Econ674

Economics of Natural Resources and the Environment

Session 13

Public Policy Criteria for Natural Resource Decisions

Criteria for public policy management of natural resources derive from the basic framework of welfare economics. As we have seen, social welfare maximization proceeds on the initial framework of Pareto optimality. We state these conditions, and from which we then examine various conditions under which market failure arises.

The standard approach for correcting for market failure is the use of Pigouvian taxes and subsidies. We elaborate here on the general framework of Pareto optimality and then proceed to examine how Pigouvian taxes and subsidies function in the presence of various levels of transactions costs and in consideration of established welfare criteria.

Static Pareto Optimality in Consumption

The standard static conditions for a Pareto optimal condition in consumption proceed on the basis of constrained utility maximization. For a two-good economy, Q_1 and Q_2, with two-consumers, we have the following initial conditions. First we state the utility functions of the two consumers:

(Eq.1) $U_1(q_{11},q_{12})$ and $U_2(q_{21},q_{22})$,

where $(q_{11} + q_{21} = q_{1})$ and $(q_{12}+q_{22}=q_{2})$.

We now state the static constrained optimization of the consumer:

(Eq.2) $$U_1^* = U_1(q_{11},q_{22}) + \lambda\left[\mathrm{U}_2\left(q_1^0 - q_{11}, q_2^0 - q_{12})\right) - U_2^0\right]$$

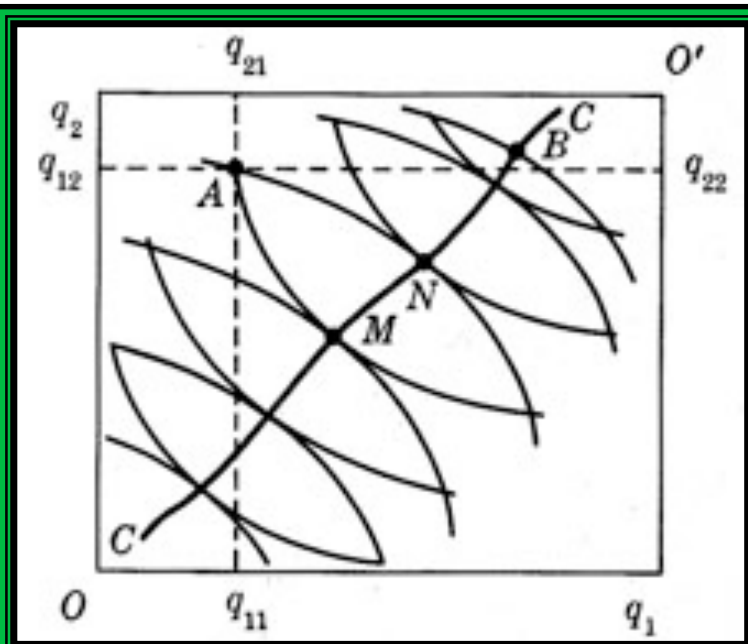
First order conditions require that the pairwise marginal utilities of each good in consumption be equal to zero, which establishes the the marginal rate of substitution (MRS) for each consumer is equal for a given distribution of income:

(Eq.3)
$$\frac{\partial U_1^*}{\partial q_{11}} = \frac{\partial U_1}{\partial q_{11}} - \lambda \frac{\partial U_2}{\partial q_{21}} = 0$$
$$\frac{\partial U_1^*}{\partial q_{12}} = \frac{\partial U_1}{\partial q_{12}} - \lambda \frac{\partial U_2}{\partial q_{22}} = 0$$
$$\frac{\partial U_1^*}{\partial \lambda} = \mathrm{U}_2\left(q_1^0 - q_{11}, q_2^0 - q_{12}\right) - U_2^0 = 0$$

and

$$\frac{\partial \mathrm{U}_1 / \partial q_{11}}{\partial U_{11} / \partial q_{12}} = \frac{\partial \mathrm{U}_2 / \partial q_{21}}{\partial U_2 / \partial q_{22}}$$

We can illustrate the Pareto consumption social welfare conditions in terms of a standard Edgeworth diagram, shown below. Each consumer maximizes utility along a consumption contract curve CC, with one starting a point O and the other at point O'. For a given distribution of income, an equilibrium is established where each consumer has maximized the pairwise marginal utilities for each good, and which is equivalent to a tangency intersection, such as at point M or N. At such a point, the ratio of pairwise marginal utilities will be equal to the relative prices of the two goods.



Static Pareto Optimality in Production

Pareto optimality also requires that firms achieve an equilibrium in profit maximization through a similar constrained optimization problem. For producers, Pareto optimality requires that the output of each level of each consumer good be at a maximum, given the output levels of all other consumer goods.

To do so requires that each firm achieve both technical and allocative efficiency, that is, the least costly way of producing a given level of output and the optimal level of output in which marginal revenue equals marginal cost. Assuming a competitive market structure, this means that in a steady-state equilibrium, firms enjoy only normal profits, that is, they earn zero economic profits. As we will demonstrate, in this static framework in equilibrium, the marginal rate of substitution among inputs will be equalized for all firms and will be equal to the ratio of their respective factor prices.

For two producers using two inputs to produce two goods, we can state the respective production functions as:

(Eq.4) $q_1 = f_1(x_{11}, x_{12})$ and $q_2 = f_2(x_{21}, x_{22})$ where :

$$x_{11} + x_{22} = x_1^0 \text{ and } x_{12} + x_{22} = x_2^0 \text{ and } q_1 \text{ and } q_2 = \text{ Output}$$

The static Lagrangian problem can now be stated as maximization of the output of good 1 subject to the constraint that the output of good 2 is at the predetermined profit-maximizing level. To do so we state:

(Eq.5) $L = f_1(x_{11}, x_{12}) + \lambda\left[f_2\left(x_1^0 - x_{11}, x_2^0 - x_{12}\right) - q_2^0\right]$

First order conditions require that the respective partials be set to zero and that the pairwise ratios of marginal inputs for each producer be equal to the factor price ratio:

(Eq.6)

$$\frac{\partial L}{\partial x_{11}} = \frac{\partial f_1}{\partial x_{11}} - \lambda \frac{\partial f_2}{\partial x_{21}} = 0$$

$$\frac{\partial L}{\partial x_{12}} = \frac{\partial f_1}{\partial x_{12}} - \lambda \frac{\partial f_2}{\partial x_{22}} = 0$$

$$\frac{\partial L}{\partial \lambda} = f_2\left(x_1^0 - x_{11}, x_2^0 - x_{12}\right) - q_2^0 = 0, \text{ and :}$$

$$\frac{\partial f_1 / \partial x_{11}}{\partial f_1 / \partial x_{12}} = \frac{\partial f_2 / \partial x_{21}}{\partial f_2 / \partial x_{22}}$$

While we could restate the static Lagrangian conditions for both consumption and production, we now turn to the use of public policy alternatives in the presence of market failure. We first concentrate on static corrective measures.

Consider two firms in a competitive environment in which external effects are present. We state their respective cost functions as:

(Eq.7)

$C_1 = 0.1q_1^2 + 5q_1 - 0.1q_2^2$ and

$C_2 = 0.2q_2^2 + 7q_2 - 0.025q_1^2$.

Now if the competitive output price is \$15.00 the optimal output for each firm will be :

$MC_1 = .2q_1^0 + 5 = 15;\ q_1 = 50;\ \pi_1 = 290$ and

$MC_2 = .4q_1^0 + 7 = 15;\ q_2 = 20;\ \pi_2 = 17.5$

Firm 1 receives external benefits while firm 2 receives external costs, thus producing differential profits and rates of return.

For Pareto optimality, consider now a joint profit function from the two firms, which can be defined as:

(Eq.8) $\pi = 15(q_1 + q_2) - .125q_1^2 - 5q_1 - .1_1^2 - 7q_2$

First order conditions are:

$$\frac{\partial \pi}{\partial q_1} = 15 - .25q_1 - 5 = 0$$

$$\frac{\partial \pi}{\partial q_2} = 15 - .20q_2 - 7 = 0$$

Solving yields the following:

$q_1 = 40$
$q_2 = 40$ and $\pi = 400\pi_1 - 40\pi_2 = 360$

While joint profit exceeds individual profits maximization, achieving a Pareto optimal outcome will require a transfer of profits from firm 1 to firm 2. Redistribution of any amount greater than 57.5 but less than 110 from firm 1 to firm 2 will leave each firm better off than under individual maximization. The table below summarizes these boundary conditions.

	Initial Profit	Transfer Min	Net Profit	Transfer Max	Net Profit
Firm 1	$400.00	-$57.50	$342.50	-$110.00	**$290.00**
Firm 2	-$40.00	$57.50	**$17.50**	$110.00	$70.00

Under a Coase (1960) style redistribution, if transactions costs are small, firms may achieve a joint gain under voluntary redistribution. Yet any positive transaction cost borne by the original external beneficiary reduces its incentive to engage in voluntary redistribution of profits, as the table below illustrates for a $.01 per dollar of profit redistributed. The result is that Pivouvian taxes and subsidies may be an alternative, but as we shall note, efficiency and equity considerations may also reduce prospective social welfare.

Transaction Unit Cost $0.01 per dollar of profit redistribted

	Initial Profit	Transfer Min	Net Profit	Transfer Max	Net Profit
Firm 1	$400.00	-$58.08	$341.93	$111.10	**$288.90**
Firm 2	-$40.00	$57.50	**$17.50**	$110.00	$70.00

Consider now a social marginal cost (SMC) cost function for firm 1 that receives a positive external benefit. A social marginal cost function embodies the private and external costs within a profit-maximizing framework. Since from our example, the first firm enjoys a positive externality at the expense of the first firm, only the first firm's cost function is affected, and whose coefficient changes from .20 to .25, as noted below in the profit maximizing solution:

(Eq.9)
$$SMC_1 = .25q_1 + 5 = 15 \qquad q_1 = 40 \qquad \pi_1 = 400$$
$$MC_2 = .20q_2 + 7 = 15 \qquad q_2 = 40 \qquad \pi_2 = -40$$

the solution then can be inserted into the respective private marginal cost functions to determine the Pareto optimal tax and subsidy level:

(Eq.10)
$$PMC_1 = 0.2q_1 + 5 + t = 15$$
$$PMC_2 = 0.4q_2 + 7 - s = 15$$

Substituting the solution values, $q_1 = 40,\ q_2 = 40$
from the preceding social marginal cost conditions
into these equations yields a tax of \$2.00 and a subsidy of \$8.00

Whether or not this represents an improvement in social welfare depends on the welfare effects of the net tax to society, which in this case constitutes the difference between the subsidy and the tax, or $6.00. We now take up this question in terms of tax criteria.

Regardless of the type, taxes affect behavior, they affect the level of revenue generated (as in funding the creation of pure and quasi-public goods and in macroeconomic stabilization), and in most instances, they are likely to have some effect on the distribution of income. Governments may impose taxes to produce any combination of these outcomes, but not always with consistency or transparency as to the mechanisms adopted.

Economists generally focus on a set of basic principles regarding the adoption of any tax: 1. Simplicity of administration and collection; 2. Efficiency versus effectiveness; 3. and fairness (based on some external social definition). Adoption of a "good" tax that embodies all of these principles often is difficult to accomplish, even in a transparent environment, largely because institutions may not exist or operate in such a fashion as to be able to implement these principles in practice.

Governments often select activities, assets,or types of income as objects of taxation based on the ease with which a tax can be imposed and collected. In many developing economies, the formal sector is relatively small and so a broad based income tax often generates a small amount of income in comparison to other types of taxes. Taxes on trade, particularly imports, are fairly easy to impose, even if they can produce large distorting consequences on the efficiency of the economy. Taxes on trade, as in the application of a Value Added Tax (VAT), sales tax, or excise tax, also are widely used, even though they may again produce large distortions in economic efficiency.

Simplicity of implementation and collection of taxes produces one definition that is widely, but mistakenly, used to define an efficient fiscal system, namely, how much must a government agency spend to collect a given amount of tax. One can rank order tax categories on the basis of how much effort is spent to receive a given dollar's worth of revenue. The only problem with this administrative definition is that it ignores the effects of taxation of producer and consumer behavior.

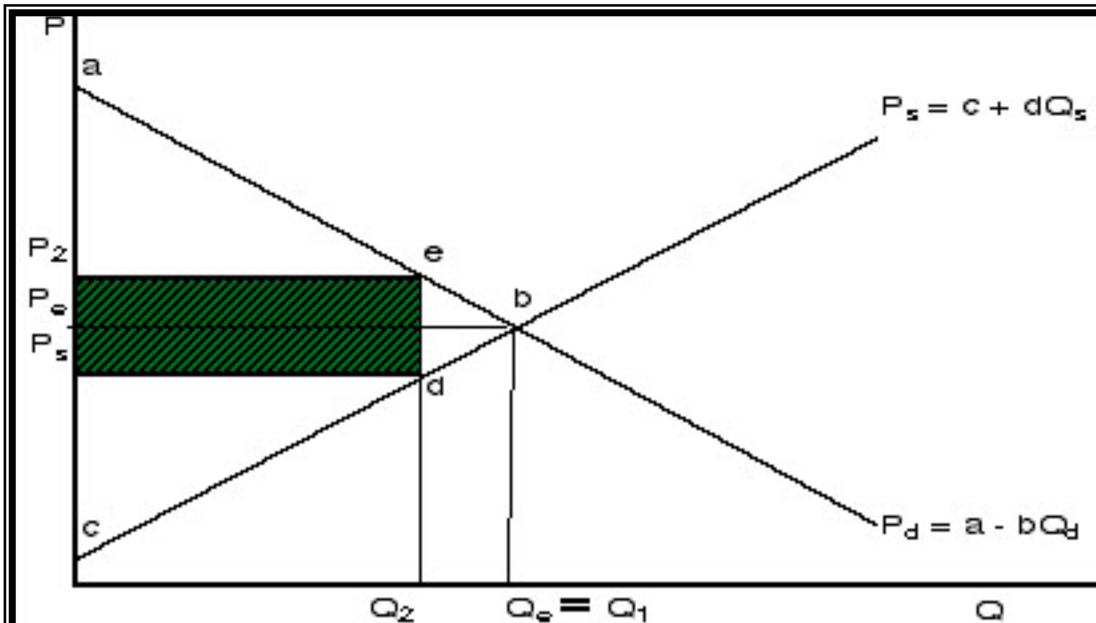
In terms of behavior, sometimes governments impose taxes to affect behavior. Examples include excise and/or sales taxes on gasoline, tobacco, and alcohol consumption, where the stated goal is to reduce consumption by some targeted amount. In this case, the evaluative reference point is not administrative efficiency, nor even economic efficiency, but simply whether the tax accomplished some broader social goal. In terms of natural resources, taxes on energy consumption fall into this category, and we will examine them in terms of both behavioral and efficiency perspectives.

Let us now examine the efficiency of taxation. Much of our perspective on the efficiency of taxation derives from the original insights put forth by Ramsay (1927), and which have been refined since. Ramsey's contribution was to utilize social welfare metrics to take into account the level of taxes collection, the distribution of the burden of taxes, as well as the deadweight loss in social welfare arising from a given tax. From this perspective we have the notion of the excess burden of taxation, which is simply the ratio of the deadweight social welfare loss to the level of tax revenues collected. Using an analogy from statistics, if the excess burden of taxation exceeds five percent, we can say that this is significant, and in terms of a strict ordering o efficiency rankings, classify various taxes in terms of whether they are acceptable on efficiency grounds.

Consider basic market conditions for a given good. In the absence of taxation, a market equilibrium will provide information on the clearing price (P_e), quantity (Q_1), total revenue, as well as in the initial level of total social welfare, shown below in the figure as the triangular area, abc.

Government now chooses to impose an excise tax, whose unit value is equal to the vertical segment, de. This reduces the market equilibrium quantity to Q_2, increases the market price to P_2, and generates tax revenues equal to the rectangle $P_sP_2$ed.

The deadweight social welfare loss from the imposition of the tax is measured as the triangle, bde. As to the efficiency of the tax, it is measured as the excess burden(EBT), which is defined as the ratio of the deadweight social welfare loss (DSWL) to the level of tax revenues collected (TXREV). Based on our preceding generalization, if the excess burden is less than five percent, the tax is acceptable on efficiency grounds. However, an excise tax may not be an effective tax in that the resulting market equilibrium quantity, Q_2, may be higher than some targeted level of consumption, in which case an additional tax may be imposed, but at the expense of our Ramsey efficiency limit value.



TSW_1 = abc
DSWL = bde
TXR = P_2edP_s
$\varepsilon_d = P_d/bQ_d$
EBT = α = DSWL/TXR

Our tax framework also can be used to examine one perspective on fairness, namely, what proportion of the tax is borne by consumers and what proportion is borne by producers. In our figure, the tax revenue rectangle above the pre-tax market equilibrium price defines the proportion of the tax borne by consumers while the area below the pre-tax market equilibrium defines the proportion borne by producers. We do not presume to impose an a priori definition of fairness, but most would agree that a tax borne equally would satisfy at least one definition of fairness.

It turns out that the absolute values of the slopes of the respective inverse demand and supply equations provide a short-hand way to derive the burden of a tax. If the slopes are equal, the burden is borne equally by producers and consumers. If not, then the steeper is the slope of the demand curve relative to the supply curve, the larger will be the burden borne by consumers, and vice versa, accordingly.

Let us illustrate the above with a simple example.
Consider the following two market condition equations:

$$P_d = 58.0 - 2.00Q_d$$

$$P_s = 2.00 + 4.00Q_s$$

$Q_e = 9.33$; $P_e = \$39.33$; TR = \$367.11; $\varepsilon_d = 2.11$

ITSW = \$261.33

Now consider an excise tax valued at \$5.09 per unit. Our preceding framework is now altered as follows:

$$P_d = 58.0 - 2.00Q_d$$

$$P_s = 2.00 + 5.09 + 4.00Q_s$$

Qe = 8.49; Pe = \$41.03; TR = \$348.14; $\varepsilon_d = 2.42$

TXREV = \$43.19; DSWL = \$2.16; EBT = 5.0 percent

If we consider efficiency as the dominant criterion, then the tax is acceptable. As to the fairness of the tax between producers and consumers, two-thirds is borne by producers while one third is borne by consumers.

There is another way of looking at the fairness of taxation, namely, in terms of the effect of taxation on the distribution of income. Moreoever, when we look at the distribution of income, we also can take into consideration not just the efficiency properties of a tax but also the effects of tax collections on the distribution of income before any redistribution occurs, and also on the effects of tax revenues redistributed to individuals after they have been collected.

	Income Function	Pre-Tax Total Utility	Tax Rate	Taxes Collected	Net Income Before Tax Redistribution	Pre-Distribution Total Utility	Net Income After Tax Redistribution	Post-Tax Distribution Total Utility
A.	$U_A = (\$200.00)^{1.20}$		10.00%					
B.	$U_B = (\$400.00)^{1.00}$		10.00%					
C.	$U_C = (\$800.00)^{0.80}$		10.00%					

	Income:	Utility:		Taxes:	Income:	Utility:	Income:	Utility:
Totals:								

Consider a case of pure income distribution in which there are three individuals, whose income and marginal utility of income functions are given above. Now consider the initial levels of total social welfare prior to the imposition of a tax. Next, consider the imposition of a flat-rate proportional tax at 10 percent, and derive the level of taxes collected, and the adjustments to personal income. Next, if the proceeds of tax revenues are redistributed (costlessly) to taxpayers on an equal per capita basis, derive the net income after tax redistribution, and finally recompute the post-tax distribution levels of total utility and social welfare. For all of the stages, also compute the corresponding Gini index of inequality, using the Champernowne proxy of I = 1 - g/x, where g = the geometric mean, and x is the arithmetic mean.

Based on these steps, now demonstrate on the basis of income changes alone whether the tax system upholds or violates the Pareto, Kaldor, and Rawlsian criteria. Finally, if social welfare is measured in terms of total utility alone, indicate whether the tax system upholds or violates the Pareto, Kaldor, and Rawlsian criteria.

	Income Function	Pre-Tax Total Utility	Tax Rate	Taxes Collected	Net Income Before Tax Redistribution	Pre-Distribution Total Utility	Net Income After Tax Redistribution	Post-Tax Distribution Total Utility
A.	$U_A = (\$200.00)^{1.20}$	577.08	10.00%	$20.00	$180.00	508.54	$226.67	670.60
B.	$U_B = (\$400.00)^{1.00}$	400.00	10.00%	$40.00	$360.00	360.00	$406.67	406.67
C.	$U_C = (\$800.00)^{0.80}$	210.12	10.00%	$80.00	$720.00	193.14	$766.67	203.09
Totals:	Income: $1,400.00	Utility: 1187.20		Taxes: $140.00	Income: $1,260.00	Utility: 1061.68	Income: $1,400.00	Utility: 1280.36

In this example, our Gini inequality coefficient initially is set at 0.1429, and because a proportional tax is used, there is no intermediate effect on the distribution of income. However, using the equal per capita distribution rule, the post-tax redistribution level of inequality falls to 0.1141. In terms of social welfare, the levels are 1187.20 initially, 1061.68 after collection of taxes but before redistribution, and finally 1280.36 after redistribution. Thus, based on the declining marginal utility of income (as reflected in the exponents of the income functions), a more egalitarian distribution of income can be achieved with an increase in total social welfare. Whether this holds true more generally, however, depends on whether the exponents of the income utility functions vary directly or inversely with the level of income.

As to our welfare criteria, using money metrics alone, the post-tax redistribution of income does not fulfill the Pareto criterion, nor does it fulfill the Kaldor criterion, but it does satisfy the Rawlsian criterion. If we use utility functions as our social welfare metric, the tax redistribution sytem fails the Pareto criterion, but satisfies the Kaldor and Rawlsian criterion.

What do the exponents in our utility function tell us about income redistributive measures? Essentially they provide a metric by which we can derive the marginal utility of money income. If there is an inverse relationship between the exponents and the level of income, then we have a declining marginal utility of income, in which case a more egalitarian redistribution policy may increase the level of social welfare. There are ways of estimating this relationship, e.g. charitable giving behavior across income levels, permitting a more direct assessment of whether purely voluntary acts of redistribution are more or less likely to improve social welfare than some form of government taxation and spending.

One additional consideration in the use of taxation and spending to affect social welfare is the level of poverty. Many developing economies have significant shares of the population that may be near or below some defined level of poverty. Where natural resource externalities are concerned, the use of taxes and subsidies to achieve economic efficiency may or may not have adverse effects on the level of poverty and on the level of income inequality. Ultimately, the level of clearly defined property rights has a critical bearing on efforts to use public sector taxes and subsidies, or even private contractual arrangements of the Coasian variety, to achieve a sustainable use of natural resources. To address this question requires that we examine the economic value of institutions, which is the focus of the next session, along with applications of natural resource evaluation examples.

	Profile Element	2004	2005	2006	2007
1.	Per Capita GDP (constant 2000 US$)	$128	$138	$146	*$158*
2.	Per Capita Consumption Expenditures (constant 2000 US$)	$116	$131	$142	*$153*
3.	Per Capita Saving Rate	10.08%	4.79%	3.03%	2.87%
4.	Daily Minimum KiloCalorie Requirement	2,100	2,100	2,100	2,100
5.	Annual Minimum KiloCalorie Requirement	766,500	766,500	766,500	766,500
6.	Cost of Annual Kcal Minimum Consumption	$103.98	$118.17	$127.80	$138.11
7.	Food Expenditures	$115.64	$122.74	$130.33	$139.04
8.	Daily Average Kilocalorie Consumption	2,335	2,181	2,142	2,114
9.	Food Expenditure Share of Per Capita GDP	0.90	0.89	0.89	0.88
10.	Primary Energy Consumption per Capita, in Kg of oil equivalent	287.65	287.78	*288.75*	*286.71*
11.	Energy Intensity in KgOE per $U.S. constant GDP per Capita	2.24	2.09	1.97	1.81
12.	Energy Expenditure Share of GDP	0.05	0.06	0.05	0.04
13.	Energy Expenditures	$6.42	$8.27	$7.32	$6.32
14.	Poverty Incidence Rate, P_0	0.41	0.37	0.36	0.36
15.	Poverty Incidence Depth Rate, P_1	0.16	0.1	0.13	0.12
16.	Poverty Incidence Severity Rate, P_2	0.08	0.09	0.06	0.07
17.	Poverty Index GM, Pi	0.7498	0.6740	0.6998	0.6487