public goods is determined within each community and second on whether there are enough communities to satisfy the variations of preferences in the population as a whole. Thus, in general, neither observation of the consumption of private goods nor of individuals' mobility between local communities provides reliable information on preferences.

Presumably as a response to the problem of market failure, decisions on public goods supply are largely made by political processes. In a democracy, the natural decision-making process to study is that of voting, and there is by now a substantial literature on this. Most of this is concerned with the stylized situation where public goods supply is determined by majority voting with the consumers themselves being the voters; thus, 'direct democracy' is assumed. The first paper in this area was that of Bowen (1943), who also considered the question of when a voting equilibrium would be Pareto optimal. Later contributions have emphasized that very restrictive assumptions on preferences are sometimes required for a voting equilibrium to exist, and these – like the so-called single-peakedness assumption – are not always attractive in the public goods context. Nevertheless, voting models have become quite popular in descriptive analyses of public goods decisions, particularly at the local government level.

There has also been a great deal of interest in studying planning procedures whereby individuals find it in their own interest to reveal truthfully their preferences for public goods. The first discussion of such a procedure – although in a somewhat different context – was that of Vickrey (1961), but the more recent developments are based on the work of Clarke (1971) and Groves (1973). It is shown there that truthful preference revelation will result if individuals pay a tax on the marginal unit demanded of the public good which is equal to the difference between the marginal cost and the sum of the marginal benefits received by all other individuals. These procedures are of great theoretical interest, perhaps mainly because they clarify the nature of the free rider problem. However, at present they seem rather far from the state where they could be implemented in practical situations; they would probably be administratively costly to operate, and they also make heavy demands on individual consumers' ability to understand and participate in the process. For surveys of this area see Tulkens (1978) and Laffont (1987).

Doubts have occasionally been voiced on whether the free rider problem has been given too much prominence in the theoretical literature. Johansen (1977) has argued that there is no clear evidence that this is seen as a major problem in practical public sector decision-making and suggests that individuals are much more likely to reveal their true willingness to pay than the literature indicates. This is so, he argues, both because truthfulness is a strong social norm and because it is a simple strategy which does not rely on complicated strategic considerations. There is also some empirical evidence from experimental situations to suggest

that the revealed willingness to pay is not very sensitive to the associated method of cost distribution; see Bohm (1972).

The point of view taken in most of the literature considered here is that the incentive revelation problem requires decisions on public goods supply to be taken by some governmental body. However, starting with Olson (1965), there has emerged a literature on the voluntary provision of public goods. This literature is perhaps most naturally interpreted as concerned with relatively small groups, in which the incentive to free ride is limited, and not with public goods provision on a national scale. In the framework of this theory, as formulated e.g. by Bergstrom, Blume and Varian (1986), the decision to contribute to a public good is formulated in the standard framework of consumer demand theory. Consumers allocate their incomes between private goods and contributions to public goods, which are made under assumption that the contributions of all other consumers are taken as given, and one can then study the properties of the resulting Nash equilibrium. Particular attention has been given to the effect on contributions of a redistribution of income; as first shown by Warr (1983), under some assumptions this will change individual contributions in such a way that the aggregate supply of the public good is unaffected.

Perspectives

The Samuelson theory of public goods has been of decisive influence for the theory of public expenditure, which has been developed in a number of directions during the following fifty years. The extensions and reinterpretations of the original theory to the cases of public factors of production, mixed (public-private) goods and local and global public goods have significantly increased the applicability of the theory. Much has also been achieved to enrich our understanding of the incentive problems that arise in actual allocation mechanisms for public goods supply; however, it is probably fair to say that the normative theory of public goods has become much more satisfactory from a theoretical point of view than the positive theory. This state of affairs may in fact be unavoidable. The normative theory has little need to model institutional details and can thus be given a more unified appearance. A positive theory, on the other hand, must to a greater extent model economic and political institutions, and there is no single institution corresponding to the competitive market in the private goods case which can serve as a unifying benchmark for the analysis. Moreover, development of the

positive theory of public goods must necessarily be closely tied to the progress of the positive theory of public sector behaviour in general; it will be interesting to see whether this theory can be developed to provide descriptive models of public goods provision which are both realistic and reasonably simple.

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Pigouvian Taxes.

'Pigouvian taxes' is the generic term for taxes designed to correct inefficiencies of the price system that are due to negative external effects. In partial equilibrium terms, the basic idea can be presented as follows:

Under competitive conditions, utility-maximizing consumers will equate their marginal benefit to the market price Q ; we may write this as $MB=Q$. Similarly, profit-maximizing producers will set their marginal private cost equal to the price, so that $MPC=Q$. In the absence of externalities, marginal private and social costs coincide: $MPC=MSC$.

Consequently, market equilibrium implies that $MB=MSC$, which is the condition for efficient resource allocation. If there are negative external effects related to the production or consumption of the good in question, the marginal social cost is higher than the marginal private cost: $MSC>MPC$. If the market prices facing producers and consumers are identical, this implies that $MB<MSC$. To restore efficiency, we may levy a tax on the commodity, so that the consumer price is Q while the producer price is $Q-t$. In the new equilibrium we have that $MB=Q$ and $MPC=Q-t$; it follows that $MB=MPC+t$. Since we wish the equilibrium to satisfy the condition that $MB=MSC$, we must have $t=MSC-MPC$, which we may define as the marginal social damage. Accordingly, the optimal Pigouvian tax internalizes the externality; producers act as if they took account of the marginal social damage associated with the production of the commodity.

This idea was first expressed by Pigou, especially in his *Economics of Welfare* (1920). He mentions a number of examples of what he calls divergence between 'social and private net product', e.g. production activities generating smoke from factory chimneys that create adverse consequences for consumers in the form of damage to buildings, increased expenses for washing clothes, house-cleaning and indoor lighting. These inefficiencies can be corrected, he says, by 'imposing appropriate rates of tax on resources that tend to be pushed too far'; he also points out that cases of positive externalities where $MSC<MPC$ can be corrected by means of subsidies or 'bounties' (Pigou 1920; 1932, 184). In his later book *A Study in Public Finance* he claims that

‘[there] will necessarily exist a certain determinate scheme of taxes and bounties, which, in given conditions, distributional considerations being ignored, would lead to the *optimum* result.’ (Pigou 1928; 1947, 99.)

An interesting and important question concerns the choice of the tax base. On what should the Pigouvian tax be levied? From a theoretical point of view, the correct tax base is the one that affects the crucial margin of decision. In the factory smoke example, the best tax base is actually the amount of smoke emission. A tax on coal is an imperfect instrument to the extent that it also affects margins that are irrelevant for smoke emission, and this is even more true for a tax on the output produced by the factory. Some would therefore reserve the term ‘Pigouvian tax’ for the tax on smoke emission, but in the literature it has become common to use the concept to refer to all cases where the policy motivation is to correct for negative externalities.

For a long time, Pigouvian taxes led an obscure life in the public economics literature; thus, in the famous treatise by Musgrave (1959), the subject is barely mentioned. However, with the increased concern for the environment that rapidly gained ground from the late 1960s, economists became much more interested in this form of tax policy both as a tool for environmental policy and as an efficient source of revenue for the public sector.

Distortionary taxes.

The partial equilibrium approach is based on some simplifying assumptions. First, it focuses solely on the market for the ‘commodity’ (final good, factor of production or emission) that gives rise to the externality, while neglecting the interconnections with other markets. Second, it assumes - rather implicitly - that there are no other violations of the efficiency conditions in the economy, so that the design of Pigouvian taxes does not need to take into account the presence of other distortions. Third, as also emphasized by Pigou, it ignores distributional concerns.

All these simplifications must be overcome if one wishes to analyze Pigouvian tax policy within the context of the overall tax system. There is actually one tax system in which the partial equilibrium analysis is valid, and that is the assumption that the rest of the requirement

for public sector revenue can be satisfied by means of individualized lump sum taxes. This leads to a ‘first best’ allocation: Tax revenue is raised without distortions of the price mechanism, and the desired income distribution can be achieved without loss of efficiency. The only commodity taxes that are used are the Pigouvian taxes on commodities that generate negative external effects. But lump sum taxes are not policy instruments that can realistically be used. Instead, actual governments have to rely on direct and indirect taxes, and these will create tax wedges and distortions of private incentives. What is the role of Pigouvian taxes within the context of an otherwise distortionary tax system?

One might perhaps come to think that in such a setting Pigouvian considerations should affect the taxes on all goods; e.g., there might be a case for subsidizing substitutes and taxing complements to the harmful commodities. However, it was shown in Sandmo (1975) that in an optimal system of commodity taxes the integration of Pigouvian taxes with the Ramsey (1927) objective - minimizing efficiency loss for a given tax revenue - takes a strikingly simple form. If there is one commodity that creates a negative externality, the tax on this commodity can be expressed as a weighted average of Ramsey and Pigou terms, while other taxes contain only a Ramsey term. Formally, suppose that there are a number of taxed goods ($i=1, \dots, n$) and that the externality is generated by the n th good. Suppose for simplicity that all cross elasticities between the tax goods are zero, so that Ramsey taxes can be characterized by the inverse elasticity formula. Then the optimal tax system can be written as follows:

$$t_i = a(-1/e_i) \quad (i=1, \dots, n-1).$$

$$t_n = a(-1/e_n) + (1-a)d_n.$$

Here e_i is the own price elasticity of commodity i , and d_n is the marginal social damage of commodity n . a is a parameter that characterizes the tightness of the government budget constraint. If the budget is extremely tight, all weight is on the need for revenue. Then $a=1$, the tax rates are chosen so as to maximize revenue, and Pigouvian taxes play no role in the tax structure. However, in the happy situation where the revenue from Pigouvian taxes is exactly sufficient to meet the government’s revenue requirement, $a=0$, and no other taxes are desirable. It can be shown that the ‘additivity’ property of the optimal tax system continues to hold when distributional considerations are incorporated in the model, but in that case the

weights on the inverse elasticity and the marginal social damage will have to reflect distributional concerns in addition to those of efficiency.

The double dividend and the marginal cost of funds.

In recent years there has grown up a strong interest in ‘green tax reforms’. Such reforms would reduce conventional distortionary tax rates and compensate for the loss of tax revenue by introducing more Pigouvian taxes. A popular view of the gain from this kind of reform is that society would reap a ‘double dividend’. First, higher Pigouvian taxes would create an improved environment; second, lower distortionary taxes would imply a more efficient tax system. This argument has a strong appeal to economic intuition; however, as often happens, when one comes to study it more closely, it turns out to contain some complicating elements. The crucial point to note is that the effects of Pigouvian taxes interact with those of the distortionary taxes. If e.g. the existing tax system has a high marginal tax rate on labour income, an increase of Pigouvian taxes together with a lowering of other indirect tax rates might exacerbate the labour market distortion if the externality-creating goods are complementary with labour supply. This argument does not imply that the argument in favour of the double dividend is groundless. It simply means that one has to be careful in taking account of the interaction between markets for taxed goods before predicting a double dividend.

Another version of the double dividend argument focuses on unemployment. If the basic cause of unemployment is that employers’ labour cost is above the market-clearing wage, a promising tax reform might be to reduce the payroll tax while increasing Pigouvian taxes. The double dividend in this case would be a better environment and lower unemployment. Again the consensus of professional opinion seems to be that this is indeed a possible outcome, but it is by no means assured. E.g., in a unionized labour market much will depend on the combined incidence of a reduced payroll tax and higher indirect taxes on union wage demands. For further discussion of both versions of the double dividend see Bovenberg (1999) and Sandmo (2000).

Related to the question of the double dividend is the relationship between Pigouvian taxes and the marginal cost of public funds (MCF), a concept whose origin can also be traced to Pigou; see Atkinson and Stern (1974). With distortionary tax finance, the direct resource cost of

public goods should be multiplied with an MCF adjustment factor which exceeds one. Since Pigouvian taxes actually increase the efficiency of the market mechanism, one might expect that for this type of tax finance one would have $MCF < 1$. Theoretical analysis has shown that this is indeed likely to be true in a number of cases, but that here too one needs to pay attention to the interaction of distortionary and Pigouvian taxes.

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