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General Equilibrium Theory, Project Evaluation, and Economic Development

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T. N. SRINIVASAN

Introduction

Among Arthur Lewis's varied contributions to the theory of economic development and the practice of development policy, one of the earliest was his book on *The Principles of Economic Planning*, published in 1950 *prior* to his justly celebrated paper on 'Economic development with unlimited supplies of labour'. He returned to this theme sixteen years later in his book *Development Planning*. Another important strand of his work is his historical as well as theoretical studies of foreign trade. In his work on planning and on the theory of economic growth he drew attention to the possible divergence between market prices and social (or shadow) prices of goods and factors. This chapter is devoted to a survey of recent contributions to a field in which the many areas of Lewis's interest, namely, development planning, development practice, foreign trade theory and policy, as well as the derivation and use of shadow prices, appear to converge. This field is social cost–benefit analysis, or more narrowly, project evaluation or appraisal.

Recent contributions to this topic involve analytical insights from the theory of international trade, general equilibrium theory and development planning. Another area of development economics that has attracted analytical attention and empirical work is that of computable models of development. Indeed, Tjalling Koopmans (1977), in his Nobel lecture, drew attention to some of the earlier work in this area as examples in which two strands of optimization models, one consisting of applications to enterprise decision-making and the other to determining the aggregate future growth of an economy are combined and merged. At present there are several general equilibrium models available and equilibria computed for a number of developing countries: Adelman and Robinson (1978); Bacha et al. (1977); Dervis and Robinson (1978); Goreux (1977); Goreux and Manne (1973); and Lysy and Ahluwalia (1977). Some work has already been done and more is in progress in designing and computing 'global' general equilibrium models (Ginsburgh and Waelbroeck, 1978).

It is fair to say, that while a number of contributions have been made by economists working in public finance, trade theory and programming to the
literature on these two topics, a consensus is yet to emerge on the analytical basis for many of the project-appraisal techniques. Nor is there agreement on the utility of computable general equilibrium models either in understanding the development process, or in devising development policy. Yet some project-appraisal technique or other is being used to decide on project choice by many governments and for project/lending by international agencies. Some national planning commissions, for instance in India, have established project-appraisal divisions within the Commissions. Substantial human and financial resources are being committed by national and international agencies in using these techniques and models for planning. It is necessary, therefore, to examine in some depth the analytical issues and policy-makers' practice.

No new results are offered in this chapter. Instead, it brings together the diverse results, coming from analysts working in different traditions and with different tools and perspectives. It relates them to policy-makers' specific practices, and to the practical recommendations contained in some of the recent 'do-it-yourself' books for bureaucrats written by economists. The underlying approach to this broad survey is of Neoclassical general equilibrium theory. Project appraisal will be examined first in some detail, followed by a discussion of computable general-equilibrium models. In the concluding section some open issues will be raised.

Project Appraisal Techniques

The Institutional Framework
Before turning to project appraisal, a few words about the economy in which the technique is to be applied are in order. It is a mixed economy in which production takes place both in the private sector, consisting of producers responding to market signals, and in the public sector. It is also an open economy trading with the rest of the world. The government controls the public sector directly and the private sector indirectly through taxes levied (and subsidies granted) on commodities and on incomes of individuals, profits of firms, and so on. The government may also have the power to prohibit outright activities in the private sector that it deems not to be in the social interest. It is also assumed that the government evaluates the consequences of its exercise of any instrument of policy through an individualistic social-welfare function that incorporates 'equity' considerations. In applications to developing countries additional institutional constraints may be involved that result in market imperfections. Producers and consumers will otherwise be assumed to operate in purely competitive markets.

A Project and its Evaluation
A project is an activity which produces a vector of outputs from a vector of inputs. The inputs and outputs will also be distinguished by the time period of
their use or availability. The government has to decide whether to go ahead with any project proposal in the public sector. In those countries where government controls capacity creation through licensing arrangements, it has to evaluate the private sector proposal as well in order to decide on issuing such a license. A private producer in a competitive environment would, of course, value the inputs and output at their going market prices and only calculate his net profit. He will undertake the project, if this is positive. The government in evaluating the same project is to value the inputs and outputs using 'shadow' prices that reflect social valuations of inputs and outputs.

Shadow Prices

The rationale for using shadow prices is that the social valuation of a commodity may differ from the price that is received by private producers and/or paid by consumers in the market. Consumer or producer prices may differ due to commodity taxation. Indeed, taxation and public production are instruments of public policy through which the government can bring social considerations to bear on private decisions. It is not surprising, therefore, that the project appraisal literature had close connection with that on public finance.

In deriving shadow prices the government is assumed to maximize social welfare subject to a set of constraints. In a mixed economy the constraints will include the fact that private producers and consumers respond to market signals. The shadow prices for a commodity would then reflect the change in the social-welfare maximum brought about by the change in the use of the commodity in the economy by one unit. The optimization exercise also would yield a set of optimum taxes and subsidies, so that the social-welfare optimum can be viewed as a (decentralized) market equilibrium. If, however, some of the socially optimal policies are either infeasible (because some relevant constraints were ignored in the optimization), or are not pursued for whatever reason, one could take as a point of departure an existing equilibrium that reflects these nonoptimal public policies and define the shadow price of a good as the change in social welfare resulting from a change in the use of that good by one unit at the existing equilibrium. A slightly different approach is to assume that levels of some instruments of public policy are specified and the maximization of social welfare is in respect of those instruments of policy not so restricted.

Since many forms of taxation involve 'deadweight' losses, attempting to achieve improvements in social welfare through such taxation can result in a trade-off between equity and efficiency. A convenient point of departure, therefore, is the ideal case where such a trade-off does not arise and, indeed, where market prices and shadow prices coincide.

Second Fundamental Theorem of Welfare Economics and Market Optimum

Such a case can be characterized by appealing to the so-called second fundamental theorem in welfare economics for closed economies. This theorem
states that given a private-ownership economy, in which the production set of each producer is convex, and each consumer has a continuous and convex preference ordering defined over his convex consumption set, any Pareto-optimal allocation can be sustained as a competitive equilibrium, provided lump-sum transfers between individuals are feasible and no consumer is on the boundary of his survival set, so to speak (Koopmans, 1957). It is then clear that, as long as social welfare is individualistic and respects the Pareto criterion, a social-welfare optimum can be sustained as a competitive equilibrium, with, of course, suitable lump-sum transfers. The important point to note is that, even though 'equity' considerations have been introduced explicitly through the maximization of social welfare, the fact that it can be sustained as a competitive equilibrium implies that production efficiency obtains. As is well known, even apart from the strong assumptions about preferences and technology, the informational requirements for the computation of the required lump-sum transfers are severe. In the absence of full information transfers that are truly lump-sum may be difficult to devise without causing problems, as has been suggested by Hammond (1979) and others.\(^2\) It is natural, then, to consider other instruments of public policy such as commodity taxation and public production. While all the models to be discussed in this context assume a mixed economy and an individualistic social-welfare function that respected the Pareto criterion, they differ in specifying the constraints on the government's tax and other policy instruments. One such elegant model for a single consumer economy (or equivalently for an economy with many identical consumers) is due to Broadway (1975).

**Optimal Taxation: Diamond–Mirrlees Economy**

Diamond and Mirrlees (1971) derive public production and tax policies that maximize social welfare. Assuming convexity, nonsatiation, and continuity of preferences, and convexity of production sets, they demonstrate that aggregate production efficiency may sometimes be traded off against equity. But in a variety of circumstances, as long as taxation (including differential taxation of profits of private production in so far as such production is subject to diminishing rather than constant returns to scale)\(^3\) is optimal, production efficiency can be shown to be desirable by adding some mild restrictions on demands if necessary. An implication of aggregate production efficiency is that the 'shadow' prices of goods and factors for public production are the same as private-sector producer prices; the common set of prices being derived from the supporting hyperplane to the convex aggregate production set at the optimal point. A particularly elegant and general derivation of this result is by Roberts (1978).

The result that private and public-sector production decisions are to be based on the same set of producer prices has important implications for project appraisal. Since, given the same producer price vector, both public and private sector will evaluate the project the same way, there is no further need for
intervention by the government to decide whether the project should be accepted or not. The need for project appraisal as such disappears altogether as long as aggregate production efficiency is optimal. The government needs only to set the correct producer prices. However, one can also argue that public-sector production has no special role to play, since in this 'convex economy there are no increasing returns or externalities inherent in public production. The optimal choice of this common producer price vector becomes particularly simple for an open economy in which all goods are traded at fixed relative prices. In such a case, since trading is merely another way of transforming one good into others, efficiency implies that relative producer prices are the same as world prices, barring production specialization to a subset of commodities at an optimum.

Nonoptimal Taxation

One can go a bit further, if public production efficiency is optimal, even though optimal taxes are not being levied, that is, some taxes are set at levels, from which a departure could improve social welfare. Diamond and Mirrlees (1976) show that in an economy where some price-taking private producers maximize profits, given constant returns to scale technologies, shadow prices for government production must be such that the profits of constant returns to scale industries calculated at these shadow prices equals zero. The essence of the argument is that scaling down a constant return to scale production activity slightly and transferring the released resources to the public sector does not change aggregate supplies. Since the public sector is assumed to transact with the private sector at producer prices, and since for a constant return to scale activity the profit from released resources is zero at the initial prices, public-sector profits at private producer prices are unchanged by the transfer. And hence, by the assumption made on consumer demands and profit taxation, producer prices do not change. Thus, if the initial production plan (given the constraints on taxation) was optimal, the transferred resources cannot change welfare. This means that the value of the resources at public-sector shadow prices must be zero. Since the transferred resources amounted to a proportion of the resources used in constant returns to scale activity, this implies that the profit of the activity evaluated at public-sector shadow prices is zero.

Two special cases of this result are worth noting. First, if all commodities can be traded internationally at fixed relative prices, any pair of them can be viewed as a constant returns industry, using (that is, exporting) a unit of one commodity as input and producing (that is, importing) \( \lambda \) units of the second commodity, where \( \lambda \) is the world relative price of the second commodity in terms of the first. Thus, the relative shadow prices for government production become the relative world prices.

The second special case is one in which the constant returns activities span the commodity set: that is, if there are in all \( n \) commodities and at least \( (n-1) \) linearly independent activities \( y^j \) \( (j = 1, \ldots, n-1) \) in the constant returns
sector. Then by denoting the producer price vector by \( p \) and government shadow price vector by \( s \), we have \( p_j^\mu = s_j^\lambda = 0 \) for \( j = 1, 2, \ldots, n - 1 \), implying that \( p = s \). In other words, the shadow prices for the public sector are the same as producer prices for the private sector. This also means that not only is there production efficiency in the public and private sectors separately, but in the aggregate as well, in spite of nonoptimal taxes.

An interesting combination of the two special cases is the following. Suppose the \( n = 2m \) commodities fell into two mutually exclusive and collectively exhaustive categories: the first \( m \) being goods traded internationally at fixed relative prices and the remaining \( m \) being primary factors of production. Suppose further each of the \( m \) traded commodities are produced by domestic constant returns to scale activities using primary factors. Then using \((m - 1)\) 'production' activities consisting of, say, exporting a unit of the first commodity in exchange for importing an amount of each of the other \((m - 1)\) traded commodities equal to its relative world price along with the remaining \( m \) constant return production activities, we can span the commodity set consisting of all the \( 2m \) commodities. Thus, the given world prices for traded commodities determine all shadow prices.

It is not entirely clear how significant the above results are from the point of view of project appraisal. Given the premiss of an initial situation that, among other things, is characterized by the efficiency of public production, public-sector shadow prices can be determined from the slopes of the supporting hyperplane to the convex public production possibility set at the initial production point on its frontier. In this sense, the above results are essentially alternative characterizations of the same set of shadow prices. Given that aggregate production efficiency is not being achieved because of nonoptimality of taxation, producer prices in the private sector presumably do not reflect social valuation of commodities. Supposing that the government can prevent a socially undesirable project from being implemented in the private sector (because of its private profitability) through licensing arrangements, the interesting question is: what are the shadow prices for evaluating private projects which by definition are worthwhile at going producer prices in the private sector? Of course, any project that is socially desirable but privately unprofitable can always be implemented in the public sectors. It would seem that the public-sector output ought to use the same set of shadow prices for evaluating public or private projects, but whether this is so is not entirely clear from the analysis. Dasgupta and Stiglitz (1974) in their comprehensive analysis study the case where all commodities are tradeable at fixed (world) relative prices and the only restriction on government is that private profits cannot be taxed. They show that while the government should use world relative prices in evaluating a public project, the same project, if it is in the private sector should only be evaluated differently, to the extent that the social cost of private profits have to be taken into account. However, unlike Diamond and Mirr (1971), they assume no restrictions on commodity taxes.
Shadow Prices for Traded Goods

In an economy where all goods are tradeable at fixed relative prices in the world market, the one robust result that seems to hold under a variety of circumstances, though not necessarily universally, is that the shadow prices for evaluation of public-sector projects are world prices. The logic of this result can be simply stated. As long as the only constraint in which quantities traded in world markets appear is the balance of trade constraint, at the initial optimal situation (subject to whatever constraints on taxes) the marginal rate of substitution (in social welfare) of any two traded goods will equal their relative price in world markets. But this marginal rate of substitution of the same two goods also equals (assuming efficiency and that both goods are being produced in positive amounts) their marginal rate of transformation in public production, provided the only constraint on public production is its transformation function. This yields the result on public-sector shadow prices. When there is aggregate production efficiency, then marginal rate of transformation in private production equals that in public production, and the world prices become the relevant shadow prices for evaluation of private-sector projects as well. The role played by there being only one restriction, namely, balance of trade, on the quantities traded in deriving this result is crucial.

It follows readily that when there is a binding import or export quota or when there is a government budgetary constraint or when import tariffs on a commodity depend on the level of imports of the same or some other commodity the above result does not go through, as has been noted by Dasgupta and Stiglitz (1974), Bhagwati and Srinivasan (1981) and Blitzer et al. (1981). In the first case this is so for the obvious reason of the binding quantity constraint, in the second because of the revenue effects of the quantities traded and in the third because the quantity imported of a commodity determines the tariff, and the tariff so determined need not be optimal.

Monopoly Power in Trade

Life is made simple if all commodities are tradeable at fixed relative prices in world markets. It gets a bit more complicated if we allow the relative prices to vary with the volume of trade, while still maintaining the assumption that all goods are traded. This is the so-called ‘monopoly power in a trade’ situation of trade theory. This is relevant for those developing countries which supply a substantial share of some primary commodities. The simplest way of introducing this notion is to assume that there is a commodity, say, tea, in which the country in question has a substantial share in world markets, while in all other commodities it is a price-taker. Thus, the price relative of any two of the set of commodities, excluding tea, is fixed, while the price of any commodity relative to tea depends on the volume of tea exported. Denoting the exports of tea by $z_1$, and net exports of other commodities as $z_i$ ($i = 2, \ldots, n$) and with the $n$th commodity as numeraire, one can write the balance of trade constraint as:
\[ \phi(z_1) - \sum_{i=2}^{n} p_i z_i = 0 \]

with \( p_n = 1 \). What this says is that exporting \( z_1 \) units of tea fetches \( \phi(z_1) \) units of numeraire in world markets which can be spent on other commodities at fixed prices \( p_i \) in terms of numeraire. As before, if the only constraint in the social-welfare optimization problem in which traded quantities enter is this balance of trade constraint, then the social value or shadow price (in numeraire terms) of a unit of \( i \) (other than 1) at the optimum is \( p_i \) and that of 1 is \( \phi'(z_1) \) or the marginal export revenue \( \phi'(z_1) \). For reaching this optimum in the situation where tea is produced by atomistic price-taking producers, government intervention in the form of an optimum export tariff would be required. Bhagwati and Srinivasan (1981) have shown, however, that, if the quantity of tea exported is not optimal in the initial situation, then the marginal export revenue at the nonoptimal export level would not be the shadow price of tea, though the shadow price of other traded commodities will continue to be their world prices (in terms of numeraire). Unfortunately, this distinction between optimal and suboptimal initial situation is not made in manuals on project appraisal which typically recommend the use of marginal revenue in place of average revenue when monopoly power in trade is present.

**Nontraded Goods**

Introducing nontraded goods leads to further complications. The literature appears to be less than perfectly clear on the derivation of shadow prices for nontraded goods. Dasgupta and Stiglitz (1974) unarguably state that the shadow price of a nontradeable (in terms of social utility as numeraire) is the loss in production of a traded good that would be incurred if an additional unit of the nontraded good were produced, the loss being valued by the utility numeraire price of that traded good. But this, of course, means that one has to know the price of a traded good (it does not matter which good) in terms of utility numeraire, whereas the project evaluator may know only the price of a traded good in terms of another traded good as numeraire (that is, world market relative prices). Only by solving the entire optimization exercise could one know the price of a traded good in terms of social utility. Little and Mirrlees (1974, p. 167) suggest that, since the shadow price of a commodity would equal its shadow cost of production (that is, value at shadow prices of the bundle of inputs needed to produce a unit of that commodity), and since there are as many such equations as prices, ‘it can be confidently asserted that these equations have a solution’. The difficulty with this assertion is seen clearly if we start with assuming constant returns to scale in production and there being \( n_1 \) traded goods (with an index set \( I \)), and \( n_2 + m \) nontraded goods, the latter consisting of \( m \) primary factors (index set \( F \)) and \( n_2 \) produced goods (index set \( II \)), and denoting the initial equilibrium input–output coefficient matrices by \( A_{I,I}, A_{I,II}, A_{F,I} \) etc. The Little–Mirrlees assertion amounts to calculating (local) shadow prices \( p_{II} \) for nontraded goods for \( p_F \) for
primary factors, given the shadow price (that is, world prices) \( \hat{p}_I \) for traded goods by solving (primes indicating transposition of a vector):

\[
\hat{p}'_I (I - A'_{II}) - p''_I A_{II} - p''_F A_{FF} = 0
\]

\[-\hat{p}'_I A_{II} + p''_I (I - A'_{II}) - p''_F A_{FF} = 0.
\]

Unfortunately, we have here \( (n_1 + n_2) \) equations in \( n_2 + m \) unknowns. But there is one case, considered at length in Bhagwati and Srinivasan (1981), in which things do work. If the number of factors \( m \) equals the number of traded goods, so that \( A_{FF} \) is a square matrix, and if there is no linear dependency in the factor-intensity vectors in traded-goods production. (That is \( A_{FF} \) is nonsingular), then we get:

\[
p_I = [(I - A'_{II}) + A'_{FF} (A''_{FF})^{-1} A''_{II}] A'^{-1} + A'_{II} (A''_{FF})^{-1} [(I - A'_{II})] p_I
\]

\[
p_F = (A''_{FF})^{-1} [(I - A'_{II}) p_I + A''_{II} p_I].
\]

Indeed, the so-called Little–Mirrlees rule of decomposing nontradables and primary factors would amount to just this. This analysis is analogous to the unique determination of factor prices and factor input coefficients by the market prices for traded goods in the fundamental model of Samuelson (1953). Given the factor prices and production technology, the market prices for nontraded goods are determined. The demand conditions determine the outputs of nontraded goods. As long as the market prices for traded goods remain unchanged because, say, they are determined by fixed ad valorem tariffs over fixed world prices, then the technical coefficients also remain unchanged. Thus, the above procedure for computing the shadow prices (in terms of a traded good) of nontraded goods goes through.

Mirrlees (1977a) also derives shadow prices for nontraded goods in a model with commodity taxation that may not necessarily be optimal but with 100 percent taxation of pure profits. His procedure, to begin with, assumes that the shadow price (in terms of social utility as numeraire) of government revenue (or equivalently of a tradeable good) is exogenous and at the second stage 'estimates' it on the basis that additional government revenue is uniformly distributed as lump-sum income among individual consumers. Thus, by equating the change in social welfare brought about by increasing each consumer's lump-sum income by one unit to the product of shadow price (in terms of social utility) of a tradeable good and the cost of meeting additional demands generated (each good being valued at its shadow price in terms of that tradeable good), he obtains the shadow price of the tradeable good in terms of social utility. Since this procedure is not based on conditions characterizing the relevant social optimum, one can judge the closeness of the shadow prices yielded by it to the true shadow prices at the social optimum only by computing both in some well-specified examples.
We may summarize the above discussion as follows. (1) In an economy satisfying the assumptions of the second fundamental theorem of welfare economics, including in particular the feasibility of lump-sum transfers among individuals, there is no need for project evaluation and shadow pricing. But then, the problem is really evaded by transforming it into one of calculating optimal lump-sum transfers to achieve maximal social welfare. The informational requirements for making such calculations are severe, not to speak of incentive-incompatibility problems. (2) In a Diamond–Mirrlees economy, in which consumer preferences and production sets (public and private) satisfy the assumptions of the theorem, but only commodity taxation is feasible and lump-sum transfers are not, as long as aggregate production efficiency obtains at the social welfare optimum (achieved through optimal commodity taxation), the need for project evaluation disappears again since optimally chosen producer prices (common to public and private sectors) reflect the social-welfare valuation of all commodities. Again, the problem of project evaluation is transformed to one of calculating optimal taxes or equivalently optimal producer and consumer prices. (3) If all commodities are tradeable internationally, and the only constraint in which quantities traded enter is the balance of trade constraint, then the relative valuation of the commodities for project evaluation (public and private) is their marginal contribution to the trade balance. In the particular case, where the country is a price-taker in world markets, this amounts to using world relative prices as shadow prices. In so far as private profits are not entirely taxed away, the social cost of such profits also have to be taken into account in the evaluation of private projects. (4) The problem of shadow-pricing a nontraded good (in situations with non-optimal taxation) involves some rather ad hoc and unrealistic assumptions, perhaps no more so than in any applied welfare analysis.

Srinivasan and Bhagwati (1978: 1981), Blitzer et al. (1981), Boadway (1975: 1976) and Mirrlees (1977a) (discussed earlier) view a 'small' project as a perturbation of an initial equilibrium in which there are distortionary taxes. They examine whether such a project will improve social welfare. Boadway’s approach is to allow for distributive effects of policy changes by using what he calls a ‘distribution characteristic’ of each good, rather than its equivalent of weighting the income gains and losses to different individuals. The distribution characteristic of good \( i \) is the average of the marginal contribution to social welfare of an additional consumption of a unit of the numéraire good by each consumer, weighted by his share in total consumption of good \( i \). While this way of rewriting the expressions for policy-induced change in social welfare is illuminating, from an informational and computational point of view it provides no particular advantage.

The approach to shadow prices by treating a project as a perturbation of an initial equilibrium is no different from the approaches discussed under the headings optimal and nonoptimal taxation, unless the initial equilibrium has some features, such as sticky wages (sector-specific or general), and so on, that make it different from a standard competitive equilibrium modified by taxes.
and transfers. A part of the contribution of Bhagwati and Srinivasan (1981) is devoted to the sticky-wage problem.

Shadow Prices of Primary Factors

Many of the models discussed so far do not treat nonproduced factors of production explicitly. Since the consumer budget constraint is written in these models as $q'c \leq$ lump-sum income + share in profits after tax (if any), where $q$ is the vector of consumer prices and the consumer’s factor endowment is subsumed in $c$. First, this means that the consumer has to pay the relevant commodity tax, even when he consumes out of his own initial endowment, including, in particular, his labor. Secondly, in models in which all commodities are tradeable, the implication is that labor, land, and so on, are also tradeable internationally. Alternatively, one could have assumed that all nonproduced factors of production are specific to production units and any returns to such factors being included in the unit’s profits. However, the straightforward thing to do would be to divide the commodities into tradeable goods and nontradeables, the latter including primary factors as well.

Shadow-pricing of primary factors (capital and labor) in an economy with distorting trade taxes or quotas but free of any other distortions is the focus of the works of Findlay and Wellisz (1976), Bhagwati and Srinivasan (1981), Srinivasan and Bhagwati (1978) and Bhagwati and Wan (1979). Using the traditional two-factor, two-commodity, constant returns to scale production, general equilibrium model (with full employment of all factors) of trade theory, and (subsuming distributional considerations) by employing a Bergson–Samuelson social utility function) Srinivasan and Bhagwati (1978) show the shadow price of a factor (in terms of a traded good) is the change in output of traded goods (valued at fixed world relative prices) with respect to a change in the endowment of that factor by a unit, if tariffs are the only distortions. If an optimum tariff is being levied to exploit monopoly power in trade, when it exists, then the changes in output are to be valued at marginal terms of trade. In the case of a quota, which is being enforced through a production tax-cum-subsidy, leaving consumption to take place at world prices, again world prices are the shadow prices for valuing the change in outputs. If the quota is enforced by permitting domestic prices (common to producers and consumers) to deviate from world prices to the required extent, then the market wages and rentals also happen to be their shadow counterparts, the reason being that the economy at the margin becomes a closed economy.

Bhagwati and Srinivasan introduce a third nontraded good which is produced under constant returns to scale and, thus, work with a model in which market prices of factors and the nontraded good are uniquely determined by traded-goods prices. In such a model all shadow prices (in terms of a traded good) are determined from the world prices of traded goods. They briefly note that in a model where the number of traded goods differs from the number of factors, the shadow price of a factor will still be the value at world prices of the change in output of traded goods induced by the availability of an
extra unit of that factor, provided nontraded-goods prices are kept constant through appropriate tax-cum-subsidy policies.

**Tax Reform**

One of the usual arguments for project evaluation is that an initial equilibrium of an economy is often subject to unremovable tax distortions, and through the selection of appropriate projects, the government can mitigate the distortionary effects of taxes. A version of this argument is that, if the government cannot tax the rich and subsidize the poor, it can accept projects that directly help the poor and reject those that help the rich. I am not convinced that this is a good theory of government or politics: a government that is unable to exercise its fiscal instruments in desired ways is unlikely to get away with accepting projects that have similar effects. A more realistic view is that for historical reasons or inertia some distortions get built into the system, and given this, one tries to mitigate the effects of distortions while at the same time trying to eliminate them. It is, therefore, worthwhile to look at tax reform (as contrasted with optimal taxation or project selection) as an instrument of improving social welfare.

The issue addressed in this body of literature is whether a tax reform that reduces distortions in some specified fashion improves welfare as in Bruno (1972), Dixit (1975), Foster and Sonnenschein (1970), Kawamata (1974), Hatta (1975; 1977a; 1977b) and Rader (1976). This literature can be related to Hotelling's (1938) work and to many of the traditional partial-equilibrium public-finance and cost–benefit theories (Harberger, 1971). The contributions to the analysis of tax changes in a general-equilibrium framework are also relevant, in particular, Guesnerie (1975; 1977; 1979), Shoven and Whalley (1973; 1977) and Whalley (1975).

Many of these contributions assume that there is only one consumer in the economy. Distortion is defined (except in Bruno) as the difference between the vector of marginal rates of substitution in consumption (with one of the commodities as numeraire) and marginal rates of transformation along the production-possibility frontier, though in deriving many of the propositions this frontier is assumed to be a hyperplane. In Bruno (1972) the distortion arises from the difference between the common producer and consumer price vector and an exogenous constant vector of shadow prices. The main result of these studies is that a simultaneous reduction by the same proportion in the distortions (relating to each good, other than the numeraire — for which the distortion is zero by definition) increases the welfare of a single consumer, assuming that there is a unique equilibrium corresponding to each level of distortion and all goods are normal in consumption. The latter assumption is weakened somewhat in Hatta's and Bruno's papers. Kawamata (1974) shows, in a model with many consumers with strictly convex preferences and producers with strictly convex production possibility sets, that even if there are multiple equilibria corresponding to a given distortion, corresponding to any of these equilibria, one can find an equilibrium corresponding to a equi-proportionate reduction in
all distortion which is Pareto-superior. Dixit (1975), and in some of his propositions Hatta (1977a) also, consider nonequi-proportionate reduction in distortions as well.

The relationship between project evaluation and these propositions on tax reforms is seen most clearly in Bruno's work. His constant shadow-price vector is best interpreted, as he himself does, as corresponding to the given world prices for traded goods (assuming all goods are tradeables) faced by a 'small' price-taking economy. Then his result that reducing all distortions proportionately leads to an increase in output evaluated at shadow prices (and welfare) could be reinterpreted in terms of project evaluation, if we identify the change in output vectors in the two situations as constituting a project.

Project Evaluation in Developing Economies

Most of the models discussed so far do not appeal to any institutional or other aspects of an economy that could be called specific to a developing economy. However, the two major 'do-it-yourself' kits on project evaluation by Little and Mirrlees (1974), Dasgupta et al. (1972) and a variant from the Little–Mirrlees cuisine by Squire and van der Tak (1975) are specifically addressed to less developed countries. All three assume an economy, presumably in an equilibrium, subject to various distortions, socially nonoptimal taxes, and so on, with some resources, such as labor, not being employed to the extent of their availability. The distribution of wealth among individuals is considered socially nonoptimal. Since most of the models discussed so far had many of these features, one may wonder what distinguishing features are brought in by considering a developing economy. One apparent difference is in the social-welfare function: the models discussed so far defined social welfare on an individualistic basis, so that the project affected social welfare only through its impact on individuals' utilities. The manuals on project analysis for less developed countries, on the other hand, implicitly define social welfare as a function of individual utilities, as well as some aggregate variables (termed 'merit wants' in Dasgupta, et al., 1972), such as total employment of unskilled labor (reflecting that employment is socially desirable over and above its contribution to incomes of individuals), balance of payments excluding induced balancing flows (reflecting the social objective of self-reliance), and so on. Another difference is in the models discussed so far, a complete set of markets in the Arrow–Debreu sense is assumed to exist, so that time-discounting, risk and locational preferences are implicit. The practitioners of project analysis for less developed countries explicitly take into account these aspects in deriving some key shadow prices, such as the shadow wage rate for unskilled labor, the social rate of discount or equivalently the shadow price of investment in terms of consumption (with public investment and consumption sometimes distinguished from private investment and consumption) and net foreign-trade deficit.

Noneconomic or Extra-Economic Objectives

The introduction of objectives, such as self-reliance, employment in specific
industries, and so on, for their 'social' value over and above their contribution to private welfare is not entirely new. For instance, Bhagwati and Srinivasan (1969) derive, using a social-utility function, optimal fiscal interventions to achieve such objectives (which they term noneconomic) in the traditional two-commodity, two-factor model. If their optimal tax subsidy policies were being followed and if any other distortions present were being tackled optimally, then the shadow prices would, of course, be the relevant tax–subsidy-corrected market prices. This would also mean that a project evaluator would, first, have to determine whether the existing set of taxes and subsidies are being levied to achieve some social objective or other before he decides to adjust for them in his shadow-price calculations. Indeed, Little and Mirrlees (1974, p. 224) explicitly state this. More generally stated, a commodity tax is 'distorting' only if it is nonoptimal from the point of view of social-welfare maximization. As such, a given tax may or may not be considered 'distorting', depending on whether the project-evaluator takes it to reflect an optimally exercised instrument to achieve an appropriate social objective. This has led some to conclude that almost any project can be claimed to be worthwhile from a social-welfare point of view, by correcting some and not correcting other market prices. In this context that the robustness of the result that world relative prices are the shadow prices for traded goods even in the presence of noneconomic objectives is particularly appealing.

Derivation of 'Key' Shadow Prices from Macromodels
The manuals of project evaluation derive two 'key' shadow prices, that of labor and investment from an explicit or implicit aggregate optimal growth model, in which aggregate output is produced with fixed capital and labor (or several categories of labor as, for instance, in Little and Mirrlees). This output is divided between additions to capital stock (investment) and current consumption. The latter depends on employment and on other constraints, if any, such as consumption floors. Little and Mirrlees (1974) argue that 'the optimization problem must, therefore, be solved as a whole, perhaps for an infinite horizon, if we are to know what ARI (accounting rate of interest or equivalently the shadow price of capital) and SWR (shadow wage rate) ought to be in the immediate future'. They continue: 'The moral is, that optimum growth calculations in solvable models are the only satisfactory way of telling at what level current accounting (i.e. shadow) prices should be put.' They conclude (p. 304) that 'in the absence of adequate guidance from computed models, presumably one should be able to make fairly sensible guesses about the general long-term development of the economy, and work backwards from these guesses to estimates (of shadow prices) ... in the present'.

It is by no means obvious that the two-stage procedure of deriving some key shadow prices (that of capital and categories of labor) from a macrooptimizing model can be grafted on to another model (optimizing or otherwise) for determining the remaining shadow prices so as to have a complete set of shadow prices for project evaluation. Further, as Rudra (1972) and Hammond (1978)
point out, once a large optimizing model has been solved to provide all shadow prices in one fell swoop, what is the role of project evaluation? After all, project selection itself could be part of such an optimization exercise.

Project Appraisal as a Planning Procedure

It would be going too far to reject any macroframework whatever for project appraisal. The need for such a framework becomes clear in the context of planning economic development. Any plan, almost by its very definition, is a collection of projects. By the same token, a plan cannot be an arbitrary collection of projects. However, it is unlikely that one could devise an all-purpose optimizing model that would produce the optimal plan, the associated set of projects, and a set of shadow prices to evaluate projects that have not yet been proposed and evaluated as part of the optimization exercise. In such a context, a macromodel (of a multisector kind) may be useful not for project selection, but for checking mutual consistency of sectoral plans and for generating broad development alternatives. In such a context one can see the role of project appraisal as that of selecting among projects proposed for meeting sectoral targets. The techniques used for appraisal should ensure that an accepted project is feasible and leads to social-welfare improvement.

The application of the first of the two criteria, namely, feasibility, is not difficult to meet, if a project is ‘small’, so that it has negligible impact on the aggregate demand for those inputs it uses. A large project leads to difficulties in several ways: first, because of its nonnegligible impact on the economy through its input demands (and output supplies), its feasibility may have to be checked as part of the macroconsistency exercise itself. Secondly, the shadow prices for inputs and outputs cannot be assumed to be unaffected by project choice, if the project is sufficiently ‘large’. This nonstationarity of shadow prices is investigated in depth by Bhagwati and Wan (1979), and by Baumol (in this volume). The latter shows that a linear approximation to a nonlinear programme (a frequent practice) can yield shadow prices which do not come anywhere near to the true shadow prices. and what is even worse, it can impute a positive (zero) shadow price to a truly free (scarce) input! However, it is not simple to specify and solve even a moderate-sized nonlinear programme. Thirdly, if the largeness of the project implies indivisibility and increasing returns to scale, then most of the shadow-price derivations that depend crucially on the convexity of the production sets lose their meaning. Setting aside the issue of large projects, we still have to address the criterion for choosing projects that improve social welfare. The question is: can we derive shadow prices that will enable one to determine whether a project provides welfare improvement without solving a full-blown optimizing model?

An analogy from linear programming is helpful. The values of the dual variables at the optimal solution of a linear-programming problem correspond to the shadow prices associated with solving the full-blown model. But the simplex algorithm also yields a set of prices at each iteration, which has the property that at these prices (1) all activities in the basis break even, and (2)
bringing into the basis any activity that is outside the basis but yields a ‘profit’, would increase aggregate ‘profits’. The analogy is complete, if we identify aggregate ‘profits’ as social welfare and a ‘project’ as an activity that is outside the current basis. The only problem may be that an activity (‘project’) rejected at one iteration may come back into the basis at a later iteration. This back-and-forth movement can in principle happen several times. One could argue, of course, that this is not a problem in that a project could indeed be socially worth while at one set of shadow prices and not at another. Be that as it may, an approach to project appraisal that comes closest to this is that in which one starts from a full specification of the initial ‘equilibrium’ of the economy, views the project as a perturbation of this equilibrium and evaluates its effect through the social-welfare function.

It is perhaps fair to say, in conclusion, that the gap between the analytical basis and practical recommendations for project evaluation is yet to be narrowed sufficiently. While the modern literature on public finance as well as optimal growth has provided valuable insights, these cannot yet be translated into procedures that can be confidently recommended for application by a project-appraisal bureaucracy in a developing country. Yet these procedures are far from useless. Indeed, by forcing the project formulations and evaluators to specify in detail the probable impact of a project on particular socioeconomic groups, decisions are likely to be made on a more informed and possibly consistent basis than would otherwise be the case. But there is also the danger that project-evaluators may become the economic counterparts of witch-doctors.

Computable General-Equilibrium Models and Development

Computable general-equilibrium models had their antecedents in the computable ‘planning’ models of the 1950s and 1960s for developing economies, most of which in no way could be characterized as ‘planned economies’. Nevertheless, whether they were relatively simple macro-models of the Harrod–Domar–Mahalanobis–Feldman variety or the more elaborate multisector consistency models or even multisector optimizing (of a target year or inter-temporal variety) models, they were mainly useful (and used!) for checking mutual consistency of macro-targets (income growth, savings, employment and foreign-capital inflow), and for delineating alternative growth patterns and their macro-policy implications. Indeed, in India, a country in which some of the earliest planning models for a developing country were built, they were viewed essentially as relatively economical and efficient ways of generating and studying alternative growth paths, by changing the parameters of the objective function or the constraint set. The model runs were intended only as diagnostic devices for locating critical bottlenecks or isolating critical parameters and not for either drawing up a national development plan, or to track the economy’s progress. This is not to say that there were no enthusiasts who contemplated the use of the dual of the programming exercise in deriving shadow prices for
project appraisal and other decisions. They did not get very far, partly because of the instability of the shadow prices (to which a reference was made earlier) with respect to even minor perturbations of the parameters of the model.\textsuperscript{9} The continuous substitution possibilities (in production and consumption) that are a feature of the computable general-equilibrium models are intended in part as a response to the instability problem.

In spite of their many drawbacks (most of which were known to some of the model-builders), these models were useful conceptual devices through which development economists thought out many crucial policy issues in \textit{quantitative} terms. In some respects they represented a practical quantitative formulation of many issues addressed in the theory of the second best, though some went too far in accepting many a market distortion as unremovable and underplayed the role of the market in the allocation process. These models were sometimes used to generate project-selection criteria (particularly in respect of projects in the foreign-trade sector), such as domestic-resources cost (of earning or saving) of foreign exchange (DRC).\textsuperscript{10} In a context where foreign-exchange availability was considered a major constraint on growth, the estimation of shadow price of foreign exchange from these models and the use of DRC in project selection were important applications of policy significance.

The \textit{state} of the art in building and using such models was reviewed in Blitzer \textit{et al.} (1975). In his systematic survey of the theoretical basis of economy-wide planning models for this volume Lance Taylor concluded: ‘If we had a better theory of prices and economic power than the Walrasian one, model builders would clearly use it. At the moment … all that can be said is that a \textit{linear programming} model is likely to be a poor facsimile of a Walrasian economy, while a nonlinear constant returns model will be a better one. If \textit{competition} is basically the only game in town, you might as well play it with \textit{elegance}’ (p. 100). Mirrlees (1977b) seems to share this emphasis on using the competitive equilibrium framework for analyzing public policy because, in his view, this would avoid debate about ‘dubious relationships of disequilibrium macro-economics or oligopoly theory, and concentrate on essentials’.

By the late 1960s and early 1970s, concern was being expressed by academics, policy-makers, aid-donors and international agencies that the fruits of growth had not trickled down to the poor in developing countries. It was forcefully argued that distributional considerations besides aggregate income growth have to be taken into account in devising policies (Chenery \textit{et al.}, 1974).

The model-builders have responded to this by concentrating on the endogenous determination of the distribution of income (among socioeconomic groups within an economy) and the structure of relative prices. It is natural to turn to the Walrasian general-equilibrium framework for this purpose, since in such a framework, the distribution of income among individuals or groups is the distribution of the market valuation of the returns to their initial endowments as modified by any fiscal interventions of the government. The problem of income distribution is then transformed into one of computing the equilibrium structure of relative prices. It cannot be denied that a manageable
model that computes the equilibrium-relative prices is at once elegant and intellectually satisfying, even though as Scarf (1973) points out, 'Walrasian model of competition ... is far from being the exclusive analytical framework for the study of micro-economic problems'. The question is whether such an exercise helps in evaluating projects and illuminates the process of development. There are several reasons for some skepticism on this count, even if we ignore the criticisms of Kornai (1971).

First, the computable models assume that a set of markets exist and these operate smoothly except for whatever policy restrictions are imposed, such as price floors or ceilings, together with rationing, and so on. But an important, if not the most important, aspect of development is the evolution of the system, in terms of integration of existing fragmented markets, coming into being of new markets, new products, new technologies, and so on. These models, operating solely on an undoubtedly important aspect of reality, namely, the mutual adjustment of quantities and prices at each point in time, have little to say on the evolution of the system. This is particularly unfortunate in models that cover long periods into the future.

Secondly, one of the stylized facts about many a developing economy that is said to distinguish it from any developed economy is that of 'dualism', where manifestation of which is the phenomenon of differential rewards to the same mobile factor in different sectors or locations (rural and urban) that are not explainable in terms of sector or location-specific factors. The theoretical and computable models incorporating this dualism in a mechanistic way by postulating, for instance, an exogenously specified wage differential between sectors or locations, resulting in excess supply of labor and unemployment in a location. This is made consistent with equilibrium by assuming a labor-migration mechanism that keeps the unemployment at such a level that a potential migrant to the high-wage location is indifferent between migrating and not migrating. The indifference arising from the fact of expected wage allowing for unemployment in the high-wage location equals the actual wage in the low-wage location. As Arrow (1967) points out, the question why such wage differentials persist is of first importance and just assuming it to be exogenous tells us nothing about development.

Thirdly, the time structure of these models is one of a sequence of equilibria, in which the productive capacity in any period is limited by inherited capital stocks (including inventories) and periods are linked by investment activities. The market clearing prices in any period are determined given either a sectoral investment (including stock changes) determination mechanism that was independent of future prices, or that depended on expected future prices which, in turn, are linked to current and past prices through an adaptive price-expectation mechanism. There is no doubt that a temporary equilibrium approach is useful for analyzing some short-period problems. But it would appear bizarre to derive a dynamic path for a developing economy as a sequence of such equilibria, in which an equilibrium (in the sense of all markets clearing) is established in each period through an unspecified process!
Fourthly, the main motivation of constructing many of these models was to improve our understanding of the process of income distribution and of poverty. The computable models can at best trace the 'functional' distribution of income, though in terms of a larger number of functional categories than just labor and capital shares. But the phenomenon of poverty at a point in time is linked to the distribution of income across households at that time and an essential aspect of the dynamics of poverty is what happens to cohorts of households and not just to household categories. Though, for instance, in a model for the Philippines (Rodgers et al., 1977), an attempt is made not only to map functional distribution into household income distribution as is done in other models, but also to model the process of household formation and its functioning through its existence. It is fair to say that this attempt is rather mechanical. It is not simple to incorporate the impact of political power (and the dynamics of power groups) on income distribution. The exercise of power can change the rules of the game, that is, the way the economy functions. It is possible that the work of Aumann and Kurz (1977) and Kurz (1977) provide the beginnings of a fruitful line of inquiry. But in their framework the government is invisible: the rules of the bargaining game, coupled with the political rule that a majority (simple, two-thirds, weighted, or unweighted) decides, determine the outcomes.

Fifthly, the particular advantage of the ability to compute numerically the equilibrium prices and quantities (ignoring uniqueness issues) is that it enables one to analyze the (comparative static) impact of government policies on such an equilibrium, without resorting to techniques (such as those used in project analysis) that require the policy changes to be 'small'. This tool, as applied to a context where the unspecified process of movement from the equilibrium before policy change to the one after is supposed to be completed within each period, is likely to be very misleading.

Finally, some of these models (in particular, Adelman and Robinson, 1978, p. 185) claim to have incorporated monetary effects in a general equilibrium model. These attempts appear faulty and certainly have not succeeded where theoreticians have failed in satisfactorily incorporating money in general-equilibrium theory. Since some of their policy simulations are sensitive to changes in aggregate price level (that is, determined through the introduction of money), their results have to be viewed with caution.

**Some Open Issues**

One would not wish to suggest that the computable general equilibrium models have come to a dead-end as far as analyzing the growth of a developing economy. Nor would one like to be accused of what Arrow and Hahn (1971) call the 'vulgar mistake' of supposing that the analysis of competitive equilibrium has nothing to teach us about an economy, developed or developing. But for the research resources spent, probably far more useful lessons can be learnt by deeper analysis of specific markets, such as those for labor, land,
agricultural resources and credit. The institutional framework within which such markets operate is important. For instance, in many agrarian societies, a landlord and his tenant farmer enter into several transactions at the same time: in land (supplied by the landlord), in labor (supplied by the tenant), in other purchased inputs for which an agreement is struck in the sharing of costs, in credit (for production and tenant’s consumption needs) supplied by a landlord and in marketing services (for output) supplied by the landlord. It has been alleged that, in such a context, a landlord may not be interested in introducing new varieties of crop or methods of cultivation that will increase the yield of land. The argument is that, though he will gain from higher yields, he will lose income from loans to his tenant, in so far as the tenant may borrow less because his income goes up with the yield increase. This has been offered as an explanation why in some parts of India the new technology of agriculture ushered in by the green revolution of the late 1960s did not take root. The logic of this argument is not entirely persuasive. Transaction costs alone do not explain why the same pair of individuals exchange goods and services across a spectrum of markets. There are other interesting issues to analyze as well: why do we observe active rental markets for mechanical power (tractors, pumps, and so on) but not for animal power (bullocks)? Why is there an active market for tenancies (that is, land rental market) but a thin one for land? A multisector general-equilibrium model with all of agriculture aggregated into a simple sector as is often done is not suitable to pose such questions. And without understanding the functioning of allocation and accumulation processes in agriculture, very little of substance can be said of effects of policies to promote development or alleviate poverty in South Asia, if not in other areas of the less developed world.

Sectoral models are useful in planning investment and its time-phasing in some key industries in which scale economies are important. An extensive literature on this has emerged since Alan Manne’s (1966) early work. Of course, inconsistencies can arise from the fact that separate industry or sector models do not take into account interdependencies that a general-equilibrium model fully articulates. This is not a serious problem, once it is realized that the consistency of the general-equilibrium model is bought, in any case, at great cost in terms of untestable assumptions and compromises to fit available data into a computable model. There is no better way to conclude this chapter than to quote the words of Arrow (1967): ‘the problems of developing countries remind us dramatically that something beyond, but including, neoclassical theory is needed’.

Chapter 14: Notes

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1 One could consider any intervention such as a regulation, a tax, or an expenditure in an initial equilibrium as a project in a general sense. Project appraisal in such a context becomes general social cost–benefit analysis. Much of the literature reviewed here is relevant for this as well.

2 The incentive incompatibility problem arising out of incomplete information is a feature not merely in the context of computing lump-sum transfers, but of almost all information-exchange-based resource allocation planning mechanisms.

3 Diamond and Mirrlees (1971) assume constant returns to scale production function.

4 It must be noted that the optima corresponding to different sets of constraints on public instruments need not be the same; nor need any of these optima belong to a set of Pareto-optimal allocations that the resources, technology and consumer preferences would permit. Finally, nonuniqueness problems can arise.

5 Other producers including public producers face convex (rather than convex cone) technology sets. In this model supply depends only on producer prices, while consumer demand depends on consumer prices and profits.

6 In a model in which Walras’s law ensures that government budget constraint is met whenever every other agent meets his or her budget constraint, this constraint is to be interpreted as applying to a part of the budget. Such a situation may arise, for instance, when a limit is set by law on the extent to which public-enterprise losses can be met from general revenues.

7 This should really be understood as characterizing the initial pattern of production, so that there are goods that the economy could have produced but is not producing. The rest of the argument is based on the assumption that this pattern of specialization is unchanged by the introduction of the project.

8 However in Diamond and Mirrlees (1971) social welfare is defined as a function of individual consumption vectors, so that at any given m-tuple of consumption vectors by the m consumers, the social marginal rate of substitution in consumption of two commodities by individual i can differ from i’s own marginal rate of substitution.

9 Of course, given the linear activity-analysis framework of these models, the problem of primal-dual instability was to be expected.

10 The related concept of Effective Rate of Protection spawned a large volume of empirical or theoretical studies. But most of these are partial-equilibrium studies.

Chapter 14: References


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