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# MANUALS FOR POLICY ANALYSIS ON THE USE OF GENERAL EQUILIBRIUM MODELS IN AGRICULTURAL POLICY ANALYSIS

IICA

INTER-AMERICAN INSTITUTE FOR COOPERATION ON AGRICULTURE

OFFICE OF THE DEPUTY DIRECTOR GENERAL

Office of Multizonal Projects
Planning and Project Management Division—PROPLAN

Collection of Contributions
San Jose, Costa Rica, 1981

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# MANUALS FOR POLICY ANALYSIS
# ON THE USE OF GENERAL EQUILIBRIUM MODELS IN AGRICULTURAL POLICY ANALYSIS

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FOREWORD

The purpose of the Collection of Contributions is to present the work done by consultants, groups and institutions connected, now or in the past, with PROPLAN Projects of the Inter-American Institute for Cooperation on Agriculture (IICA).

This document focuses on the area of policy analysis and was written specifically as a contribution to the Project on Agricultural Planning and Policy Analysis in Latin America and the Caribbean, PROPLAN/AP.

Policy decisions are made by organizations or persons representing those organizations. Most decisions will also be joint decisions, in the sense that they involve the participation of more than one institution. This type of policy analysis involves an examination of the doctrine and services exchanged among organizations which belong to the "socio-economic environment of the planning system".

This document illustrates one aspect of policy analysis: measuring the impact of proposed policies, and selecting the most suitable, in accordance with the neoclassic posture. Thus, it evaluates how a proposed alternative affects performance variables of social importance, in both the public and private sectors, and how to determine an optimal policy level, taking this into consideration. The analysis of the incidence of a policy (or policies) and the choice of the optimal level of the policy (or policies) are treated as two sequential, but nevertheless separate, steps.

The reader familiar with large-scale linear or quadratic spatial, commodity or input programing models will realize that with that approach, policy incidence and optimal policies are solved for simultaneously.

The document does not follow that approach because the author believes that the economist's contribution is primarily in predicting the incidence of policies. Given the absence of a unique social welfare criterion, the economist must by needs obtain information about the social welfare function, the objectives to be

pursued, limitations as to the instruments to be used, etc from the policy makers, i.e. from the "administrative environment". This substitution of the economist's judgement as to what is to be optimized, e.g. agricultural value added or minimum production cost is arbitrary and possibly misleading.

This publication was prepared by Hylke Van de Wetering, of the Iowa State University, Economics Department. It was written in the framework of the PROPLAN/AP Project, jointly funded by IICA and the Agency for International Development.

TABLE OF CONTENTS

## 1. Introduction

In the following pages, we make the assumption that the Agricultural Sector Planning Office of an IICA member country may be asked to study the incidence and desirability of the following classes of policy measures

1) input price controls
2) input subsidies or taxes
3) commodity price controls
4) commodity subsidies or taxes
5) programs that improve and conserve the productivity of resources and services used in agricultural production.

The incidence of these policies is to be measured in terms of predicted changes in factor employments, production, factor prices, commodity prices, factor incomes, commodity earnings, and tax revenue. Additional measures of change in producer's surplus, consumer's surplus, and foreign exchange reserves, all of which may play a role in assessing the desirability of these policies, are also to be calculated.

We emphasize from the outset that in order to establish the desirability of a policy, one must have a system of social valuation of the changes in factor employment, production, consumption or concepts derived therefrom. Guidelines as to how to put social values on market exchange induced changes are the prerogative of the Sistema Administrativo.[1/] If they do not exist, one usually assumes that market exchange induced changes are socially optimal. Planners in recent years have attempted to construct comprehensive systems of

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[1/] For a definition of this term, see Lizardo de las Casas and Eduardo Cobas, Conceptual framework of the agricultural planning process in Latin America and the Caribbean, Latin American and Caribbean Agricultural Planning and Policy Analysis Project (PROPLAN), Document No. 1, Inter American Institute of the Agricultural Sciences (IICA), San Jose, Costa Rica, 1978.

social accounting prices which do not necessarily accept competitive market prices as measures of social value. Such systems, however, are rarely understood or sanctioned by decisionmakers.

## 1.2 Problem statement

A common notion of planning is that of policy coordination. It implies that a change in policy X generally entails a change in policy Z for a given objective Y. The rational conduct of agricultural policy therefore requires simultaneous changes in agricultural policies, rather than piecemeal changes. Nevertheless, policy decisions are usually taken one at a time. This is because coordination itself is costly (in terms of time and human or financial resources), impossible (in terms of reducing a complex system to manageable analytical dimensions), irrelevant (whenever policy X does not affect the effectiveness of policy Z given objective Y) or politically infeasible (politicians typically focus on one decision at a time).

Nevertheless, the Agricultural Sector Planning Office should in principle study all of the following four questions:

1) What is the incidence of this policy, assuming no changes in other policies?
2) What is the desirability of this policy, assuming no changes in other policies?
3) What are the major policies in place which affect the incidence of this policy?
4) What is the desirability of this policy given proposed adjustments in other policies?

As of 1981, no Agricultural Sector Planning Office has constructed or has access to a comprehensive system of social accounting prices, nor has any such

office been charged by law with the implementation of such a system. If, furthermore, the Sistema Administrativo is committed to taking one decision at a time, it must follow that the major role of the Agricultural Sector Planning Office is that of answering the first of the four questions listed above. That question asks how a proposed policy (change) affects private sector behavior. It is a subject which can be studied objectively utilizing for that purpose established principles of economic analysis. The answers to the remaining three questions above involve prior normative and conditional elements. The normative element refers to the guidelines as to how to evaluate changes in the private sector from a social point of view. The conditional element refers to the set of policies which will be changed simultaneously with policy X.

2. What is policy analysis?

Policy analysis can take many forms. This very fact negates the existence of a definition sufficiently comprehensive to accomodate the very large number of specialized forms or methods of policy analysis. Nevertheless, most types of policy analysis involve four steps.

1) "to examine current and past ends and means of separate or interrelated policies affecting the institutions and performance of the private and public agricultural sector and its clients"

2) "to report, evaluate, or propose one or more desirable changes in the ends and means of such policy(ies) as suggested by the clients of the public agricultural sector, by the public agricultural sector itself, or by outside experts"

3) "to consider the feasibility of the desired changes under existing constraints and under relaxation of selected limiting constraints"

4) "to formulate on basis of the foregoing a set of immediately feasible desirable changes in ends and means and others which will become feasible only in a longer-run perspective"

A comprehensive policy analysis will include all four steps, but genuine policy analysis may nevertheless contain only one, two, or three of the steps mentioned. For example, a policy analysis which studies the desirability of a proposed policy under existing constraints will yield results very different from a policy analysis which focuses on the relaxation of constraints which must take place to make the proposed policy effective. Policy decisions are made by organizations or persons representing those organizations. Most decisions will also be joint decisions, in the sense that they involve the participation of more than one institution. This type of policy analysis involves an examination of the doctrine and services exchanged among organizations which belong to the "ambiente economico social", the "sistema de planificacion."[1/]

In the succeeding pages we emphasize a different, but complementary, aspect of policy analysis, i.e. the measurement of the incidence of proposed policies and the choice of optimal policies. We ask how a proposed policy will affect socially significant performance variables of the private and public sector and how, given this, the optimal level of the policy is to be determined. The analysis of the incidence of a policy (or policies) and the choice of the optimal level of the policy (or policies) are here treated as two sequential, but nevertheless separate, steps.

The reader familiar with large-scale linear or quadratic spatial, commodity or input programming models (7, 11, 18, 34, 40) will realize that with that approach, policy incidence and optimal policies are solved for simultaneously.

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1/ For a detailed discussion of these terms, see de las Casas et. al. (6).

We do not follow that approach here, because we believe that the economist's contribution is primarily in predicting the incidence of policies. Given the absence of a unique social welfare criterion, the economist must by needs obtain information about the social welfare function, the objectives to be pursued, limitations as to the instruments to be used, etc. from the policy makers, i.e. from the "ambiente administrativo". The substitution of the economist's judgement as to what is to be optimized, e.g. agricultural value added or minimum production cost is arbitrary and possibly misleading.

We also divorce ourselves from administrative or political aspects. We therefore do not ask ourselves in what follows how the interaction among institutions leads to the formulation of policies, nor do we ask which obstacles need to be overcome in the private and public sector to put the proposed policy into effect. Basically, we ask ourselves as to the benefits and costs of a proposed policy, should it be put into effect. We make no judgement as to the probability of its being put into effect.

It follows that the ex-ante measurement of benefits and costs of proposed policies is but a small part of the basic range of topics covered by policy analysis. It is nevertheless an important part. Policy decisionmaking involves a choice between alternatives. The outcome of these alternatives can never be known with certainty, but it is desirable to reduce our area of ignorance as to probable outcomes.

The perception as to the impact of policies is very much influenced by the policy maker's or policy analyst's perception of the economic and social environment. It is this perception that influences a predisposition towards certain lines of action, either because they are needed or because experience has shown them to be effective. Major policy issues arise when the participants in the

decision-making process have strong disagreements as to the need for action or its effectiveness.

Policies are always based on an implicit model or view as to how the socio-economic environment works, because it is through the latter that policy means influence policy objectives. Proponents of the major schools of economic thought (Marxist, structuralist, neo-classical) have irreconcilable perceptions as to how the socio-economic environment functions. Consequently, they will also differ on the role of the private and public sector and the specification as to ends and means for most policies. The major behavioral hypotheses of the above-mentioned schools are well known. For the purpose of policy analysis, it is important to state which of these hypotheses has been accepted or rejected implicitly or explicitly. In these pages we use the neo-classical principle, which assumes that producers and consumers are price takers while trying to maximize material gain.

A policy analyst, through experience or special study, usually has a preliminary inventory of desirable changes in the ends and means of policy X, as suggested by the different organizations belonging to the "ambiente economico", the "sistema politico administrativo" and the "sistema de planificacion" itself. This inventory of desirable changes can be referenced to the specific aspects discussed under steps 1 through 4 of our earlier definition. A diagnostic analysis of a given policy is relatively easy. To suggest arbitrary changes in a given policy is easier yet. But this does not capture the spirit of policy analysis. It supposes the construction of a serious and logically positivistic argument in favor of changing or introducing a given policy.

Among other things, attention will have to be given to the opportunity costs involved in changing a policy. In a system working under effective constraints, a variety of opportunity costs must be taken into consideration.

Methodologically, it requires an analysis of the direct and indirect displacement effects of changing a given policy. Its execution requires the existence of a model, which integrates the constraints and behavioral responses that characterize the "ambiente economico", the "ambiente politico administrativo" and the "sistema de planificacion". No such model exists. Consequently, one may have to settle for less, that is an analysis of the direct and indirect private sector displacement effects.

The essential characteristic the problem-solving phase of policy analysis is that such incidence must be predicted. Such predictions must be based on an implicit or explicit model of the environment upon which the policy is to operate. Given the absence of a single model of universal validity, the analyst will necessarily have to make a choice. Several choices, in fact, if the analysis of each direct displacement effect requires a separate model. This requires a wide variety of proven knowledge about the behavioral response of the private sector. Under many circumstances, such knowledge will not exist. Policy decisionmaking is, therefore, as much an art as it is a science.

Predictions are subject to error. They are almost worthless under conditions of rapid structural change. When policy is the embodiment of structural change (i.e., agrarian reform, the creation of public enterprises, etc.) the analyst must anticipate an emerging model or environment. Correspondingly, the possibility of major predictive errors as to the impact of the policy embodying structural change is increased. This is also true for the remaining policies, because the constancy of essential aspects of the socio-economic environment can no longer be taken for granted. The methods discussed in this manual therefore apply to marginal and not revolutionary change.[1/]

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[1/] While the outcome of revolutionary change cannot be predicted, the possible range of outcomes can be studied, see e.g. (49) on the impact of land expropriation and allotment.

3. A classification of agricultural policies

Table 1 contains a typology of agricultural policies that affect agriculture-related outputs, inputs and services. We have constructed a preliminary list of 191 such measures. This list is evidently not complete, but our expectation is that the agricultural policy[1/] of most countries can be adequately described by less than this. If, in addition, we should focus on the more important policies, such a list would be even shorter. The purpose of the list is primarily to sensitize the reader to the possible range of agricultural policies.

The potential number of matrix entries is 26 x 191 or 4966 specific policy measures. Additional commodity and input dimensions increase the above number. On the other hand, many policy measures are output, input or service specific and diminish the above number. However, one conclusion holds; i.e., that for each country, one will very likely encounter a large and very diverse number of agricultural policies. It follows that the coordination of agricultural policy is therefore difficult, if not impossible. It also follows that if such policies are to be evaluated, singly or in combination, by means of analytical tools, one will very likely need a variety of such tools. Indeed, some of them may not yet exist, or if in existence, have not been validated as yet.

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[1/] Agricultural policy. The totality of decisions originated in the institutions belonging to the public agricultural sector or public non-agricultural sector that affect the private agricultural sector and the private non-agricultural sector. These can be of four types:

1) Decisions originated in institutions belonging to the public agricultural sector that affect the private agricultural sector.

2) Decisions originated in institutions belonging to the public agricultural sector that affect the private non-agricultural sector.

3) Decisions originated in institutions belonging to the public non-agricultural sector that affect the private agricultural sector.

4) Decisions originated in institutions belonging to the public non-agricultural sector that affect the private non-agricultural sector.

Agricultural policies can be grouped in various ways. In Table 1, we have adopted a classification which is particularly useful for economic analysis.[1/] The underlying concepts are those of the production, distribution and demand for outputs, inputs and services. The policies then can be classified into four broad groups:

1. measures that affect the ownership of agriculture-related outputs, inputs and services;
2. measures that affect the production and supply of agriculture-related outputs, inputs and services;
3. measures that affect the demand, distribution and allocation of agriculture-related outputs, inputs and services;
4. measures that affect the improvement or preservation of the quality of agriculture-related outputs, inputs and services.

For purposes of planning, it is also very important to be explicit about their basic mode of implementation:

1. through decree of similar legal dispositions;
2. through incentives;
3. through direct public sector participation in the production of outputs, inputs and services.

Indicative planning will typically concentrate on policy incentives, but a majority of agricultural planners would favor an increased emphasis on implementation through legal disposition or through direct public sector participation. Agricultural planners must develop a capability of assessing the relative merits of these modes of implementation as related to specific policies. The fundamental changes between successive development plans can often be

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[1/] For an alternative classification, see Josling (25, 26).

summarized in terms of the relative emphasis given to above modes of policy implementation.

An alternative classification would match individual policies with the institutions who are, in first instance, responsible for them. Typically, these would be related to agricultural credit, extension, research, land and water administration, marketing and other organizations of the public agricultural sector. The financial and human resources of these organizations can be considered as allocated to individual policies. This provides an important quantifiable linkage between individual policies and the annual budget for the public agricultural sector. It thereby facilitates the preparation of the annual operational plan for the agricultural sector.

Above schemes of classifying agricultural policies are not the only ones. One could correlate, for example, the policies listed in Table 1 with the degree of decision-making participation of agricultural planners in the tactical specification of the following aspects:

1. higher and lower order objectives
2. direct beneficiaries
3. institutional participation
4. forms in which the planning system participates
5. authority under which the planning system participates
6. phases in which the planning system participates
7. aspects on which the planning system must make decisions
8. required information and professional manpower
9. estimating the incidence of decisions
10. current levels of policy outputs
11. current levels of policy funding
12. current sources of policy funding

The role of planners in each of above twelve aspects has been considered in detail elsewhere (50). A few observations must be made, however, with respect to the first two aspects of above list.

The objectives of agricultural policy are related in the first instance to consumption, marketing, production, ownership and property rights, agriculture-related income objectives, rural area development, national development, and international development. For each of these objectives, several important sub-goals have been enumerated in Table 1, 44 in all. Missing from the above list is the triad of frequently listed macro objectives: growth, employment and equity. The objectives of Table 1 are close substitutes for growth, employment and equity, but their precise interconnectedness is by no means easily established. The problem of goal aggregation is of considerable practical and theoretical importance. It requires the existence of one ultimate goal; e.g., social welfare. It furthermore requires the measurability of the relative contribution of the attainment of sub-goals to this ultimate goal. The above scientific requirement cannot be fulfilled in agricultural planning unless social welfare is given a narrow interpretation as, for example, being equal to the sum of consumer's and producer's surpluses. But this definition leaves out important subjective income distributional considerations, the issue of ownership and property rights, and other development objectives listed in Table 1.

The adoption of a social welfare criterion, as mentioned above, is therefore normative and cannot claim to be representative of the outcome of a collective decision-making process. Ideally, a formally-approved National Development Plan can make such a claim. But for it to be truly so, one must suppose the prior participation of all those affected, particularly representative groups of the private sector. Planners therefore have an important role

in the reconciliation of multiple objectives with their corresponding policies given limited financial, human and organizational resources at the disposal of the public agricultural sector.

Agricultural policies must result in the improved well being of people. The beneficiaries of agricultural policy are respectively the consumer, the the owner-producer, the worker, the middleman, the public sector, the national and extra-national entities. Each of these categories has subcategories; e.g., the nutritionally vulnerable in urban areas. Often policies are designed for and influenced by special interest groups who represent the main beneficiaires of such policies. On the other hand, no specific policy measures are designed to benefit the politically disadvanteged, such as the unemployed workers or consumers in rural areas. A systematic qualitative, but preferably quantitative, analysis of the incidence of agricultural policy measures by beneficiaries is a practical way of assessing the equity aspects of a country's development strategy. Planning by objectives is fairly common in agricultural planning. Planning for and with the beneficiaries of agricultural policy is the exception. In policy analysis it might be a useful idea to start out with the clientele the plan hopes to reach. A subsequent step would cross-tabulate this with the objectives of agricultural policy as in Table 1. Such a cross-tabulation would provide for an improved qualitative assessment as to whom is going to be benefited by the attainment of the objectives suggested in Table 1.

## 4. The interdependence of economic policies

Estimation of the economic incidence of proposed policies is technically the most challenging aspect of agricultural planning. Table 1 presents a checklist of 191 questions as to the economic incidence of selected agricultural policies. In principle, a single agricultural policy will affect all major and

minor objectives listed in the left-hand column of Table 1. Technically, Table 1 can be considered as the reduced form of a very comprehensive agricultural sector model.[1/] Its features are the inclusion of a large number of objectives of social or political significance. Equally so, it offers a very detailed list of measures within the domain of the public sector that can be used to reach such objectives.

Table 1 is also remarkable because of what is apparently excluded. The very detailed spatial commodity and input characterization so typical of large-scale linear programming models is absent. Similarly, exogenous variables, such as income and population so typical of econometric models, are missing. This does not imply that detailed disaggregation of the spatial, commodity and input dimensions are irrelevant to estimating the incidence of policies. The implication is rather that the intersections in Table 1 already reflect the aggregated spatial, commodity or input effects, as, for example, in (40). Similarly, the intersections in Table 1 can be thought to reflect developments in exogenous variables, such as population and income.

Table 1 can be interpreted as the reduced form of a general equilibrium model. A select number of such large-scale models of the agricultural sector have been constructed ( 5, 11, 18, 34 ). None of them has been empirically validated. Most concentrate on the modeling of the private sector including only a small number of the objectives and policies mentioned in Table 1. Agricultural planners therefore may have to be satisfied with something less. In Table 1 we selected that objective on which a given policy would have its

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[1/] A reduced form is a system of equations, which expresses the endogenous variables exclusively in terms of exogenous variables. Endogenous variables are determined within the system, endogenous variables are determined without the system. For details, the reader may consult any textbook on econometric methods.

immediate impact. We deliberately ignored the fact that policies have important indirect effects on other major or minor objectives. Usually the bulk of such indirect effects would be limited to one or two additional objectives. Should this not be so, then all objectives must be simultaneously matched with all policies. The coordination of agricultural policies would then serve the primary task of policy administration.

The logical framework for a coordinated approach towards economic policy was originally elaborated by Professor Tinbergen ( 47, 48) and is basic to the theory of macro-economic policy (10, 37). The determination of alternative combinations of policies to attain socially and politically significant objectives can be illustrated by the quantification of the inter-relationships between the four principal sub-sectors that characterize the role of the agricultural sector in the national economy as in Table 2. Let us suppose for the time being that the "Sistema de Planificacion" has completed a quantitative analysis of all the variables which enter above scheme. Some of these variables are controlled directly by the public sector, e.g. the routine and development budget, wage rates, prices, the distribution of investment and imports, etc. Other variables are not directly controllable by the public sector, for example, agricultural production and employment. Nevertheless, these two variables are of great socio-economic importance. In fact, they usually are important strategic objectives of overall development policy.

Generally, it will be possible to determine a quantitative relationship between the dependent variables (Y) and the independent variables (X). These relationships are indicated by the coefficient matrices Aij; Bij; Cij and Dij in Table 2. An important problem in policy incidence is the determination of the policies ($X_3$) as related to the objectives ($Y_1$). Generally, there exists no simple direct relationship between objectives and policies. If so, however,

TABLE 2

SCHEMATIC INTER-RELATIONSHIPS BETWEEN THE AGRICULTURAL SECTOR TARGETS AND AGRICULTURAL SECTOR POLICIES

| INDEPENDENT VARIABLES / DEPENDENT VARIABLES | AUTONOMOUS VARIABLES | | CONTROLLABLE VARIABLES | |
|---|---|---|---|---|
| | Agricultural Sector ($X_1$) | Non-Agricultural Sector ($X_2$) | Agricultural Sector ($X_3$) | Non-Agricultural Sector ($X_4$) |
| Variables of social-economic importance | | | | |
| Agricultural Sector ($Y_1$) | $A_{11}$ | $A_{12}$ | $B_{11}$ | $B_{12}$ |
| Non-Agricultural Sector ($Y_2$) | $A_{21}$ | $A_{22}$ | $B_{21}$ | $B_{22}$ |
| Variables of no social-economic importance | | | | |
| Agricultural Sector ($Y_3$) | $C_{11}$ | $C_{12}$ | $D_{11}$ | $D_{12}$ |
| Non-Agricultural Sector ($Y_4$) | $C_{21}$ | $C_{22}$ | $D_{21}$ | $D_{22}$ |

then

$\underline{1/}$ $Y_1 = B_{11}.X_3$

and by solving for the instrument or agricultural policy vector ($X_3$) in terms of the predetermined target or goal vector ($\hat{Y}_1$), we have

$\underline{2/}$ $X_3 = (B_{11})^{-1}. \quad \hat{Y}_1$

Generally, the inverse matrix $(B_{11})^{-1}$ will not be diagonal. Consequently, all targets in principle, influence all agricultural sector policies.

But this statement is never quite correct. The autonomous, or self-guided, variables of the agricultural sector also should be considered. Symbolically, therefore,

$\underline{3/}$ $Y_1 = A_{11} \cdot X_1 + B_{11} \cdot X_3$

Where ($X_1$) is a vector of autonomous variables, e.g. population growth in rural areas. Solving above equation for the optimal agricultural sector policies ($X_3$) in terms of agricultural sector objectives ($Y_1$), we have

$\underline{4/}$ $X_3 = (B_{11})^{-1} \quad (Y_1 - A_{11} \cdot X_1)$

From this can be seen that the optimal agricultural sector policies are influenced by both agricultural sector objectives ($Y_1$) and autonomous variables ($X_1$). But even this statement is not quite correct. The agricultural sector and non-agricultural sector are interdependent, and we must take account of this in policy incidence. First of all, we must take account of the planned objectives in the non-agricultural sector ($Y_2$) and its autonomous variables ($X_2$). Secondly, we should not solve for the optimal agricultural sector policies independently of the optimal policies of the non-agricultural sector. The should be solved for simultaneously, i.e. policies should be coordinated between sectors. Symbolically

$\underline{5/}$ $B_{11} X_3 + B_{12} X_4 = Y_1 - A_{11} X_1 - A_{11} X_2$

$\underline{6/}$ $$B_{21} X_3 + B_{22} X_4 = Y_2 - A_{21} X_1 - A_{22} X_2$$

and solving these matrix equations simultaneously for $X_3$ and $X_4$, we have

$\underline{7/}$ $$\begin{pmatrix} X_3 \\ X_4 \end{pmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix}^{-1} \cdot \begin{bmatrix} Y_1 - A_{11} \cdot X_1 - A_{12} \cdot X_2 \\ Y_2 - A_{21} \cdot X_1 - A_{22} \cdot X_2 \end{bmatrix}$$

From matrix equation 7/ follows, that the optimal determination of agricultural sector policies must take account of

1) the objectives of the agricultural sector itself ($Y_1$).
2) the objectives of the other sectors ($Y_2$).
3) the projected development of autonomous, or self-guided, variables of the agricultural sector ($X_1$).
4) the projected development of autonomous, or self-guided, variables of the non-agricultural sector ($X_2$).

Above statement is little else but a generalized algebraic formulation of the process of policy formulation. The National Planning Agency determines the objectives ($Y_2$) and forecasts the development of the autonomous variables ($X_2$) on the basis of a macroeconomic model. The Ministry of Agriculture, and more particularly the Sector Planning Office, determines the strategic objectives for the agricultural sector ($Y_1$). The technical aspect of planning then involves the formulation of a set of internally consistent policies for the agricultural sector ($X_3$), given agricultural ($Y_1$) and non-agricultural objectives ($Y_2$) and projected autonomous developments ($X_1$, $X_2$).

According to above design, it requires specific quantitative knowledge about the Aij; Bij; Cij; and Dij interaction coefficient matrices. It encourages the view of looking upon the agricultural sector as a system with several important internal and external interdependencies.

From equation 7/ can be seen that the optimal agricultural policies must be revised if a change in strategic objectives should occur (which occurs not very often), or when the autonomous variables, i.e. the environment within which the policy operates, changes. The latter occurs frequently. Consequently, the implementation of policies makes it necessary to recalculate equation 7/ at least on an annual basis. As such, it can be a fundamental input into the preparation of the annual operational plan and budget. With unlimited financial resources, it will always be possible to reach all of the objectives in equation 7. The size of the budget for the typical Ministry of Agriculture is, however, such that not all objectives are attainable simultaneously, particularly if one formulates an ambitious target for one or more of the strategic objectives. Consequently, it is important to maintain a relative balance among the minimally acceptable values of the objectives in equation 7. In fact, it might even be desirable not to assign a priori values for these objectives, but to construct first Table 2. Systematic manipulation of the data in Table 2, as expressed in equation 7, will provide an estimate as to how strongly the stated objectives ($Y_1$) influence agricultural sector policies, and hence the required agricultural budget, including subsidies.

Given this, we know which combinations of agricultural objectives imply feasible agricultural policies. As indicated above, there are also reasonable lower and upper limits for agricultural policies. Consequently, the upper and lower limits on both objectives and policies must be considered simultaneously. Generally, it should be possible to generate several acceptable conjoint combinations of objectives and policies.

At this stage, one might apply a sub-optimization procedure, such as goal programming.[1/] Particularly important is the study of the impact of the relaxation of the effective boundary conditions of agricultural policies on strategic objectives. Such a study would shed light on the marginal social productivity coefficients of particular policies in relation to major objectives. It would therefore indicate which policies need revision if the agricultural sector is to improve its performance in terms of basic social objectives.

5. The use of core models in policy analysis

The foregoing pages support that the policy analyst should be sensitive to the following aspects:

1) that the development of the agricultural sector must be measured in terms of multiple objectives, and not only in terms of a single criterion.
2) that the desirability and impact of agricultural policies should not be measured in terms of a single criterion, but in terms of multiple performance indicators.
3) that in order to evaluate the desirability of different policies, one must have a fairly precise idea as to how they affect the development of the agricultural sector.
4) that it is not sufficient to study one single policy package, but that one should study alternative policy packages.
5) that the validity of a certain policy is not constant over time. Autonomous and erratic changes, make it necessary to adjust existing policies vis a vis the objectives.

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1/ B. M. Wheeler et. al., Goal programming and agricultural planning, Operations Research Quarterly. Vol. 28, 1977. pp. 21-32.

6) that agricultural policy analysis is a continuous activity with important elements of prognosis as to the future expected situation of the sector.

7) that the method of analysis must be capable of identifying and simulating the probable behavior of producers, consumers, workers and the public sector agencies, given the proposed agricultural sector policies.

8) that the method must be of a quantitative nature where possible.

9) that the method must blend traditional economic theory with country-specific conditions, particularly as to types of farms and the distribution of income.

The execution of above mentioned ideas, while conceptually simple and desirable, is nevertheless rarely feasible, given the limited human, financial and informational resources of the typical "Sistema de Planificacion".[1/] The problem is compounded by the fact that the policy analyst is usually given very little time to come up with the requested estimate as to policy incidence. Scientific study by nature is not compatible with absolute deadlines. Because of this, policy analysis is often a compromise between what ideally should be done and the dictates of circumstances as to what can be done.

Economists have a long familiarity with this dilemma. It is expressed most fundamentally in the use of partial vs. general equilibrium theory. A rough transliteration of this notion is that in Table 1 we should not concentrate on all possible interdependencies but only those which are socially or politically relevant. A more practical approach, therefore, might be to consider each important objective-instrument pairing separately. It requires the

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[1/] For a comprehensive survey of the human, financial and informational resources available to agricultural planning organizations in IICA member countries, the reader should consult PROPLAN Document No. 2, i.e. reference 22.

applications of core theoretic ideas as taught in the economics curricula of U.S., Latin American, and European graduate schools.

The approach is not without disadvantages. It enters into uncharted waters. Theoretical writings are available on most, but not all, of the objective-policy pairings indicated in Table 1. The translation of theoretical work into didactically easily understandable material is a major task in itself. Not all of such objective-instrument pairings have been the subject of applied research in the context of IICA countries. The conclusions of applied research cannot readily be transferred between one country and another. The theory needs to be tested anew, with updated data under specific country circumstances. The limitations on professional manpower and data are particularly noticeable in this respect.

It also raises the question as to whether a core analytical approach can be used in articulating the interdependence between what appears to be at first sight a very heterogeneous collection of policies and objectives. Policy analysis would consist then of adopting a core analytical approach to specific policy analytical contexts. If, furthermore, the core analytical approach is easily understood or accessible to most policy analysts, one would have created one of preconditions for improved policy analysis.

The second condition is that policy analysts be skilled in adopting specific policy analytical contexts to the core analytical approach. Some of the difficulties in this can be anticipated and illustrated by case studies. Nevertheless, the specificity of data and other circumstances are such that in each instance, policy analysts would have to make contributions of their own. Policy analysis, therefore, can never be a purely mechanical or repetitive process.

Policy analysis in support of policy decision making must make explicit choices in relation to the following:

1. the choice of model that reflects the essential behavioral features of the institutions (e.g., consumers and producers) that constitute the private sector.
2. the selection of the essential behavioral features of the institutions that constitute the public sector in terms of policy objectives and policy instruments in place, to be introduced, or to be withdrawn.
3. given 1 and 2, determine the appropriate level of the policy instruments for given levels of objectives.

The quantitative theory of economic policy has traditionally focussed on the third point. It takes the set of admissible objectives and instruments as given as in equation 7. The danger in this approach is that important side effects on the remaining endogenous variables may go undetected. More importantly, however, it overlooks the possibility stressed under point 2 that an alternative set of instruments may be socially more efficient in accomplishing the same objectives.

The choice of model that reflects the essential behavioral features of the institutions that constitute the private sector in principle can be made positivistically. The same observed phenomena, however, may give credence to substantially different models. Consequently, there usually remains some latitude in model selection.

The 191 agricultural policy measures listed in Table 1 can be divided into four large categories:

1. measures that affect the ownership of agriculture-related outputs, inputs and services.
2. measures that affect the production and supply of agriculture-related outputs, inputs and services.

3. measures that affect the allocation of agriculture-related outputs, inputs and services.
4. measures that affect the improvement or preservation of the quality of agriculture-related outputs and services.

This classification suggests the applicability of traditional economic analysis, such as production, consumption and distribution theory at the industry levels. Specifically, it would focus on the determinants of the industry output and factor supply and demand curves.

Basic economic theory, however, does not usually concern itself as to how public policies affect the equilibrium of the industry as to output, factor employment and prices. The initial task for policy analysis is, therefore, to integrate the theory of economic policy with the theory of production, distribution and consumption at the industry level. This integration should yield a class (or classes) of policy models which can be adopted to the needs of the policy analyst.

For that purpose we have developed in detail three classes of policy models. The nature of the models can be put in perspective with reference to Table 3. The assumption is that the markets for agricultural commodities, inputs and services are essentially competitive, i.e. producers as well as consumers are price takers. Each market is characterized by a set of variables that determine the demand or supply of the commodity, input or service in question. Introductory economics texts concentrate on one market at a time, i.e. the (1 x 0) or (0 x 1) configuration, i.e. one analyzes the demand for or supply of a commodity or an input without reference to related outputs or inputs. In this section we assume that the reader has a familiarity with that type of model.

Table 3: Core models for agricultural policy analysis

| numer of output markets | number of input markets | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | m |
| 0 | (0 x 0) | (0 x 1) | (0 x 2) | (0 x m) |
| 1 | (1 x 0) | (1 x 1) | (1 x 2) | (1 x m) |
| 2 | (2 x 0) | (2 x 1) | (2 x 2) | (2 x n) |
| n | (n x 0) | (n x 1) | (n x 2) | (n x m) |

The (0 x 1) and (1 x 0) are called partial equilibrium models. Much of what is useful in economics can be illustrated by these models. They continued to dominate applied economic analysis until the late fifties when it became evident that this type of model has substantial drawbacks for rigorous policy analysis. At the same time it was realized that a Walrasian (m x n) general equilibrium model was also unsatisfactory for policy analysis. The outcome was the construction of three core models.

1) the Hicksian (19) one product-two factor model, i.e. the (1 x 2) configuration in Table 3.
2) the Carlson (3) two product-one factor model, i.e. the (2 x 1) configuration in Table 3.
3) the Harberger (15) two product-two factor model, i.e. the (2 x 2) configuration in Table 3.

It is these models that currently dominate much of applied economics in public finance, international trade and welfare economics. The essential feature of these models is that they are very compact, yet analytically sound and powerful. Detailed discussions of the theory and applications of two of these models is available in this manual. As an introduction, we present convenient expository form of these models so as to convince the reader that these models are indeed structurally simple and accessible to anyone with basic training in economics.

6. <u>The Hicksian one product-two factor model</u>

The structural equations of the one product-two factor model are as follows:[1/]

I.1 $x_1 = -k_2\sigma p_1 + k_2\sigma p_2 + 1 \cdot q$

I.2 $x_2 = k_1\sigma p_1 - k_1\sigma p_2 + 1 \cdot q$

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[1/] The production and distribution theory underlying the derivation of equations I.1 through I.3 is discussed in pages 1 through 6 in (51).

$$I.3 \quad p = k_1p_1 + k_2p_2 + o \cdot q$$

$$I.4 \quad x_1 = e_{X_1} \cdot p_1$$

$$1.5 \quad x_2 = e_{X_2} \cdot p_2$$

$$1.6 \quad q = e_q \cdot p$$

Equations I.1 and I.2 are the factor demand equations for a given level of output. The rate of change in factor demand ($x_1$ or $x_2$) depends on the rate of change in the prices ($p_1$ and $p_2$) of the factors of production and the rate of change in output (q). The critical parameters are the cost shares $k_1$, $k_2$ and the elasticity of substitution $\sigma$. Equation I.3 shows how the cost of production (p) changes as determined by the rates of change in factor prices for a given output. Equations I.1, I.2 and I.3 suppose that the firms composing the industry are in long-run equilibrium. Average cost then equals marginal cost. Alternatively, one could assume that the production function for the industry is linear homogeneous in the two factors of production.

Equations I.4 and I.5 are the factor supply functions. Equation I.6 is the demand function for output. The factor supply and commodity demand functions can include arguments other than commodity or factor prices. They are discussed in sections 9, 10, 11, 15 and 16.

The above linearized model of six equations in six unknowns determines the competitive equilibrium of the industry. Changes in this equilibrium stem from various sources. It is the planned changes in this equilibrium which are our concern. They relate to the introduction, withdrawal or change in selected economic policies. Policies aimed at technological progress within the industry (e.g., agricultural research and extension) will require modification of the factor demand and cost formation functions. Policies aimed at technological progress outside the industry will modify the factor supply equations. Policies

aimed at direct control of one or more of previously endogenous variables (e.g., price, output, and factor use controls) will modify the corresponding commodity or factor demand or supply functions. Policies aimed at indirect control of the endogenous variables (e.g., taxes, subsidies, import, and export controls) will modify the appearance of these variables in the above basic model. Policies aimed at creating market clearing mechanisms (e.g., rationing, production certificates) parallel to that of the competitive market clearing mechanism add additional equations to the basic model.

The introduction, withdrawal or change in the above policies implies an initial shift in one or more of the commodity and factor supply and demand equations that characterize the initial competitive equilibrium of the industry. An initial shift in one of these relationships causes subsequent adjustments in the remaining functions, resulting in a new competitive equilibrium of the industry.

The impact of selected policies involves a comparison of the old and new equilibria. To carry this out we can use a narrative, graphical or algebraic format. In (51) we stress the latter two. The narrative procedure comes to the foreground once we move from an abstract situation to applications. The algebraic manipulations underlying the comparative statics of the one output-two factors of production model are simple. Yet, even this basic model allows for a very large number of policy model specifications. Those involving direct controls of prices, or factor employments are discussed in sections 9 and 10 of this manual. Policies involving indirect controls and autonomous developments outside the industry are discussed in section 11 of this manual. Policies related to technological progress within the industry are discussed in sections 15 and 16. Additional consequences of policies that suppress the competitive market clearing mechanism are discussed in pages 85 through 90 in (51).

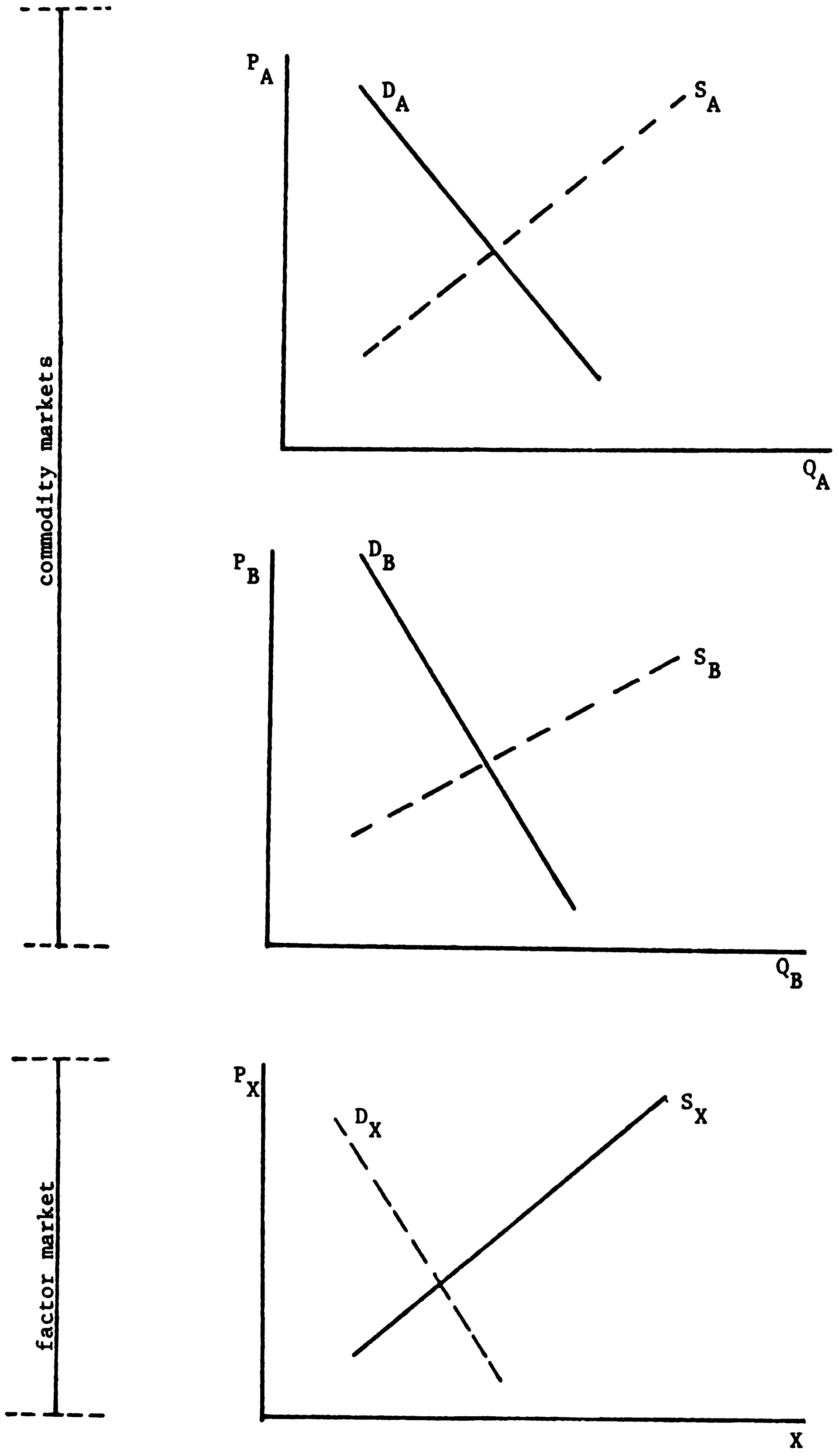
It follows that in principle a large array of policies can be used to achieve a single or multiple objective. A systematic study of logical candidates of the above categories of policies grafted on a core model such as in equation I.1 through I.6 can help us understand the comparative social and private benefits and costs of different policies. This is an important area for future research, particularly in order to discover qualitative results, whereby one class of policies can be judged to be superior to other classes of policies under a wide range of circumstances.

## 7. The two product-one factor model

The natural counterpart of the one product-two factors model is the two product-one factor model. Much of the economy literature focuses on things which have a common destiny. Hence, the theory of derived demand for factors of production, input-output analysis being its best known special application. But the pricing of things which have a common origin is also of interest. What, for example, are the consequences of controlling the price of bread but not the price of flour? What are the consequences of an export quota on cotton cake on the production of cotton? What are the consequences of subsidizing the price of milk for human consumption on the price of raw milk, butter and cheese?

All of above examples of market intervention can be analyzed in the context of two product-one factor model. Figure 1 contains in initial equilibrium demand-supply configuration in the two commodity markets and the remaining (composite) factor market. In figure 1 $S_A$ and $S_B$ are derived supply relationships, giving rise to a derived demand $D_X$ for the composite factor X. The demand functions $D_A$ and $D_B$ usually can be taken as independent of developments in the factor market. If $Q_A$ and $Q_B$ are close substitutes or complements in consumption, then the position of the demand curves $D_A$ and $D_B$ will be mutually dependent, but they are independent of the derived supply functions $S_A$ and $S_B$.

Figure 1: Demand and supply curves that characterize the two product-one factor model



Marshall emphasized the symmetry between the theory of derived demand and the theory of derived supply, stating that (28, p. 388)

> "it may be discussed almost in the same words by merely substituting "demand" for "supply" and vice versa."

Corresponding to the four Marshallian rules of derived demand, we can formulate four rules that govern the elasticity of derived supply. These rules can be used to examine the presumably low price responsiveness of food production relative to export production in developing countries. They are also important in demonstrating how food price controls under these circumstances can be used to increase national welfare. Marshall restricted himself to the case where joint products were produced in fixed proportions. Sune Carlson (3, p. 74-102), following Fanno (8), studied joint production with technically variable proportions of the products. We follow that approach in sections 12, 13, 14 and 15, the case of fixed proportions being a special case of this more general approach.

The 2 x 1 model can also be interpreted as a general equilibrium model. As such, it has been used extensively in the theory of international trade and public finance. Its essential characteristic is that developments in the factor market, specifically changes in the level of factor income, directly influence the demand for commodities. All of the relationships in Figure 1 then become endogenous. The analysis of policy measures such as tariffs, quotas and taxes nevertheless remains straightforward.

The two output-one (composite) factor model can be coupled with a one output-two input model. For example, a composite factor (e.g. milk) is itself produced by, for example, two factors of production. Consequently, one obtains an augmented [(2 x 1) x (1 x 2)] model. The structural equations of this model are those of the (2 x 1) and (1 x 2) model, in addition to a coupling identity.

The essential characteristic of augmented models, such as sketched above, is that they simplify the full general equilibrium characteristics of a policy problem by eliminating a priori a large number of possibly insignificant interdependencies between the demand and supply relationship that characterize the several commodity and resource markets. The advantages of above blockwise decomposability of policy problems is considerable for the purposes of analysis and statistical estimation.

There is a fundamental symmetry between the (1 x 2) model and the (2 x 1) model. The six structural equations of the two commodity-one factor model are as follows:[1/]

II.1 $q_A = -k_B\sigma^* p_A + k_B\sigma^* p_B + 1.x$

II.2 $q_B = k_A\sigma^* p_A - k_A\sigma^* p_B + 1.x$

II.3 $p_x = k_A p_A + k_B p_B + 0.x$

II.4 $q_A = e_{q_A} \cdot p_A$

II.5 $q_B = e_{q_B} \cdot p_B$

II.6 $x = e_X \cdot p_X$

Equations II.1 and II.2 are the general equilibrium supply functions for commodities $Q_A$ and $Q_B$ respectively. Commodity supplies are determined by relative commodity prices $P_A$ and $P_B$ and factor supply X. The critical parameters are the value shares $k_A$ and $k_B$ of $Q_A$ and $Q_B$ in gross agricultural income and the elasticity of product substitution $\sigma^*$. This elasticity measures the degree of curvature of the production possibility curve found in any introductory text on economics. If $\sigma^*$ is small, then one product is not readily sub-

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[1/] For details, see section 12.

stitutable for another product. If $\sigma^*$ is large, the production possibility curve will approach a straight line. Equation II.3 shows how the value or shadow price of resources used in the production of commodities is determined by the prices of commodities and available factor supplies. Because we assume joint production to be linear homogeneous, the scale of production or average size of farm does not affect the unit value of the resources used in production. Equation II.4 represents demand for commodity $Q_A$. We assume it to be influenced only by its own prices, the price elasticity being $e_{q_A}$. This hypothesis is easily modified and made more comprehensive. It has been explored in (54). Equation II.6 represents the factor supply function of factor X. We assume it to be influenced by its own price only. The supply elasticity $e_X$ has no predetermined sign. If, however, II.6 is interpreted as a factor compensated supply curve, $e_X$ must be positive.

Above model is applied in sections 13, 14 and 15 to investigate a variety of typical agricultural policy problems in IICA countries, such as the incidence of commodity price controls, export taxes, and tariffs. It is shown under what conditions these policies can be used to increase national welfare. Section 11 in (54) introduces a system of income-compensated commodity demand curves, symmetric to the general equilibrium supply functions. It is this type of model that allows us to measure the real income losses associated with price distortions. It was first used by Hotelling (21) and subsequently by a large number of well-known economists active in the field of public finance, international trade and welfare economics.

## 8. When to use general equilibrium models

### 8.1 Is a system variable endogenous or exogenous?

The essential characteristic of partial equilibrium models is that not all variables which are covered by the analysis need to be studied simultaneously. The variables so excluded may be considered as exogenous. The essential characteristic of general equilibrium models is that one or more variables considered as exogenous by partial equilibrium models ought to be considered as endogenous variables. Consider, for example, the incidence of a tax on agricultural exports. The first task is to choose a model that reflects the essential behavioral features of the institutions (e.g. consumers and producers) that constitute the private sector. This choice must be based on observed phenomena. It should be recognized from the outset that the same set of observed phenomena can support models which are substantially different as to their theoretical foundations and predicted consequences. Thus, because observed phenomena can only disprove theoretical constructs, they can never prove the "truth" of a single theoretical construct. The observed phenomena are necessarily quite heterogeneous. In order to arrive at a manageable analytical construct, we must suppress much of this heterogeneity and retain only its essential features. This, too, can be done in many different ways. Often the questions to which we seek an answer will be helpful in this respect. The incidence of the tax is to be measured in terms of predicted changes in factor employments, production, factor prices, commodity prices, factor incomes, commodity earnings and tax revenues. The underlying observable variables are therefore quantities, prices and monetary aggregates. Much of this information is collected and published on a routine basis in the form of agricultural statistics. Let us assume that this information can be used to construct the following six indices.

1) An index of the volume of agricultural production of the export crop ($Q_B$) to be taxed.

2) An index of the volume of the remaining agricultural production ($Q_A$).

3) An index of the volume of the factors of production (X) (land, labor, fertilizer, machinery, etc.) used in agricultural production.

4) An index of the prices received by producers for the export crop ($P_B$).

5) An index of the prices received by producers for the remainder of agricultural production ($P_A$).

6) An index of the prices paid (or imported) for the factors employed in all of agricultural production ($P_X$).

Provided such indices can be constructed, we have reduced the data base of the incidence problem to the study of the interrelationships between six variables.

$$\begin{matrix} Q_A & Q_B & X \\ P_A & P_B & P_X \end{matrix}$$

This small number of variables makes the problem analytically more tractable.

8.2 What is held constant?

Having made a choice as to the variables which characterize the problem, we must then inquire as to the relationships between these variables. These relationships can be depicted in terms of standard supply and demand diagrams for commodities $Q_A$ and $Q_B$ and the factor of production X. Such two dimensional diagrams must necessarily make assumptions as to the constancy of variables which do not appear in that diagram. For example, the demand for commodity $Q_A$ is influenced not only by its own price $P_A$, also by the level of income and population. Neither of these two variables appears among the six variables of

the model. The usual assumption is that the incidence of the tax is to be analyzed holding income and population constant. If the export commodity $Q_B$ is a food product (e.g. wheat, coffee, banana), then its price $P_B$ may influence the demand for commodity $Q_A$. Assume that this cross price effect is negligible (a partial equilibrium assumption). Similarly, the demand for agricultural exports $Q_B$ is influenced not only by its price $P_B$, but also by the level of income and population at home and abroad. Again, we assume that changes in these variables can be ignored for the purposes of tax incidence. Similarly, we ignore the cross price effect of $P_A$ on the demand for $Q_B$ (a partial equilibrium assumption).

## 8.3 The factor supply curve

The supply of the factor aggregate X is influenced not only by its weighted price $P_X$, but also by semi-autonomous variables, such as population and capital accumulation. The latter will be related to agricultural income if part of agricultural investment is financed out of current agricultural income. If the export tax affects agricultural income, it will bring about a shift in the factor supply curve $S_X$ in figure 1. In what follows, we ignore the impact of export taxes on agricultural investment (a partial equilibrium assumption). Nevertheless, a priori considerations such as these must be made with care. Disagreement between policy analysts as to the reasonableness of such assumptions may have important consequences as to the calculated incidence of the export tax, and hence its desirability from a social point of view. Policy analysis then rarely leads to definitive conclusions, its primary role is to clarify and deepen our understanding of the issues and effects involved.

## 8.4 The commodity supply curves and the factor demand curve

### 8.4.1 Partial equilibrium

We now turn to the commodity supply curves $S_A$ and $S_B$ and the factor demand curve $D_X$ in figure 1. Assume that these curves are represented by the following functions:

$$Q_A^S = S_A(P_A, P_B, P_X)$$
$$Q_B^S = S_B(P_A, P_B, P_X)$$
$$Q_X^D = D_X(P_A, P_B, P_X)$$

where $Q_A^S$ and $Q_B^S$ are quantities supplied of commodities A and B, and $Q_X^D$ is the quantity demanded of factor X for given prices $P_A$, $P_B$ and $P_X$.

Assume that along the commodity supply curve $S_B$ in figure 1, the price $P_A$ of commodity $Q_A$ and the price $P_X$ of factor X are held constant. Is such an assumption justifiable? Put differently, can the price $P_B$ of agricultural exports change without bringing about concomittant changes in the price $P_A$ producers receive for other agricultural products $Q_A$ and the price $P_X$ producers pay for factor X? If the answer is in the affirmative, then all of the effects of the imposition of an export tax can be captured in a single diagram, i.e. the second diagram of figure 1. Much of what is useful in the analysis of tax incidence is based on this approach [20, 43, 55]. Generically it is known as the partial equilibrium approach. Its simplicity makes it preferable to the more complex general equilibrium approach proposed here. As to whether the simpler approach is justified depends on the independence of the price variables $P_A$, $P_B$, $P_C$ appearing in the supply relationships $S_A$, $S_B$ and $S_C$ above.

### 8.4.2 General equilibrium

In our view the supply of agricultural exports $Q_B$ is influenced not only by its own price $P_B$ but also by the price $P_A$ producers receive for other agricultural commodities $Q_A$ and the price $P_X$ producers must pay for the composite factor of production X. When analyzing the demand for agricultural exports we ignored the cross price effect related to a change in the price of non-export products. There seems less justification to ignore similar cross price effects when analyzing supply, particularly when the typical producer produces both export and non-export crops. Under these circumstances a decrease in the price of export crops relative to the price of non-export crops, because of the imposition of an export tax, will lead to an increase in the production of non-export crops and a decrease in the production of export crops, provided total factor employment X remains constant. But the changes in commodity prices $P_A$ and $P_B$ will affect the demand for factor X. If we assume that the demand curve for X in figure 1 shifts to the left, then the equilibrium level of factor employment must decrease. Under these circumstances a decrease in the price of export products may also decrease the production of non-agricultural exports. The analysis therefore must take into account both commodity substitution and factor employment effects. Because of this, $P_B$ cannot be changed without bringing about simultaneously changes in $P_A$ and $P_X$. Given this, the partial equilibrium approach cannot be used. This does not preclude the use of supply-demand diagrams as in figure 1. But we must be very careful in specifying what is held constant along the commodity supply curves $S_A$, $S_B$ and the factor demand curve $D_X$ appearing in those diagrams. These curves are now represented by the following functions:

$$Q_A^S = S_A[P_A, P_B(P_A); P_X(P_A)]$$

$$Q_B^S = S_B[P_A(P_B), P_B, P_X(P_B)]$$

$$Q_X^D = D_X[P_A(P_X), P_B(P_X), P_X]$$

The reader should compare this formulation with the functions appearing on page 37. Let us examine the supply curve $S_B$ of agricultural exports in both instances. With the partial equilibrium approach, we are justified to keep the price $P_A$ of non-agricultural exports and the price $P_X$ of factor X constant. With the general equilibrium approach, $P_A$ and $P_X$ are variable and related to changes in $P_B$. The changes in $P_A$ and $P_X$ reflect the commodity supply and factor demand shifts brought about by a change in $P_B$ outside its own demand-supply diagram. Along supply curve $S_B$ no price (or quantity) is held constant, all prices (and quantities) being ultimately influenced by changes in $P_B$.

The foregoing example made specific reference to an export tax. But the argument in support of the general equilibrium approach extends to all commodity taxes and subsidies whenever intervention in one commodity market causes significant displacements in either the supply or demand curves in interrelated commodity or factor markets. Similarly, intervention in a factor market such as input subsidies or taxes may cause significant displacements of the demand and supply curves in related commodity and factor markets. Finally, technological progress may cause not only simultaneous changes in the factor supply curves but also technological changes in the production process itself, leading to a combination of initial displacement effects with subsequent repercussions in all markets. Whenever the policy analyst judges that the displacement of a supply or demand curve in one market causes significant displacements of the supply and demand curves in other markets, the general equilibrium approach, rather than the partial equilibrium approach, should be used.

8.4.3 Statistical estimation of general equilibrium demand or supply curves

Assume the existence of the following data base in the form of six time series

$Q_A Q_B X$

$P_A P_B P_X$ .

How does one utilize above information to estimate e.g. the general equilibrium demand curve for factor X? Should one use Ordinary Least Squares or a more advanced maximum likelihood techniques of estimation? Should one use single regression or multiple regression techniques? Given the availability of data processing equipment, there will be a tendency to estimate the partial equilibrium factor demand curve $Q_X^D = D_X(P_A, P_B, P_S)$ by means of a multiple regression technique.

$$X = a_0 + a_1 P_A + a_2 P_B + a_3 P_X$$

A problem which often arises is that factor prices and output prices are highly correlated precisely because of general equilibrium interdependence. In practice, this condition often prevents statistical identification of $a_1$, $a_2$ and $a_3$. Selective addition of exogenous variables, dummy variables and deletion of data may then be called upon until the signs and sizes of the slope coefficients correspond with our expectations in such matters.

If commodity prices and factor prices are highly correlated, then

$$P_A = b_0 + b_1 P_X$$

$$P_B = c_0 + c_1 P_X$$

Substituting for $P_A$ and $P_B$ above, we have

$$X = (a_0 + a_1 b_0 + a_2 c_0) + (a_1 b_1 + a_2 c_1 + a_3) P_X \ .$$

This suggests that the general equilibrium factor demand curve be estimated by means of the simple Ordinary Least Squares equation

$$X = d_0 + d_1 P_X$$

where $d_0$ and $d_1$ take into account all induced effects in the commodity and factor markets related to a change in $P_X$. Paradoxically, the statistical quantification of the incidence of a policy measure is easier with the general equilibrium approach than with partial equilibrium models.

## 9. The derived demand for inputs

In this section, we consider an agricultural sector which uses two major inputs $X_1$ and $X_2$ to produce output Q. We want to derive the general equilibrium properties of the demand curve for input $X_2$.[1/]

Consider the following (1x2) agricultural sector model

9.1 $x_1 = -k_2 \sigma p_1 + k_2 \sigma p_2 + 1.q$

9.2 $x_2 = k_1 \sigma p_1 - k_1 \sigma p_2 + 1.q$

9.3 $p = k_1 p_1 + k_2 p_2 + 0.q$

9.4 $x_1 = e_{X_1} \cdot p_1$

9.5 $x_2 = e_{X_2} \cdot p_2$

9.6 $q = e_q \cdot p_2$

The above linearized model of six equations in six unknowns determines the competitive equilibrium of the agricultural sector. Assume that the public sector decides to control the price $P_2$ of input $X_2$. This previously endogenous variable now becomes an exogenous variable. In equations 9.1 through 9.6, the supply of labor is no longer simultaneously analyzed with the demand for labor, i.e. the factor supply curve of labor $x_2 = e_{X_2} \cdot p_2$ is no longer an integral part of the system of equations. Elimination of equation 1.5 leaves five equations in five unknowns ($x_1$, $x_2$, q, $p_1$, p) all related to changes in the

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[1/] The properties of the demand curve for input $X_1$ can be derived by appropriate changes of subscripts. It therefore need not be derived separately.

exogenous input price $p_2$. Substitution for $x_1$ and q in equations 1.4 and 1.6 yields the following matrix equation

(9.1)

| $x_2$ | $P_1$ | $P$ | $P_2$ |
|---|---|---|---|
| 0 | $(e_{X_1} + k_2\sigma)$ | $-e_q$ | $k_2\sigma$ |
| 1 | $-k_1\sigma$ | $-e_q$ | $-k_1\sigma$ |
| 0 | $-k_1$ | 1 | $k_2$ |

Use of Cramer's rule yields the following solution:

$$(9.2) \qquad E_{X_2} \cdot P_2 = \frac{\sigma(e_{X_1} - e_q) - k_2 e_{X_1}(\sigma + e_q)}{-k_2(\sigma + e_q) + (e_q - e_{X_1})} < 0$$

The determinant of the coefficients of the endogenous variables in 9.1 is the denominator of 9.2. It can be shown to be always negative, because

$$(9.3) \qquad k_1 e_q - (e_{X_1} + k_2\sigma) < 0$$

The numerator is always positive because

$$(9.4) \qquad (1 - k_2)\sigma e_{X_1} - (\sigma + k_2 e_{X_1})e_q > 0$$

The direct price elasticities of derived demand $E_{X_2} \cdot P_2$ and $E_{X_1} \cdot P_1$ are, therefore, always negative. From 9.2 follows that the own price elasticity of derived demand for input $X_2$ depends on four parameters.

1) the elasticity of factor substitution $\sigma$
2) the price elasticity $e_{X_1}$ of the factor supply curve of cooperant factors of production $X_1$
3) the price elasticity of demand $e_q$ for agricultural output Q

4) the cost share $k_2 = P_2X_2/PQ$ of labor in production.

Marshall [28] gave four rules for the things on which the elasticity of derived demand depends. These rules as summarized by Pigou [38] are:

I. "The demand for anything is likely to be more elastic, the more readily substitutes for that thing can be obtained."

II. "The demand for anything is likely to be less elastic, the less important is the part played by the cost of that thing in the total cost of some other thing, in the production of which it is employed."

III. "The demand for anything is likely to be more elastic, the more elastic is the supply of cooperant agents of production."

IV. "The demand for anything is likely to be more elastic, the more elastic is the demand for any further thing which it contributes to produce."

Rules I, III and IV are easily confirmed by differentiating 9.2 with respect to $\sigma$, $e_{X_1}$ and $e_q$. The second rule is not necessarily true. Differentiating $E_{X_2} \cdot P_2$ with respect to $k_2$, we obtain

$$(9.5) \quad \frac{dE_{X_2} \cdot P_2}{dk_2} = \frac{[-e_{X_1}(\text{denominator}) + \text{numerator}](\sigma + e_q)}{[\text{denominator}]^2}$$

The term in brackets is always positive. Consequently, the sign of (9.5) depends on the sign of $(\sigma + e_q)$. Marshall's second rule is, therefore, true only if $\sigma + e_q < 0$.

This was first demonstrated by Hicks [19, p. 245]. Using Hicks' terminology we have $E_{X_2} \cdot P_2 = -\lambda$; $\sigma = \sigma$; $e_q = -\eta$. Rewriting (9.5), we obtain

$$(9.6) \quad \frac{d\lambda}{dk_2} = [\text{a positive number}](\eta - \sigma)$$

The above expression will be positive only if $\eta > \sigma$, or if $(\sigma + e_q) < 0$.

If $\sigma = 0$, as Marshall assumed, then the above condition is fulfilled. Hicks argues [19 , p. 246, p. 376] that usually $\eta > \sigma$. However with respect to agricultural production empirical studies [13 ] would indicate the opposite to be true. A factor may then find it easier to benefit itself by a restriction in supply if it plays a large part in the process of production than if it plays a small part. This appears to apply to agricultural labor. Rapid out migration of agricultural labor would, therefore, become an effective way of raising agricultural wages.

If factor supplies of the first factor are infinitely price elastic (i.e., $e_{X_1} = \infty$) we obtain Allen's result[1/]

$$(9.7) \quad \lim_{e_{X_1} \to \infty} E_{X_2} \cdot P_2 = k_2 e_q - (1 - k_2)\sigma < 0$$

Matrix equation 1 can be utilized to compute the cross price elasticity of derived demand $E_{X_1} \cdot P_2$

$$(9.8) \quad E_{X_1} \cdot P_2 = e_{X_1} \cdot E_{P_1} \cdot P_2$$

where $E_{P_1} \cdot P_2$

$$(9.9) \quad E_{P_1} \cdot P_2 = \frac{-k_2(\sigma + e_q)}{-k_2(\sigma + e_q) + (e_q - e_{X_1})} \gtrless 0$$

1/ This assumption of infinitely price elastic factor supplies is used by Griliches [12] and Welch [56]. It is doubtful, however, that the U.S. supply of agricultural land and labor is infinitely price elastic.

The denominator in (9.9) is always negative. A sufficient and necessary condition for the numerator in (9.9) to be positive is that $\sigma + e_q < 0$. Consequently, the cross price elasticity of derived demand $E_{X_1} \cdot {}_{P_2}$ will be negative whenever $\alpha + e_q < 0$. An increase in $P_2$ will then decrease the equilibrium price $P_1$. Hence, it must shift the demand curve for $X_1$ towards the price axis. But if $X_1$ and $X_2$ are easily substitutable such that $\sigma + e_q > 0$, then the demand curve for $X_2$ will shift away from the price axis.

Matrix equation 9.1 can also be used to calculate the effect of an increase in $P_2$ on the equilibrium price P of output Q.

$$(9.10) \quad E_{P \cdot P_2} = \frac{-k_2(e_{X_1} + \sigma)}{-k_2(\sigma + e_q) + (e_q - e_{X_1})} > 0$$

As expected an increase in $P_2$ will always increase the equilibrium price P of output Q. The effect on equilibrium output Q is given by $E_{Q \cdot P_2}$ where

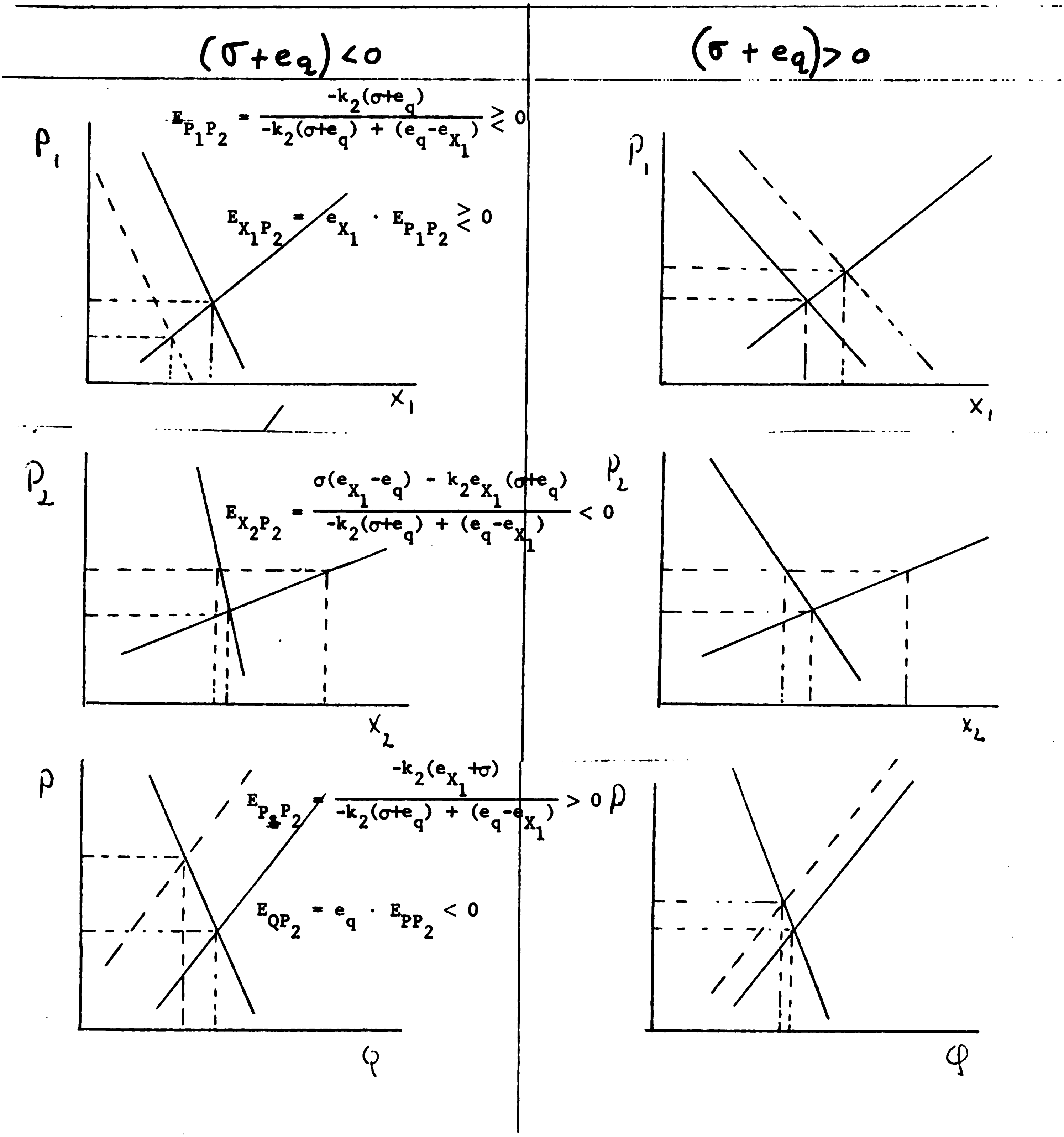
$$(9.11) \quad E_{Q \cdot P_2} = e_q \cdot E_{P \cdot P_2} < 0$$

Since $e_q$ is negative an increase in $P_2$ will always decrease equilibrium output Q. The above results are represented graphically in Figure 2 for $\sigma + e_q \gtrless 0$. The smaller the elasticity of substitution, all other things being equal, (in particular $e_q$, $e_{X_1}$, $e_{X_2}$) the steeper the slopes of the factor demand curves for $X_1$ and $X_2$. Furthermore if $\sigma + e_q < 0$, then $E_{P_1} \cdot {}_{P_2} < 0$, i.e., the factor demand curve for $X_1$ shifts to the left. If $\sigma + e_q > 0$ an opposite shift must take place.

## 10. The incidence of minimum wage legislation

Agriculture is the major source of gainful employment in a large number of countries. Yet, surprisingly, little is known about properties of the sector

Figure 2: Effects of an Increase in the Factor Price $P_2$ on the Equilibrium of the One Output-Two Factors of Production Model



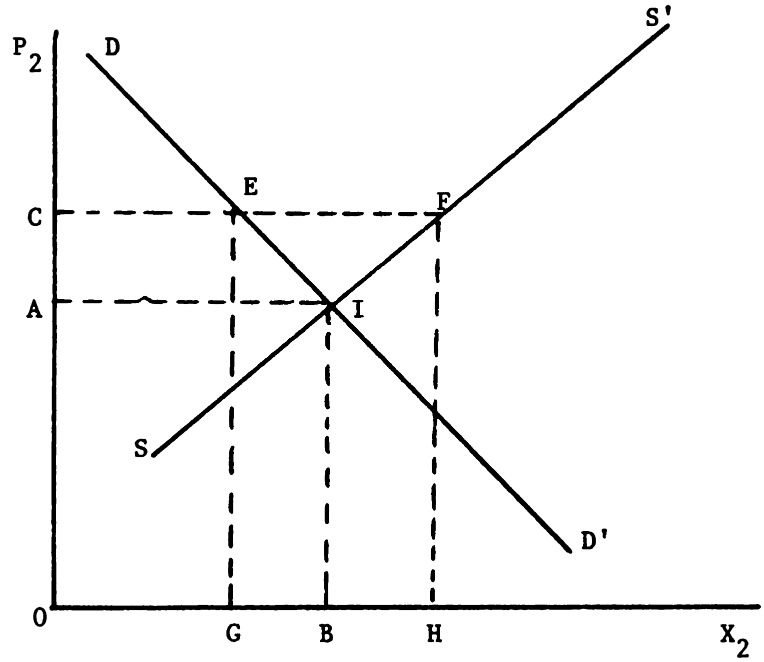
supply curve of labor and the sector demand curve for labor. The bulk of the literature on economic growth and development assumes that the sector supply curve of labor is infinitely wage elastic. The micro theoretic assumptions for this result to come about are not plausible. In this section, we will assume that the wage elasticity $e_{X_2} > 0$, excluding thereby the possibility that for the sector as a whole, the labor supply curve is backward sloping. The properties of the derived demand curve for labor have also received little attention. But for this purpose, we can use the results in section 9.

Assume then that in Figure 3 the public sector decides to enforce a minimum wage OC. In Figure 3, OA represents an initial wage such that the demand for labor equals the supply of labor. By increasing the wage rate from OA to AC, an excess supply of labor equal to EF will be created. The amount of unemployment so created depends on the wage elasticities of the demand curve for labor and the supply curve of labor. What are the things that determine the wage elasticity of the demand curve for labor DD' in Figure 3? This depends on the specification of DD'. There are at least three possible specifications.

1) $X_2 = X_2[P_1, P_2, Q]$
2) $X_2 = X_2[P_1, P_2, P]$
3) $X_2 = X_2[P_1(P_2), P_2, P(P_2)]$

In the first specification, the price $P_1$ of cooperant factors of production $X_1$ is held constant, as well as the output level Q of a cost minimizing firm. The second specification is the demand curve for labor for a profit maximizing firm facing constant factor price $P_1$ and commodity price P. Neither of above two specifications allows for the fact that for the competitive industry, a change in the price of labor ($P_2$) will bring about shifts in the industry demand curve for the cooperant factor of production $X_1$ and the industry supply

Figure 3: The derived demand curve for labor



curve of output Q. Given continuous equilibrium in the markets for $X_1$ and Q above shifts will usually change the equilibrium price and quantity in the market for $X_1$ and Q. A proper specification of the industry demand curve for labor must anticipate therefore that a change in the price of labor ($P_2$) will also bring about changes in the equilibrium price ($P_1$) of the cooperant factor of production ($X_1$) and the equilibrium price (P) of output (Q). This results in an equilibrium adjusted specification as in relationship 3. The derived demand curve DD' in Figure 3 is drawn under that assumption.

It follows that the appropriate wage elasticity along the (point) interval EI is given by

$$(9.2)\quad E_{X_2P_2} = \frac{\sigma(e_{X_1} - e_q) - k_2e_{X_1}(\sigma + e_q)}{-k_2(\sigma + e_q) + (e_q - e_{X_1})} < 0$$

Given this, we can calculate the excess supply of labor EF as follows

10.1 $EI = GB + BH$

10.2 $GB = E_{X_2 \cdot P_2} \cdot (CA/AO)$

10.3 $BH = e_{X_2} \cdot (CA/AO)$

where $(CA/AO) = p_2$ represents the percent increase in the wage rate $P_2$.

11. <u>The incidence of an input subsidy (or tax)</u>

In the foregoing section, we considered the (un)employment effect associated with a publicly controlled wage rate. We observed that such legislation will typically create an excess supply or excess demand for labor. Yet, another class of public policies is related to input subsidies or input taxes. Social security legislation in essence constitutes a tax on labor. Such legislation will have an impact on wages and unemployment in agriculture. But, it will not create an excess supply or demand for labor, because the labor market

is allowed to regain a new equilibrium. In contrast to the previous example, we must retain all six equations of the model.

In a similar vein, a subsidy on fertilizer will not create an excess demand for fertilizer. On the other hand, the prices paid by farmers for fertilizer and its quantity used will change. A fertilizer subsidy will shift the demand for cooperant factors of production and therefore also shift the industry supply curve of agricultural output. Above are but two examples of a large number of input taxes or subsidies that can be analyzed by means of the 1 x 2 model.

Analytically, the imposition of an input tax or subsidy is equivalent to a shift in the factor supply curve of the input being subsidized or taxed. Suppose that input $X_2$ is to be taxed or subsidized. The factor supply equation 9.5 can then be rewritten as

9.5.B $x_2 = e_{X_2}(p_2 + c)$

where c represents the tax or subsidy as a fraction of the initial equilibrium price. If the input $X_2$ is subsidized, then the shift variable c will be positive. If the input is to be taxed, then c will be negative. To obtain the effect of the tax or subsidy c on the six endogenous variables $X_1$, $X_2$, Q, $P_1$, $P_2$ and P, we substitute equations 9.4, 9.5B, and 9.6 in equations 9.1, 9.2, and 9.3 which yields the following matrix equation

(11.1)

| $p_1$ | $p_2$ | $p$ | $c$ |
|---|---|---|---|
| $(e_{X_1} + k_2\sigma)$ | $-k_2\sigma$ | $-e_q$ | $0$ |
| $-k_1\sigma$ | $(e_{X_2} + k_1\sigma)$ | $-e_q$ | $-e_{X_2}$ |
| $k_1$ | $k_2$ | $-1$ | $0$ |

The determinant of the coefficients of the endogenous variables in 11.1 can be rewritten as (11.2) where $E_{QP}$ is known

(11.2) $\Delta = (e_q - E_{QP})(k_1 e_{X_2} + k_2 e_{X_1} + \sigma) < 0$

or alternatively as (11.3) where $E_{X_2P_2}$ is known

(11.3) $\Delta = (e_{X_2} - E_{X_2P_2})[-k_2(\sigma + e_q) + (e_q - e_{X_1})] < 0$

Using Cramer's rule, we obtain

(11.4) $$E_{P_2C} = \frac{e_{X_2}}{E_{X_2P_2} - e_{X_2}} < 0$$

In above expression, the price elasticity $e_{X_2}$ of the factor supply curve $X_2$ will be positive.[1/] We previously established that the price elasticity of the derived demand for the taxed or subsidized factor $E_{X_2P_2}$ was negative. Consequently, the expression to the right of the equality sign will be negative. The imposition of a subsidy ($c > 0$) implies that after both the commodity and factor markets have fully adjusted to the subsidy, the previously prevailing equilibrium price $P_2$ will decrease. The opposite result prevails if $X_2$ is being taxed, i.e. when the shift variable $c < 0$. The equilibrium price will change by the full amount of the subsidy (or tax) only if $E_{X_2P_2} = 0$, and hence $E_{P_2C} = -1$. Whenever the derived demand curve for the taxed (subsidized) factor of production has a negative slope, its initial equilibrium will change by less than the amount of the tax (subsidy).[2/]

Matrix equation (11.1) could be used to solve for the effect of the tax (subsidy) on the equilibrium price $P_1$ of the cooperant factor of production. Alternatively, we can utilize the following identity among total elasticities.

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[1/] We disregard the possibility of a backward-sloping curve for labor, i.e. a situation when $e_{X_2} < 0$.

[2/] A similar result holds when general equilibrium adjustments are ignored.

(11.5) $E_{P_1C} \equiv E_{P_1P_2} \cdot E_{P_2C}$

Above identity states that the incidence of a tax or subsidy C on the equilibrium price $P_1$ of the cooperant factor of production can be considered as the product of two components, i.e. the effect of C on $P_2$, and then the effect of $P_2$ on $P_1$. The sign and size of the second component is given by equation (11.4). The sign of the cross price effect $E_{P_1P_2}$ was analyzed in section 9. It was found to be of negative sign for $(\sigma + e_q) < 0$, and of positive sign for $(\sigma + e_q) > 0$.

Assume now that $X_2$ represents a subsidized capital input (e.g., machinery). Assume furthermore that capital ($X_2$) and labor ($X_1$) can be substituted for each other such that $\sigma = 1$.[1/] Also, assume that the industry demand for agricultural output is price inelastic. It then follows that $(\sigma + e_q) > 0$, and therefore $E_{P_1P_2} > 0$. If $X_2$ is subsidized, then the shift variable C is positive, and therefore $E_{P_2C} < 0$. Consequently, $E_{P_1C} < 0$, i.e. the equilibrium adjusted price for labor $P_1$ decreases. Assume that the supply of labor is given by the following equation

$$x_1 = e_{x_1} \cdot p_1$$

In above equation, the wage elasticity $e_{X_1}$ of the labor supply curve can be taken to be positive. A capital input subsidy then decreases both the agricultural wage rate ($P_1$) and agricultural employment ($X_1$).

Above results depends critically on the sign of the sum of the elasticity of factor substitution $\sigma$ and the price elasticity of demand $e_q$ for agricultural output. If part or all of agricultural output is exported, and if the country

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[1/] For a Cobb-Douglas production function, $\sigma = 1$. For a Constant Elasticity of Substitution (CES) production function, $\sigma$ typically is found to be smaller than one.

in question is a price taker on the world market, then $e_q$ approaches minus infinity, i.e. $(\sigma + e_q) < 0$. Under those circumstances, a (capital) input subsidy will increase both the renumeration and employment of the cooperant factor of production (e.g. labor)

Input subsidies and taxes affect the price received P for agricultural output Q. Equation 11.1 could be used to solve for this effect. As before, it will be expedient to use an identity between total elasticities.

(11.6) $E_{PC} \equiv E_{PP_2} \cdot E_{P_2C}$

Above identity states that the effect of a tax or subsidy C on output price P can be obtained as the product of two components, i.e. the effect of the tax or subsidy C on the equilibrium price $P_2$ of the taxed or subsidized input $X_2$ and the effect of a change in $P_2$ on output price P. The sign and size of $E_{P_2C}$ were previously determined. From the previous section, we know that $E_{P_1P_2} > 0$. Assume that the shift variable C represents an input subsidy $(C > 0)$. Then, $E_{P_2C} < 0$, and $E_{P_C} < 0$, i.e. an input subsidy will decrease the equilibrium price P of output Q.

We previously established that an input subsidy will increase the employment of the subsidized input, whereas it might decrease the employment of the cooperant factor of productivity. Can equilibrium output decrease, e.g. can a fertilizer subsidy actually lead to a decrease in agricultural production? The demand curve for agricultural output was previously given as

(9.6) $q = e_q \cdot p$

The price elasticity of demand $e_q$ can be taken to be negative. In the foregoing paragraph, we established that an input subsidy decreases the equilibrium price P. Consequently, equilibrium output must expand, i.e. an input subsidy shifts the general equilibrium supply curve for agricultural output to the

right. With a stable demand curve for agricultural output, equilibrium price will fall, and equilibrium output will increase.

Formulas 11.4, 11.5, and 11.6 can be used to arrive at numerical estimates of the (percentage) changes in $P_1$, $P_2$, $P_1$, $X_1$, $X_2$ and Q as related to an ad-valorem subsidy or tax. c.[1/] Such information in turn can be used to calculate (percentage) changes in money aggregates such as $(P_1X_1)$, $(P_2X_2)$ and (PQ).[2/] Basic to all these calculations are the numerical values of five parameters.

1) the elasticity of factor substitution ($\sigma$)

2) the elasticities of factor supply ($e_{X_1}$ and $e_{X_2}$)

3) the price elasticity of demand ($e_q$)

4) the cost share $k_2$ of input $X_2$ (or its complementary share $k_1 = 1 - k_2$ of the cooperant factor of production $X_1$).

The informational needs of above scheme of analysis are few. Yet, the parameters need to be estimated for each specific situation, subsidy or tax analyzed. A priori, one should effect substantial variation in these parameters as between specific taxes, subsidies or countries.

## 12. The derived supply curve for a jointly produced commodity

Agricultural products are often produced jointly. Land, in order to preserve its natural fertility, must often be cultivated in rotation. Wheat is produced not only for grain but also for straw. Cotton is grown not only for fiber but also for seed. The dairy cattle industry produces not only milk but also beef. The beef cattle industry produces not only meat but also hides.

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1/ Note that a specific tax C equals an ad-valorem tax c = C/P, where P is the initial equilibrium price.

2/ See section 15.7.

The sheep industry produces both mutton and wool. The hog industry produces both lard and pork. The poultry industry produces chickens and eggs.

The joint products in above examples when processed yield further joint products. Grain yields flour and by-products. Flour can be used for bread, noodles or pastry products. Cotton seed yields cake and oil. Milk yields butter and cheese and so forth.

Much of the economics literature focuses on things which have a common destiny. Hence, the theory of derived demand for factors of production, input-output analysis being its best known application. But the pricing of things which have a common origin is also of interest. What, for example, are the consequences of controlling the price of bread but not the price of flour? What are the consequences of an export quota on cotton cake on the production of cotton? What are the consequences of subsidizing the price of milk for human consumption on the price of raw milk, butter and cheese? All of above examples of market intervention can be analyzed in the context of the two product-one factor model.

Assume the existence of a competitive firm, which desires to maximize revenue $P_A.Q_A + P_B.Q_B$ subject to the transformation frontier $X(Q_AQ_B) = X$, where commodity prices $P_A$, $P_B$ and X are given. This yields the first order conditions

12.1 $P_A - \lambda.g_A = 0$

12.2 $P_B - \lambda.g_B = 0$

12.3 $\overline{X} - X(Q_A, Q_B) = 0$

This implies that in equilibrium the marginal resource requirements $g_A$, $g_B$ must be proportional to the commodity prices $P_A$, $P_B$. The marginal rate of transformation $MRT_{BA}$ at that point equals the commodity price ratio $(P_A/P_B)$.

In above equations $\lambda$ can be interpreted as the shadow price $P_X$ of the composite factor X. It follows that $\lambda \cdot g_A$ and $\lambda \cdot g_B$ are the marginal costs of producing respectively one additional unit of commodity $Q_A$ and $Q_B$. Equations 12.1 and 12.2 then state that in equilibrium, marginal revenues ($P_A$, $P_B$) must equal marginal costs ($P_X \cdot g_A$; $P_X \cdot g_B$). Substituting for $g_A$ and $g_B$, we obtain

(12.4) $P_X \cdot X = P_A \cdot Q_A + P_B \cdot Q_B$

Consequently, the sum of commodity revenues equals factor income $P_X \cdot X$.

In equations 12.1, 12.2, and 12.3, commodity prices $P_A$, $P_B$ and composite factor supply X are parameters. Given initial equilibrium, we want to ascertain the characteristics of the changes in commodity production $Q_A$, $Q_B$ and the shadow price $P_X$ given exogenous changes in commodity prices $P_A$, $P_B$ and the supply of composite factor X. Total differentiation of equations 12.1, 12.2, 12.3 yields matrix equation 12.4.

(12.4)

| $dP_X$ | $dQ_A$ | $dQ_B$ | $dX$ | $dP_A$ | $dP_B$ |
|---|---|---|---|---|---|
| 0 | $g_A$ | $g_B$ | 1 | 0 | 0 |
| $g_A$ | $P_X \cdot g_{AA}$ | $P_X \cdot g_{AB}$ | 0 | 1 | 0 |
| $g_B$ | $P_X \cdot g_{BA}$ | $P_X \cdot g_{BB}$ | 0 | 0 | 1 |

The determinant $\Delta$ of the coefficients of the endogenous variables should be negative if ($Q_A^0$; $Q_B^0$) represents a proper maximum.

(12.5) $\Delta = -P_X [g_B^2 \cdot g_{AA} - 2 g_A g_B g_{AB} + g_A^2 \cdot g_{BB}] < 0$

Matrix equation 12.4 can be solved to yield the elasticity coefficients of the general equilibrium supply functions and the shadow price of the (composite) factor as related to the prices of commodities and the supply of the (composite) factor. The inclusion of the latter is often overlooked when describing the properties of the general supply function.

| | | $\Delta P_A/P_A$ | $\Delta P_B/P_B$ | $\Delta X/X$ |
|---|---|---|---|---|
| | $\Delta Q_A/Q_A$ | $-k_B\sigma^*$ | $k_B\sigma^*$ | 1 |
| (12.6) | $\Delta Q_B/Q_B$ | $k_A\sigma^*$ | $-k_A\sigma^*$ | 1 |
| | $\Delta P_X/P_X$ | $k_A$ | $k_B$ | 0 |

In above matrix equation, $k_A$ and $k_B$ are the initial equilibrium shares of $Q_A$ and $Q_B$ in factor income $P_X \cdot X$. The elasticity of product substitution $\sigma^*$ is negative.[1/] Consequently, all the coefficients have the expected signs.

In the foregoing paragraphs, we took commodity prices and factor availability as given. However, the determination of equilibrium in the commodity and factor markets requires that these variables be considered as endogenous. We therefore must introduce the missing commodity demand and factor supply relationships. We assume that these relationships depend on their own price only and possibly other exogenous variables determined outside the system of equations under consideration, such as income, population and technological progress. Therefore, in log differential notation[2/]

(12.7) $q_A = e_{q_A} p_A + a$

(12.8) $q_B = e_{q_B} p_B + b$

(12.9) $x = e_X \cdot p_X + c$

where a, b, c are exogenously determined shift variables. Transcribing the results of matrix equation 12.6, we have

(12.10) $q_A = -k_B\sigma^* \cdot p_A + k_B\sigma^* \cdot p_B + x$

---

1/ For a linear homogeneous joint product function, as assumed here, $\sigma^* = \frac{g_A \cdot g_B}{X \cdot g_{AB}} < 0$. For details, see (54), pp. 8-16.

2/ $\frac{\Delta Q_A}{Q_A} = q_A$; $\frac{\Delta P_X}{P_X} = p_X$, etc.

(12.11) $q_B = k_A\sigma^*\cdot p_A - k_A\sigma^*\cdot p_B + x$

(12.12) $p_X = k_A\cdot p_A + k_B\cdot p_B$

Above six equations complete the model of the competitive industry characterized by joint production. The model lends itself to two types of exercises in comparative statics. The first type of exercise includes all six equations. This approach assumes continuous equilibrium adjustment in all markets. The second type of exercise selects a subset of the six equations. That approach may reach the extreme of suspending equilibrium adjustment in all markets. Equations 10-12 form such a subset. Of greater interest are subsets of equations which assume equilibrium adjustments in all but one market. It is these assumptions that allow us to determine the price elasticity of derived supplies and derived demands, i.e. the fundamental characteristics of the commodity supply and factor demand curves drawn in figure 1.

In order to obtain the price elasticity of derived supply for commodity $Q_A$ we eliminate the equilibrium condition which would otherwise prevail in that market, i.e. we eliminate the demand equation for $Q_A$ and take its price $P_A$ as exogenously determined. Substitution for $q_B$ and x in equations 12.10 and 12.11 yields the following matrix equation.

| | $q_A$ | $p_B$ | $p_X$ | $p_A$ | b | c |
|---|---|---|---|---|---|---|
| | 1 | $-k_B\sigma^*$ | $-e_X$ | $-k_B\sigma^*$ | 0 | 1 |
| (12.13) | 0 | $(k_A\sigma^* + e_{q_B})$ | $-e_X$ | $k_A\sigma^*$ | -1 | 1 |
| | 0 | $-k_B$ | 1 | $k_A$ | 0 | 0 |

The determinant $\Delta_1$ of the coefficients of the endogenous variables is negative

(12.14) $\Delta_1 = k_A\sigma^* + e_{q_B} - k_B e_X < 0$

**Using Cramer's determinantal equation, we obtain the elasticity of derived supply.**

$$(12.15) \qquad E_{Q_A \cdot P_A} = \frac{\sigma^*(e_{q_B} - e_X) - k_A e_{q_B}(\sigma^* + e_X)}{-k_A(\sigma^* + e_X) + (e_X - e_{q_B})} > 0$$

The elasticity has the expected sign. The expression in 12.15 has been written so as to emphasize its symmetrical relationship with Marshall's elasticity of derived factor demand $E_{X_2P_2}$ (p. 42), where

$$9.2 \qquad E_{X_2P_2} = \frac{\sigma(e_{X_1} - e_q) - k_2 e_{X_1}(\sigma + e_q)}{-k_2(\sigma + e_q) + (e_q - e_{X_1})} < 0$$

Analogous to the four Marshallian rules that govern the elasticity of derived factor demand, 12.15 can be used to derive four rules that govern the elasticity of derived supply:

1) **The supply of a commodity is likely to be more elastic, the larger (in absolute value) the elasticity of product substitution.**

2) **The supply of a commodity is likely to be more elastic, the larger the share of that commodity in total commodity earnings, provided $(\sigma^* + e_X) > 0$.**

3) **The supply of a commodity is likely to be more elastic, the more elastic the supply of the (composite) factor of production.**

4) **The supply of a commodity is likely to be more elastic, the more elastic is the demand for the remaining jointly produced commodity.**

**Differentiation of $E_{Q_A \cdot P_A}$ with respect to the elasticity of product substitution $\sigma^*$ confirms the first rule. The second rule is confirmed by differentiation with respect to $k_A$, which yields**

$$9.3 \quad dE_{Q_A P_A}/dk_A = \frac{[-e_{q_B}.\text{denomin.} + \text{numerator}](\sigma^* + e_X)}{[\text{denominator}]^2} \gtrless 0$$

The terms in square brackets are positive. The sign of 12.16 therefore depends on $(\sigma^* + e_X)$. Marshall's analysis of joint supply (28, p. 388-390) was restricted to the case where $\sigma^* = 0$. In that case, the second rule holds whenever $e_X > 0$. The third rule is confirmed by differentiating 12.15 with respect to the price elasticity of factor supply $e_X$. The fourth rule is heuristically confirmed by comparing the values of 12.15 for $e_{q_B} = 0$ and $e_{q_B} = \infty$, which yields

$$9.4 \quad \frac{(15)/e_{q_B} = 0}{(15)/e_{q_B} = -\infty} = \frac{-\sigma^* e_X}{k_A k_B(\sigma^* + e_X)^2 - \sigma^* e_X} < 1$$

## 13. Is the supply curve for food price inelastic?

It is often stated that the price elasticity of the supply curve of food products is close to zero, whereas the price elasticity of the supply of industrial products, often agricultural exports, is deemed price responsive. According to the results of the previous section, the price elasticity $E_{Q_A \cdot P_A}$ of the supply curve for food is determined by four parameters.

1) the production elasticity of substitution $\sigma^*$ between food crops and nonfood agricultural commodities
2) the price elasticity of demand $e_{q_B}$ for nonfood agricultural commodities.
3) the price elasticity of supply $e_X$ of the composite of factors used in agricultural production
4) the share $k_A$ of food crops in total agricultural income

Under what circumstances will $E_{Q_A \cdot P_A}$ approach zero, i.e. under what circumstances will the general equilibrium supply curve of food be parallel to the

price axis? According to the first rule, the supply of food will be less price elastic the smaller the elasticity of commodity substitution $\sigma^*$. The lower limit of $\sigma^*$ equals zero. Substitution of this value in 12.15 yields

$$13.1 \quad E_{Q_A P_A} = \frac{-k_A e_{q_B} e_X}{k_B e_X - e_{q_B}} > 0$$

The value of 13.1 will be larger than zero unless the price elasticity of demand $e_{q_B}$ for nonfood agricultural commodities equals zero or if the price elasticity of factor supply $e_X$ equals zero.

According to the third rule, the supply of food will be less price elastic the smaller the price elasticity $e_X$ of the composite factor supply curve. The lower limit for this parameter equals zero. Substitution in 12.15 yields

$$13.2 \quad E_{Q_A P_A} = \frac{k_B e_{q_B} \sigma^*}{-k_A \sigma^* - e_{q_B}} > 0$$

The value of 13.2 will be positive unless $e_{q_B}$ or $\sigma^*$ equal zero.

According to the fourth rule, the supply of food will be less price elastic the smaller the price elasticity of demand $e_{q_B}$ for nonfood commodities. The lower limit for $e_{q_B} = 0$. Substituting this value in 12.15 yields

$$13.3 \quad E_{Q_A P_A} = \frac{-\sigma^* e_X}{-k_A \sigma^* + k_B e_X} > 0$$

The price elasticity of food is greater than zero unless $\sigma^* = 0$ or $e_X = 0$. From the foregoing follows that the price elasticity of supply of food products will be greater than zero unless two out of three elasticity parameters ($\sigma^*$, $e_{q_B}$, $e_X$) equal zero. There is no a priori reason why this should be so.

What are the conditions such that the general equilibrium supply curve for food is price elastic? According to the first rule, the larger $\sigma^*$ the larger

$E_{Q_A P_A}$. The upper limit of $\sigma^*$ equals (minus) infinity, i.e. the production processes of food and nonfood commodities are technologically independent. Substitution in 12.15 yields

$$13.4 \quad E_{Q_A \cdot P_A} = \frac{k_B e_{q_B} - e_X}{-k_A} > 0$$

A sufficient, but not necessary condition, for the price elasticity to be larger than unity is that $e_{q_B}$ or $e_X$ approach infinity.

According to the third rule, the supply of food is likely to be more elastic, the more elastic the supply of the composite factor of production. Substitution for $e_X$ equal to infinity in 12.15 yields

$$13.5 \quad E_{Q_A \cdot P_A} = \frac{-\sigma^* - k_A e_{q_B}}{k_B} > 0$$

A sufficient, but not necessary condition, for the price elasticity 13.5 to be larger than unity is that $\sigma^*$ or $e_{q_B}$ approach infinity.

According to the fourth rule, the supply of food is likely to be more elastic, the more elastic is the demand for the remaining jointly produced commodity. Let $e_{q_B}$ approach (minus) infinity. Substitution in 12.15 yields

$$13.6 \quad E_{Q_A \cdot P_A} = \frac{k_B \sigma^* - k_A e_X}{-1} > 0$$

A sufficient, but not necessary condition, for 13.6 to be larger than unity is that $\sigma^*$ or $e_X$ approach infinity. From the foregoing follows that if two of the price elasticities ($\sigma^*$, $e_{q_B}$, $e_X$) approach infinity, the supply curve for food will be price elastic. There is no a priori reason why this should be so.

Most linear programming models and two-sector models assume independent production processes such that the elasticity of commodity substitution $\sigma^*$ approaches infinity (11, 40). If one furthermore assumes that the nonfood

commodity can be internationally traded and that the country in question is a price taker on the world market, then the supply curve for food must be price elastic ($E_{Q_A P_A} > 1$) even if the price elasticity of factor supply $e_X = 0$.

$$13.4 \quad E_{Q_A P_A} = \frac{k_B e_{q_B} - e_X}{-k_A} > 0$$

In 13.4, $e_{q_B}$ approaches infinity and $e_X$ approaches zero, which yields the foregoing conclusion. Even when $e_{q_B}$ is less than infinity, 13.4 may be larger than unity, provided the revenue share $k_A$ from food crops is small relative to the remaining revenue share $k_B$ of nonfood commodities.

We conclude above obesrvations by positing the following stylized values of the parameters: $e_{q_A} = -.7$, $e_{q_B} = -2.0$, $\sigma^* = -1$, $k_A = .80$ and $e_X = .3$. We then obtain[1/]

$$13.5 \quad E_{Q_A P_A} = .41$$

$$13.6 \quad E_{Q_B P_B} = 1.05$$

In this possibly representative example, food crop production ($Q_A$) is price inelastic, and export crop production ($Q_B$) price elastic.

## 14. The incidence of commodity price controls

### 14.1 Preliminaries

Developing countries often resort to price controls for food products. The theory of joint supply can be used to analyze the incidence of such policies. The supply curve for food SS' in Figure 4 reflects continuous equilibrium in the remaining commodity and factor markets, i.e. SS' has the properties of the general equilibrium supply curve developed in the previous section.

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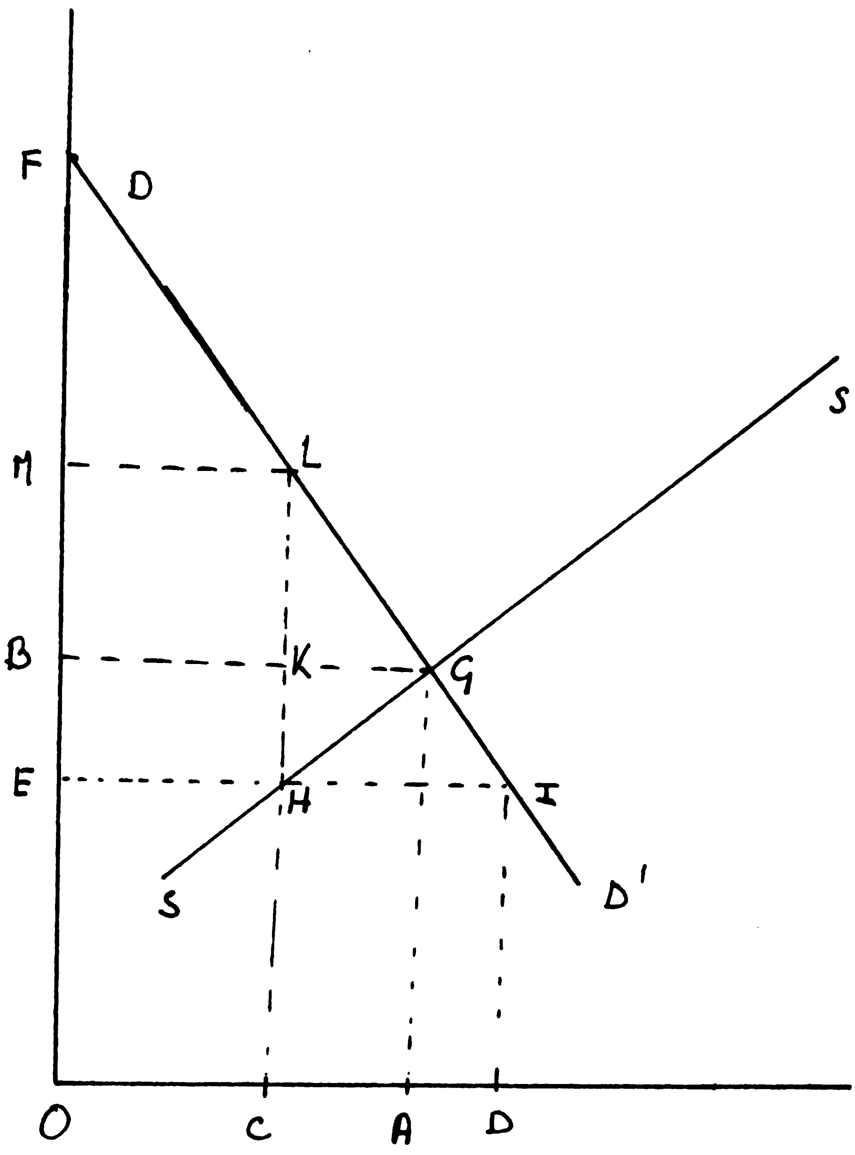
1/ $$E_{Q_B \cdot P_B} = \frac{\sigma^*(e_{q_A} - e_X) - k_B e_{q_A}(\sigma^* + e_X)}{-k_B(\sigma^* + e_X) + (e_X - e_{q_A})} > 0$$

Figure 4



Statistically, therefore, one should estimate the reduced form relation $Q_A = Q_A (P_A, b, c)$. Note that the remaining endogenous variables $P_B$, $Q_B$, $P_X$, X and the shift variable a pertaining to the demand for $Q_A$ have no legitimate reason to appear in above relationship. The nature of the demand curve in Figure 4 merits separate discussion. Assume, however, that food products do not compete with export products in consumption and that agricultural income has a negligible impact on the demand for food.[1/]

In figure 4, OB and OA are the initial equilibrium price and quantity for food products. We assume that a price control measure lowers the equilibrium price by BE. Because of this, production will decrease by CA, but demand would increase by AD. The resulting excess demand CD is not sustainable. We assume, therefore, that the price control measure is accompanied by a non-price distribution scheme, such as rationing. We furthermore assume that producers sell food at the legally stipulated price OE.

Initial consumer's surplus is measured by the triangle BFG. Subsequently, it is measured by the trapezoid EHLF. The net change in consumer's surplus is the difference between what is gained, i.e. the rectangle BKHE, and what is lost, i.e. the triangle LKG. A counterclockwise rotation of the demand curve shows that for a given supply curve a more elastic demand curve will decrease the loss triangle LKG while leaving the gains rectangle BKHE unaffected. Other things constant, price controls will benefit consumers of a product proportionately more if the demand for that product is price elastic.

Clockwise rotation of the supply curve shows that for a given demand curve a more elastic supply curve will decrease the gains rectangle and increase the loss rectangle LKG. Other things constant, price controls will benefit

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[1/] These assumptions are relaxed in section 11 of (54).

consumers of a product proportionately more if the supply of that product is price inelastic.

14.2 When do consumers benefit from price controls: the cardinal utility approach

Above observations do not tell us whether the consumers in a given situation derive a net benefit from price controls, i.e. the sign of the change in consumer's surplus $\Delta CS$ is undetermined

1) $$\Delta CS = \text{rectangle BKHE} - \text{triangle LKG} \gtrless 0$$

In what follows we will express the change in consumer's surplus as a fraction of initial expenditure on that commodity. Hence,

2) $$\frac{\Delta CS}{OB \times OA} = \frac{OC \times BE}{OA \times OB} - \frac{1/2 \times LK \times KG}{OA \times OB} \gtrless 0$$

In above expression BE/OB is the known percentage change $p_A$ in the price of commodity $Q_A$. The change in $p_A$ is defined as positive. Failure to do so yields a negative value for the gains rectangle as a fraction of $P_AQ_A$. The percentage change in quantity supplied as related to $p_A$ is given by 13.5 Hence,

3) $$CA/OA = E_{Q_AP_A} \cdot p_A$$

It follows from OA = OC + CA that

4) $$OC/OA = 1 - \frac{CA}{OA} = 1 - E_{Q_AP_A} \cdot p_A > 0$$

Above expression must be constrained to positive values only because in figure 4 the quantity supplied OC cannot be less than zero. The area of the gains rectangle as a fraction of initial consumer expenditure $P_AQ_A$ equals

5) $$(1 - E_{Q_AP_A} \cdot p_A) \cdot p_A > 0 \quad \text{where } p_A > 0$$

For a constant elasticity of supply the gains rectangle BKHE in figure 4 will become an increasingly large fraction of initial consumer expenditure $P_A \cdot Q_A$.

In figure 4 the supply curve SS' has been drawn as a straight line with a positive intercept. The elasticity of supply along such a supply curve is not constant. The gains rectangle BKHE will then reach a maximum when $E_{Q_A P_A}$ equals 1. Since $e_{q_A}$ is the price elasticity of demand of DD' in figure 4, we have by definition

$$6) \qquad e_{q_A} = - \frac{KG}{KL} \times \frac{OB}{OA} < 0$$

Note that in 6 the decrease in quantity supplied KG is taken as positive. Also, because $E_{Q_A P_A}$ is the price elasticity of supply SS' in figure 4, we have

$$7) \qquad \frac{KG}{BG} = E_{Q_A P_A} \cdot p_A \qquad \text{where } p_A > 0$$

Substitution on 6 and 7 in 2 yields the loss triangle LKG as a fraction of initial consumer expenditure $P_A Q_A$.

$$3) \qquad \frac{LK \times KG}{2 \times OA \times OB} = \frac{[E_{Q_A P_A}]^2 \cdot (p_A)^2}{-2e_{q_A}} > 0$$

Substitution of 5 and 82 into yields the net change in consumer's surplus expressed as a fraction of initial consumer expenditure on commodity $Q_A$.

$$9) \qquad \frac{\Delta CS}{P_A \cdot Q_A} = (1 - E_{Q_A P_A} \cdot p_A) p_A + \frac{[E_{Q_A P_A}]^2}{2e_{q_A}} \cdot p_A^2 \gtrless 0$$

The first term in above expression is positive, the second term is negative. The consumer, therefore, does not necessarily benefit from price controls.

The expression in 9 is a simple quadratic equation in $p_A$. Net benefits, as expected, will be zero for $p_A = 0$ and also for values of $p_A$ such that[1/]

10) $0 < p_A = \dfrac{-2e}{E^2 - 2Ee} < 1$

The critical values of $p_A$ for combinations of the price elasticity of demand (e) and price elasticity of supply (E) for which net benefits become zero have been calculated in Table 4. The results indicate that the consumer benefits from price controls, provided e and E fall within the ranges indicated.

### 14.3 When do consumers benefit from price controls: the ordinal utility approach

In figure 5 we have drawn a conventional indifference map for a consumer who spends all of his income on food and non-food items. At the initial prices for these items, the consumer chooses OA of food. Price controls lower the price of food, and the initial budget line BC swings upward to BD. With money income constant, the consumer increases the consumption of food to point K.

If, however, real income is held constant, by means of a compensating decrease in income equal to BE, the consumer would move from point G on indifference curve $I_1$ to point H on that same indifference curve. But the consumer cannot move from point G to point H or point K. Price controls cause the supply of food to decrease.

At the controlled price of food, the feasible set of consumption points is restricted to a specific point on segment BN of budget line BD. If the supply price elasticity is zero, then the consumer will choose N. If the supply of

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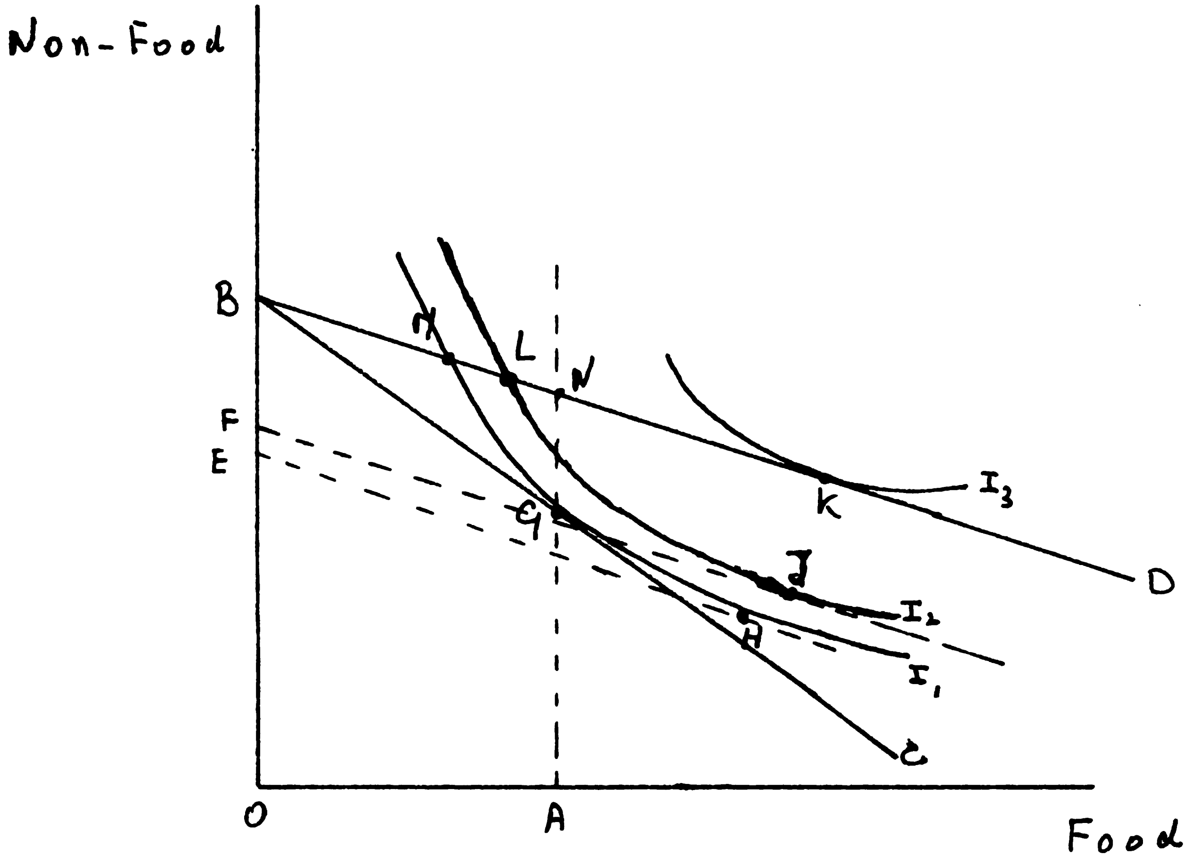
1/ Because at that point

$$\frac{\Delta CS}{P_A Q_A} = 0 = p_A + \left(\frac{E^2}{2e} - E\right) p_A^2 .$$

Division by $p_A$ and transposition yields 10.

Figure 5



increase in consumer's welfare between points G and L caused by the imposition of price controls is given by the compensating variation in income equal to EF. This amount, when expressed as a fraction of the initial expenditure, should give approximately the same results as 9.[1/]

14.4 Food price controls and agricultural income

When analyzing food price controls of a given commodity e.g. food producers will have an incentive to reallocate resources towards productive activities whose commodity prices are not controlled. This reallocation effect is already reflected in the general equilibrium supply curve SS' in Figure 4. Nevertheless, that figure as such does not allow us to calculate the incidence of price controls on nonfood production, factor demand and agricultural income.

The change in nonfood production is given by the following expression:

$$11)\quad E_{Q_B \cdot P_A} = e_{q_B} \cdot E_{P_B \cdot P_A}$$

Solving equation 12.13 for the change in the price $P_B$ of nonfood and substituting above, we have

$$12)\quad E_{Q_B \cdot P_A} = \frac{-k_A e_{q_B}(\sigma^* + e_X)}{-k_A(\sigma^* + e_X) + )e_X - e_{q_B})} \gtrless 0$$

The sign of above expression is determined by the sign of $(\sigma^* + e_X)$, i.e. by the relative strengths of the substitution effect as measured by the elasticity of product substitution $\sigma^*$ and the factor employment effect as measured by $e_X$. If the latter equals zero, then $E_{Q_B \cdot P_A} < 0$. In such circumstances, food price controls, i.e. a decrease in $P_A$, will increase nonfood production. The increase in nonfood production will be proportionately larger if the demand for nonfood

[1/] The order of approximation is given in 54 section 9.5.

products is price elastic.

$$13)\quad E_{Q_B P_A}\Big|_{\substack{e_X = 0 \\ e_{q_B} = -\infty}} = k_A \sigma^* < 0$$

Farm income is measured by $P_X X$. The percentage change in farm income, therefore, equals $(p_X + x)$, where $x = e_X \cdot p_X$ as in equation 12.9. The sign of the change in farm income is, therefore, determined by the sign of the change in the shadow price $p_X$ of factor X, provided the factor supply elasticity $e_X$ remains positive. Solving equation 12.3 for $P_X$, we find

$$14)\qquad E_{P_X P_A} = \frac{-k_A(\sigma^* + e_{q_B})}{-k_A(\sigma^* + e_X) + (e_X - e_{q_B})} > 0$$

Food price controls always depress the shadow price $P_X$ of resources used in agricultural production, and by the foregoing argument also depress agricultural incomes. The percentage change in the latter is measured by the following expression:

$$15)\qquad E_{(P_X . X)P_A} = \frac{-(1 + e_X)k_A(\sigma^* + e_{q_B})}{-k_A(\sigma^* + e_X) + (e_X - e_{q_B})} > 0$$

Differentiation of 15, with respect to the critical parameters e , $e_X$ , $\sigma^*$ and $k_A$, establishes the following rules:

1) Food price controls are likely to decrease agricultural income more if the elasticity of product substitution $\sigma^*$ is small (in absolute value).1/

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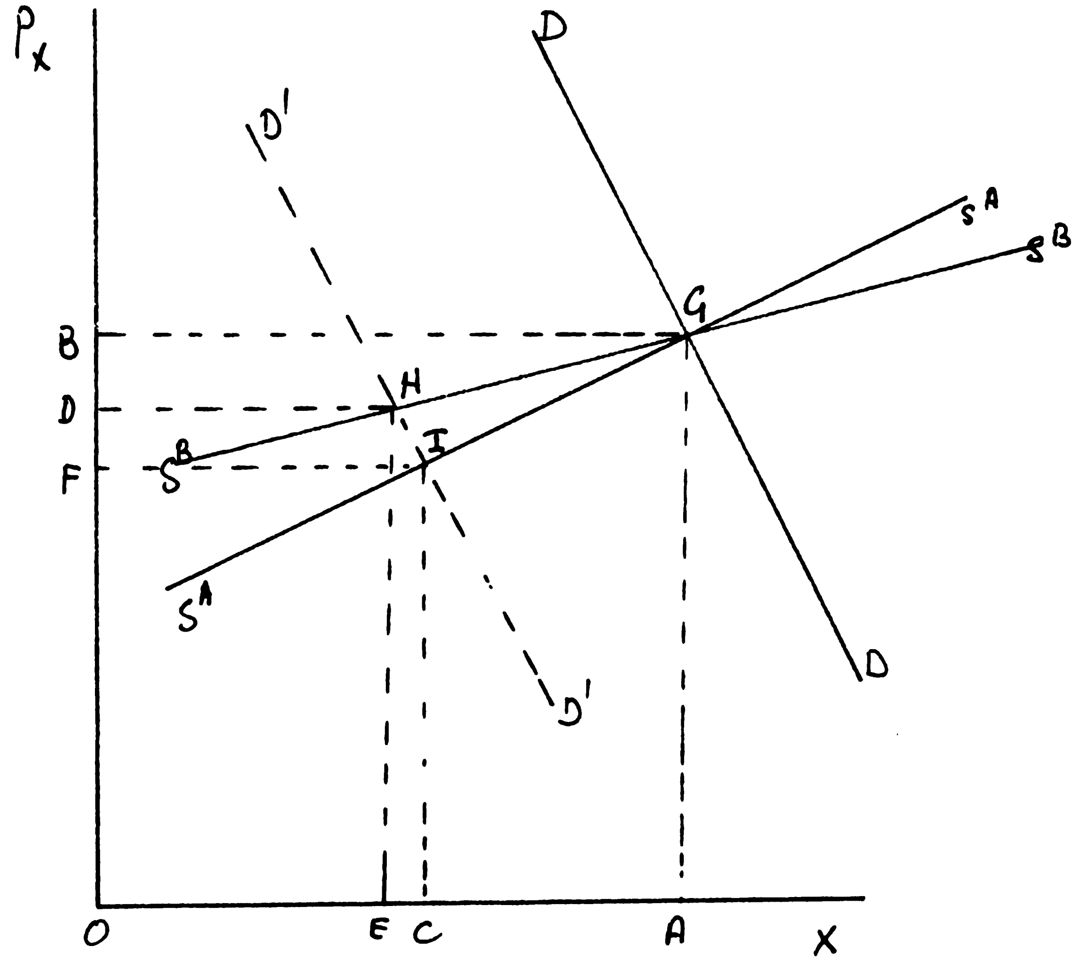
1/ because $$\frac{dE_{(P_X X)P_X}}{d\sigma^*} = \frac{k_A l_B(1 + e_X)(e_{q_B} - e_X)}{[\text{denominator}]^2} < 0$$

Figure 6



decrease proportionately more, because the area of rectangle OEHD is less than that of rectangle OCIF.

To determine the elasticity of derived factor demand in figure 6, we suspend the equilibrium condition in the factor market, in addition to considering the price of food as given. In what follows, we derive this elasticity in two steps. First, by considering equilibrium in both commodity markets, and then suspending equilibrium in the market for food by assuming $P_A$ constant, i.e. by assuming that the elasticity of demand for food approaches infinity.

Eliminating equation 12.9 and rearranging the remaining variables in equations 12.7 through 12.12 yields matrix equation 16.

| | x | $p_A$ | $p_B$ | $p_X$ | a | b |
|---|---|---|---|---|---|---|
| | -1 | $(e_{q_A} + k_B\sigma^*)$ | $-k_B\sigma^*$ | 0 | -1 | 0 |
| 16) | -1 | $-k_A\sigma^*$ | $(e_{q_B} + k_A\sigma^*)$ | 0 | 0 | -1 |
| | 0 | $k_A$ | $k_B$ | 1 | 0 | 0 |

The determinant $\Delta_2$ of the coefficients of the endogenous variables is negative

17) $$\Delta_2 = k_A e_{q_B} + k_B e_{q_A} + \sigma^* < 0$$

Using Cramer's determinantal equation, obtain the elasticity of derived factor demand. This elasticity is always negative.

18) $$E_{X \cdot P_X} = \frac{k_A e_{q_A} \sigma^* + k_B e_{q_B} \sigma^* + e_{q_A} e_{q_B}}{k_A e_{q_B} + k_B \cdot e_{q_A} + \sigma^*} < 0$$

Figure 5 was constructed under the assumption that the price of food was controlled, thereby suspending the equilibrium condition in the food market. An exogenously controlled price of food $P_A$ is equivalent to assuming that the demand for food at price is infinitely price elastic. Therefore,

19) $$E_{X \cdot P_X}\Big|_{e_{q_A} = \infty} = \frac{k_A\sigma^* + e_{q_B}}{k_B} < 0$$

In order that agricultural income decreases with an increasingly elastic factor supply, the derived demand for that factor must be price elastic, i.e.

20) $$E_{XP_X}\Big|_{e_{q_A} = \infty} = \frac{k_A\sigma^* + e_{q_B}}{k_B} < -1$$

which yields the qualification to our third rule. We can, therefore, restate that rule as follows:

3[B]) Food price controls are likely to decrease agricultural income more, the more elastic the supply of the (composite) factor of production, provided the derived demand for that factor for $e_{q_A} = -\infty$ is price elastic.

A price elastic demand for agricultural exports is usually a sufficient condition for above rule to hold.

If we assume as before that $e_{q_B} = -2.0$; $\sigma^* = -1$; $k_A = .30$ and $e_X = 0$ we find upon substitution in 15

21) $$E_{(P_X X)P_A} = .39$$

A one percent decrease in the equilibrium price of food would decrease agricultural income by almost four tenths of one percent. Above example is possibly typical of the incidence of food price controls on agricultural incomes.

## 14.5 Food price controls and national welfare: a compensation test

In the foregoing section we argued that price controls on food tend to benefit the consumer, whereas they decrease agricultural income. It is natural then to ask as to whether consumers could compensate producers by means of an

income transfer so as to leave neither consumer or producer worse off. If so, price controls on food constitute a potential means of increasing domestic economic welfare.[1/] We now demonstate that possibility.

The upper quadrant in figure 7 is a replica of the indifference mapping in figure 5. The lower quadrant in figure 7 represents the transformation product curve for a given composite factor supply. We assume that the prices of non-food items and agricultural exports are given. OG' is the initial amount of food produced such that consumers maximize utility for a given income M, and producers maximize factor income $P_X.X$ for a given factor supply X. Because food price controls lower the price of food relative to the price of exports, output of the latter will increase, whereas the production of food will decrease to OL'. This causes agricultural income to decrease. The decrease in agricultural income measured at <u>constant before price control</u> prices equals RS.

The consumer's budget constraint equals

22) $$M = P_{non\text{-}food} \cdot Q_{non\text{-}food} + P_{food} \cdot Q_{food}$$

Above equation can be solved for the quantity of non-food items consumed, because income, the price of non-food, the price of food and the quantity of food consumed at the controlled price of food are known. We can, therefore, draw the budget line BK in figure 7. We assume that the consumption point L is such that price controls increase the welfare of the consumer. Points L and J lie on the same indifference curve. The increase in real income measured at <u>constant after price control</u> prices equals TU. Visual inspection of figure 7 shows that

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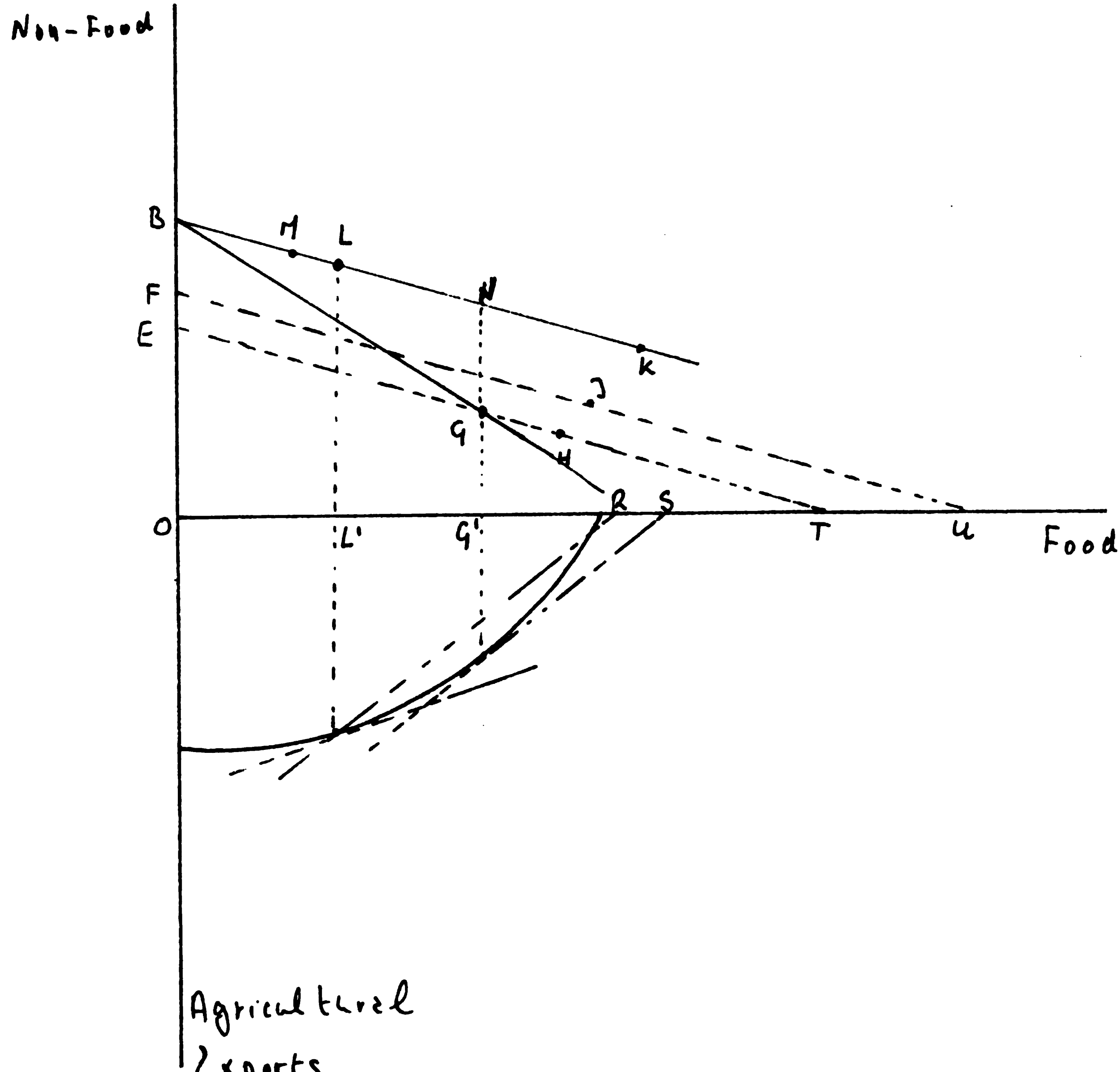
1/ A Pareto potential improvement would also consider the international welfare effects of domestic controls on the price of food. We focus exclusively on domestic welfare repercussions.

Figure 7



23) $RS \gtrless TU$

If TU > RS, then consumers could transfer RS of their income to producers so as to leave the latter no worse off than before. Consumers meanwhile would still be better off.

In a previous section, we developed numerical approximations for RS and TU, i.e. equations 9 and 15. These expressions allow for a non-zero factor supply elasticity, whereas in figure 7 we assume $e_X = 0$ and $e_{q_B} = -\infty$. Rewriting 24 we have

24) $\Delta(P_X X) \gtrless \Delta CS$

where

25) $\Delta(P_X X) = E_{(P_X X)P_A} \cdot (P_X X) \cdot p_A$

26) $$\Delta CS = \left\{ 1 + \left[ \frac{(E_{Q_A P_A})^2 - 2e_{q_A} \cdot E_{Q_A P_A}}{2e_{q_A}} \right] p_A \right\} k_A (P_X X) p_A$$

Assume as before $e_{q_A} = .7$, $e_{q_B} = -2.0$; $\sigma^* = -1$, $k_A = .30$ and $e_X = 0$. Also, assume that $p_A$ is moderately small so as to increase the probability that the consumer will benefit from price controls. Let $p_A = .25$. Substitution of these parameters in 12, 15 and 26 yields

27) $\Delta(P_X X) = -.10\ P_X X$

28) $\Delta CS = .24\ P_X X$

If the marginal utility of income is assumed equal for consumers and producers, then under the numerical assumptions made, price controls will increase domestic welfare. It the per capita income of producers is substantially less than that of consumers, one might want posit the value of the marginal utility of income as a function of the level of income. Such a procedure is methodologically well established in benefit-cost analysis (46, p. 63-67). Application of this method could lead to the rejection of the previously stated conclusion.

If one wants to avoid interpersonal comparisons of welfare, one cannot state that in 27 and 28 price controls improve domestic welfare. This would be true only if consumers would compensate producers for their loss of welfare. Nevertheless, in practice a potential welfare improvement is often taken as an actual improvement of welfare.

## 15. The incidence of commodity taxes or subsidies

### 15.1 Adaptation of the 2x1 model for this purpose

Tax revenue derived from agricultural exports is often an important source of revenue to the governments of developing countries. In this section, we analyze the incidence of a tax on agricultural exports $Q_B$. For this purpose, we can avail ourselves of mathematical, numerical and graphical methods. It will be shown subsequently that only the mathematical method is to be relied upon. Graphical interpretation of general equilibrium adjustments is tricky, if not impossible. It is for this reason that we start with the mathematical method and finish with a graphical illustration of the results obtained.

Assume that $P_B^*$ is the price of exports f.o.b. Assume that exports are taxed at an ad valorem rate t.[1/] The price received by producers $P_B$ then equals $(1-t)P_B^*$. Therefore

1) $$\frac{\Delta P_B}{P_B} = \frac{\Delta(1-t)}{1-t} + \frac{\Delta P_B^*}{P_B^*}$$

If the initial tax rate t = 0, then above expression can be rewritten as

2) $$P_B = P_B^* - t$$

We assume that the revenue collected by this tax does not influence the demand

[1/] An ad valorem tax is equivalent to a tax which collects a constant share of the value of exports. It must be distinguished from a specific tax. The revenue collected with the latter is proportional to the volume of exports. For every ad valorem tax there is an equivalent revenue yielding specific tax and vice versa.

for food, nor is food an internationally traded good. We do not inquire as to other potential uses of the export tax, e.g. to improve factor productivity in cotton or food production or other "second generation" effects. The imposition of an export tax will affect the demand for the composite factor X in figure 1. It will also affect the derived supplies of export and food production in figure 1. But the imposition of export taxes does not suspend any of the equilibrium conditions in the commodity and factor markets as e.g. with food price controls. Because of this, we need to make only a minor modification of the original model on page 60. The complete model as before consists of six equations:

3) $q_A = e_{q_A} p_A$

4) $q_B = e_{q_B} (p_B + t)$

5) $x = e_X \cdot p_x X$

6) $q_A = -k_B\sigma^* p_A + k_B\sigma^* p_B + x$

7) $q_B = k_A\sigma^* p_A - k_A\sigma^* p_B + x$

8) $p_X = k_A p_A + k_B p_B$

Substituting the first three equations into the latter three equations yields the following matrix equation:

| | $p_A$ | $p_B$ | $p_X$ | $t$ |
|---|---|---|---|---|
| 9) | $(e_{q_A} + k_B\sigma^*)$ | $-k_B\sigma^*$ | $-e_X$ | 0 |
| | $-k_A\sigma^*$ | $(e_{q_B} + k_A\sigma^*)$ | $-e_X$ | $-e_{q_B}$ |
| | $k_A$ | $k_B$ | -1 | 0 |

The determinant of the coefficients of the endogenous variables $\Delta_3$ is negative.

10) $\Delta_3 = (e_{q_B} - E_{Q_B P_B})[-k_B(\sigma^* + e_X) + (e_X - e_{q_A})] < 0$

where the total elasticity $E_{Q_B P_B}$ corresponds to the derived elasticity of commodity supply in equation 12.15.

15.2 Incidence on product and factor prices

Using Cramer's determinantal equation, we find successively

$$11) \quad E_{P_B \cdot t} = \frac{e_{q_B}[e_{q_A} + k_B\sigma^* - k_A e_X]}{\Delta_3} < 0$$

$$12) \quad E_{P_B^* \cdot t} = \frac{-k_A\sigma^* e_{q_A} + k_B e_X e_{q_A} + \sigma^* e_X}{\Delta_3} > 0$$

$$13) \quad E_{P_A \cdot t} = \frac{k_B e_{q_B}(\sigma^* + e_X)}{\Delta_3} \gtrless 0$$

$$14) \quad E_{P_A \cdot t} - E_{P_B \cdot t} = \frac{e_{q_B}(e_X - e_{q_A})}{\Delta_3} > 0$$

$$15) \quad E_{P_X \cdot t} = \frac{k_B e_{q_B}(\sigma^* + e_{q_A})}{\Delta_3} < 0$$

A tax on agricultural exports $Q_B$ will decrease the price $P_B$ received by farmers and increase the price $P_B^*$ paid by consumers. An important policy question is as to whom pays the major share of the tax. Can it be shifted onto consumers abroad or will it have to be absorbed by domestic producers? The answer revolves around the respective demand and supply price elasticities of agricultural exports $Q_B$. Using 13 we can rewrite 14 as below

$$16) \quad E_{P_B \cdot t} = \frac{e_{q_B}}{E_{Q_B \cdot P_B} - e_{q_B}} < 0$$

If the country supplies only a small fraction of world exports, we would expect the demand for the country's exports to be quite price elastic. Assume, therefore, that $e_{q_B} = -\infty$. Substitution of this value in 16 shows that the price producers receive decreases by the full amount of the tax.

$$17) \quad E_{P_B \cdot t} = -1.$$

Under those circumstances none of the tax is shifted abroad. This may well be the typical situation.

Assume now that the country is a major exporter of $Q_B$ and that the supply curve $S_B$ is quite price elastic, i.e. $E_{Q_B \cdot P_B} = -\infty$. Substitution in 16 reveals that the price producers receive stays the same

18) $E_{P_B \cdot t} = 0$

All of the tax is shifted onto consumers abroad. The f.o.b. price of exports $P^*_B$ will increase by the full amount of the tax, as follows from the expression below

19) $E_{P^*_B \cdot t} = E_{P_B \cdot t} + 1$

An export tax is often thought to increase the production of commodities for domestic markets. Typically, a tax on exports is thought to increase food production. However, the imposition of the tax has no predetermined effect on the price of food $P_A$ as can be inferred from equation 13. The numerator in that equation contains two critical parameters, the elasticity of substitution $\sigma^*$ and the factor supply elasticity $e_X$. The impact of an export tax on food production therefore consists of a product substitution and factor employment effect. If the elasticity of product substitution $\sigma^*$ is large relative to the factor supply elasticity $e_X$ such that $(\sigma^* + e_X) < 0$, then the price of food $P_A$ will decline because of the imposition of the export tax. Under these circumstances domestic consumers of food benefit from the export tax.

The shadow price $P_X$ of resources used in export and food production always declines with the imposition of an export tax. If the factor supply elasticity $e_X$ is positive, agricultural income $P_X X$ must also decline. The possible increase in farm income derived from the production of food is never sufficient to offset the decrease in agricultural income derived from export production.

In the post-tax situation, the price of food will have increased relative to the price of exports. Proportionately more resources will be devoted to food production. However, with a sufficiently elastic factor supply $e_X$, the absolute amount of resources dedicated to either food or export production may decline.

15.3 A numerical example

The parameters that determine the incidence of the export tax appear in equations 10 through 15. They are six in number.

1) The price elasticity of demand for "food", $e_{q_A} < 0$.

2) The price elasticity of demand for "exports", $e_{q_B} < 0$.

3) The price elasticity of the factor supply curve, $e_X > 0$.

4) The elasticity of commodity substitution, $\sigma^* < 0$.

5) The share of agricultural exports in agricultural income, $0 \leq k_B \leq 1$.

6) The share of "food production" in agricultural income, $k_B = 1 - k_A$.

We proceed by positing the following possibly typical values of above six parameters: $e_{q_A} = -.7$, $e_{q_B} = -1.5$, $\sigma^* = -1.0$, $e_X = .2$, $k_A = .7$, $k_B = .3$.

Given above information, we first calculate the price elasticity of agricultural exports, using equation 12.15 for that purpose

20) $E_{Q_B \cdot P_B} = .642$

The supply curve for export crops is moderately price inelastic. The price elasticity of the "food" supply curve can be shown to equal 12.15.

21) $$E_{Q_A \cdot P_A} = \frac{\sigma^*(e_{q_B} - e_X) - k_A e_{q_B}(\sigma^* + e_X)}{-k_A(\sigma^* + e_X) + (e_X - e_{q_B})} > 0$$

Substitution of our numerical assumptions in 21 yields

22) $E_{Q_A \cdot P_A} = .381$

The supply curve of food products is relatively more price inelastic than the supply curve of export products, a not uncommon opinion among development specialists.

Equation 10 can be used to calculate the value of the determinant $\Delta_3$ appearing in the tax incidence formulas 11 through 15 .

23) $\Delta_3 = -2.442$

Using equation 11 we calculate the incidence of the ad valorem tax t on the price $P_B$ farmers receive

24) $E_{P_B \cdot t} = -.700$

An ad valorem tax of 10 percent causes the price received by farmers for that product to decline by 7 percent. It follows, because of equation 51, that the price paid by consumers for agricultural exports $P_B^*$ increases by 3 percent. Domestic producers pay seventy percent of the tax revenue collected, foreign consumers pay the remaining share. Most of the export tax cannot be shifted onto consumers abroad.

The effect on the price of food $P_A$ can be calculated using equation .

25) $E_{P_A \cdot t} = -.147$

A 10 percent ad valorem tax on exports will decrease the price of food by 1.5 percent. In this case the commodity substitution effect will outweigh the factor employment effect and food production will increase.

The prices farmers receive for exports $P_B$ and for food $P_A$ both decrease. The general decrease in prices received by farmers is reflected in a decline of the shadow price $P_X$ of resources used in agriculture. Using equation 15 we find

26) $E_{P_X \cdot t} = -.313$

A ten percent ad valorem tax on exports decreases prices paid by farmers for resources used in agriculture by 3 percent.

Agricultural income by definition equals $P_X X$. The imposition of the tax decreases both $P_X$ as well as the volume of resources X employed in agriculture. Their combined effect on agricultural income is measured by the following equation:

$$27)\quad \frac{\Delta P_X X}{P_X X} = p_X + X$$

From equation 5 we have $x = e_X p_X$. Substituting this result above we have

$$28)\quad \frac{\Delta P_X X}{P_X X} = (1 + e_X)p_X$$

The factor supply elasticity $e_X = .2$. From 26 we have $p_X = -.313$. Hence, under the numerical assumptions made

$$29)\quad \frac{\Delta P_X X}{P_X X} = -.376$$

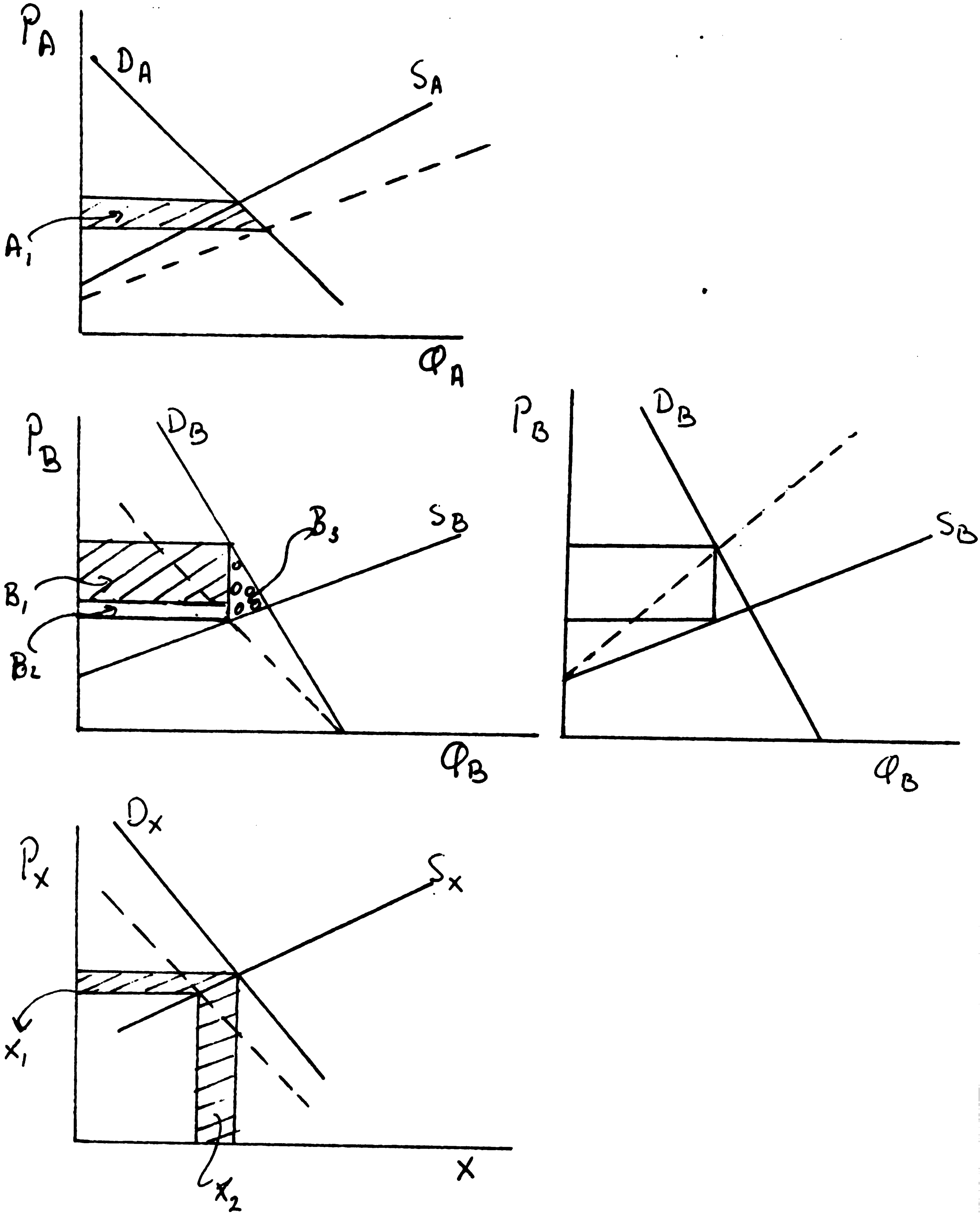
A ten percent ad valorem tax on exports will decrease agricultural income by 4 percent. This result shows that the taxation of agricultural exports may have substantial consequences for agricultural income.

To the extent that above numerical assumptions are typical, we would expect the results to coincide with accepted opinions in this matter. This is indeed the case. The merit of the approach of course lies in the possibility of handling atypical cases, when accepted notions are misleading. It might be argued that no product and no country is typical. Should this be true, then great care should be taken in estimating the six parameters underlying this model. As to how to statistically estimate these parameters is discussed in section 15.

## 15.4 A graphical analysis

The solid black lines in figure 8 are the demand and supply curves for commodities $Q_A$, $Q_B$ and factor X prior to the imposition of the tax on the

Figure 8: The incidence of a tax on agricultural exports



exported commodity $Q_B$. In figure 8 all markets are initially in equilibrium. Let us assume that the government imposes an ad valorem tax on agricultural exports $Q_B$. Such a tax drives a wedge between prices consumers pay and producers receive. If the demand curve for exports $D_B$ is expressed in terms of prices farmers receive, then the imposition of the tax will rotate the demand curve $D_B$ to the left. Alternatively we may assume that the cost of producing agricultural exports increases. The supply curve $S_B$ will then rotate upward. The demand curve $D_B$ is then expressed in terms of prices consumers pay, not in terms of prices producers receive. Under either assumption the incidence of the tax will be the same.

The price producers receive after imposition of the tax declines. Production of $Q_B$ declines concomitantly. Because of this, $P_B$ decreases relative to $P_A$. Because of this, producers would like to substitute the production of $Q_A$ for $Q_B$. But if $\sigma^* = 0$, then $Q_A$ and $Q_B$ must be produced in fixed proportions. Consequently, $Q_A$ will decrease if $Q_B$ decreases. The supply curve $S_A$ in figure 8 will shift to the left.

Assume now that $\sigma^*$ is unequal to zero. Producers will then substitute $Q_A$ for $Q_B$. The production of $Q_A$ will increase and $S_A$ in figure 8 will shift to the right. But given a downward sloping demand curve $D_A$ the price $P_A$ producers now receive will decrease. This will decrease the demand for resources X. If the supply curve $S_X$ is very price sensitive, then the reduction in factor employment may be so large as to cause $S_A$ to shift to the left rather than to the right as supposed above.

If, however, $S_X$ is very price inelastic, i.e. $S_X$ in figure 8 is perpendicular to the X-axis, then factor employment X remains the same, even for a very large decrease in $P_X$. If then the resources used in agriculture remain the same, and if the production of $Q_B$ decreases, as is known for sure,

it must follow that the production of $Q_A$ must increase. $S_A$ in figure 8 shifts to the right.

Above narrative illustrates that we do not know a priori as to whether $S_A$ will shift to the right or the left. The mathematical analysis in section 15.2 showed that this depends on the sign of $(\sigma^* + e_X)$. This crucially important condition is impossible to detect by graphical and numerical techniques. It is for that reason that mathematical analysis must take precedence over these other techniques.

15.5 Consumer's surplus and producer's surplus

In sections 15.1 and 15.2, we calculated the incidence of the tax in terms of changes in factor utilization, production, prices, commodity and factor incomes. Other concepts, such as tax revenue collected and foreign exchange earned, are also reasily calculated. In section 15.2, we found that producers suffered a loss of income $(\Delta P_X X)$ because of falling commodity prices, that consumers abroad suffered a loss of real income $[(\Delta P^*_B)\cdot Q_B]$ due to an increase in the price of that country's imports, that domestic consumers registered an increase in real income $[(\Delta P_A)\cdot Q_A]$ due to a decrease in the price of food, that the economy suffered a loss in foreign exchange equal to the difference in export revenue before and after taxes because of a price elastic demand for exports, and finally that the public sector gained a substantial amount of tax revenue.

Given these changes, we must now inquire as to the desirability of the tax, this because the tax involves a wide variety of monetary gains and losses. An export tax presumably is desirable if the sum of the gains are larger than the sum of the losses. But should such monetary gains and losses be summed forthwith? If so, we assume that the country that imposes the tax values the loss of one dollar real income of foreign consumers of exports at a par with

the gain in one dollar of real income of domestic consumers of food. Most governments, however, could put a zero social price on losses inflicted on consumers abroad. More generally, the public sector should provide planners with social accounting prices such that the real income effects $[(\Delta P_B^*)\cdot Q_B]$ and $[(\Delta P_A)\cdot Q_A]$ can be added.

Simple summation of gains and losses is also questionable when considering the domestic redistributive incidence of the export tax. Is one dollar gain in real income by (urban) consumers equal to a one dollar loss in income by (rural) producers? Agricultural policies in IICA countries show that this is not so, i.e. a dollar gain in real income by urban consumers is valued higher than a one dollar loss in income by producers. If producers are equated with workers in urban areas, then above discrepancy in weights becomes understandable from a historical and political perspective. But what are the appropriate weights if producers are small farmers and as such consume a significant proportion of their own production?

Finaly, assume the tax revenue collected is used to expand a burgeoning bureaucracy while the foreign exchange lost would have resulted in an expansion of investment. Should we assume under these circumstances that one dollar of tax revenue gained equals one dollar of foreign exchange lost?

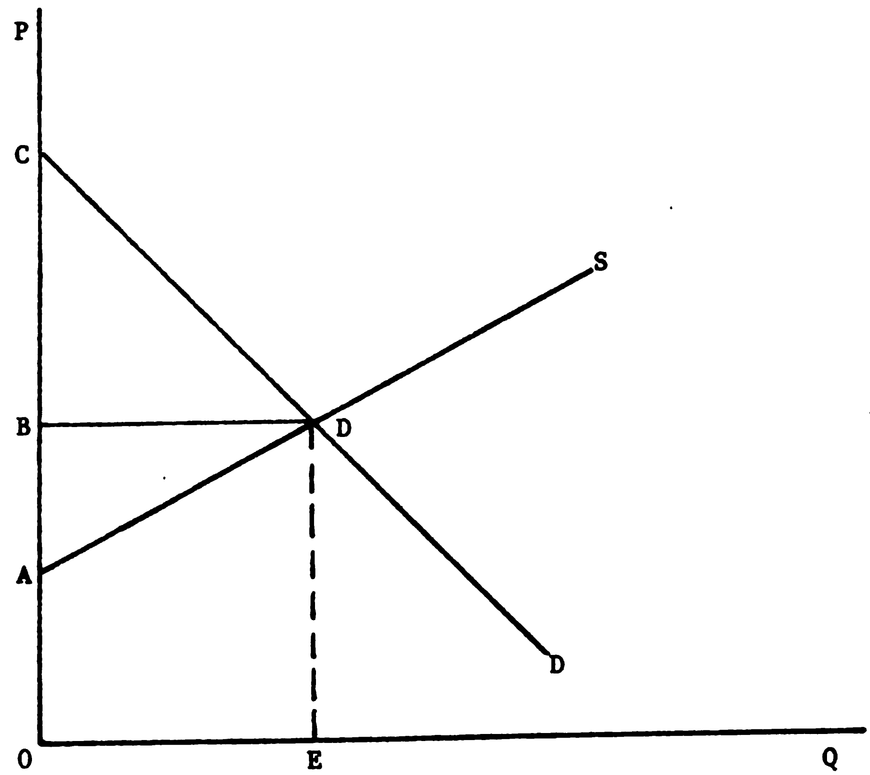
In section 1, we emphasized the need for guidelines to be used in the social valuation of these changes. For this we need to have access to social accounting prices. They can be provided directly by decision makers or derived indirectly by planning technicians in the form of a comprehensive scheme of social accounting prices. Let us assume that such guidelines are not forthcoming. Under these circumstances we may adopt the assumption that market prices are the equivalent of social accounting prices. We therefore dispose of

the means to effect social evaluation of the economic changes brought about by the export tax.

Accepting market prices as measures of social value does not imply that the desirability of the tax is established by the simple summation of monetary gains and losses. This because prices are the social values to be put upon quantities evaluated at the margin. The value to be put upon intramarginal units or quantities is generally different from the value to be put on quantities at the margin. This possibility suggests the use of consumer's and producer's surplus as comprehensive measures of economic welfare [4, 30, 31, 53]. In figure 9, we have drawn a conventional demand-supply diagram for a commodity Q. The prevailing market price is DE. Under our assumptions, this price measures the social value of the marginal quantity of Q consumed at point E. Intramarginal quantities, however, must be evaluated at a higher price. For example, the first unit of Q consumed at point 0 should be valued at a price equal to the distance OC. It follows that the trapezoid OCDE measures the social value of the quantity OE in consumption.

In order to produce OE, we must incur a cost. The supply curve S indicates the marginal social cost of producing successive units of Q. In equilibrium, i.e. at point E, the marginal social cost of production DE equals the price consumers pay for Q. But for intramarginal units the marginal social cost of production will be less than the equilibrium market price. For example, the first unit of Q is produced at a marginal social cost OA. Consequently, the social cost of producing a quantity equal to the distance OE is measured by the trapezoid OADE. Society produces the quantity OE, because it gains by doing so. The net social gain is the difference between what consumers gain and what has to be sacrificed in order to make that gain possible. The net social gain is measured by the difference between trapezoid

Figure 9: Consumer's surplus and producer's surplus



OCDE and OADE, but this difference equals the triangle ACD. That triangle also indicates the distribution of the net social benefit. Producers receive a price DE, and consumers pay that same price. The consumer's gain on the first unit of Q purchased at point O equals (OC-BD) or BC. The consumer's gain on the marginal unit of Q purchased at point E equals (DE-DE), i.e. it equals zero. Intramarginal consumer's gains are represented by the triangle BCD. Using analagous reasoning, it can be shown that ABD equals the representative producer's gains.

The distribution of the gains is affected by the slopes (or price elasticities) of the demand and supply curves. If the supply curve S becomes more price elastic, it will rotate clockwise. The triangle ABD becomes smaller without affecting the triangle CBD. Consequently, a relatively price elastic supply curve skews the distribution of the net social benefit in favor of consumers. A counter-clockwise rotation of the demand curve D shows that a more price elsatic demand skews the distribution of the net social benefit in favor of producers. The triangle BCD is called consumer's surplus. The triangle ABD is called producer's surplus.

15.6 Admissible and inadmissible welfare measures

A reading of the previous section gives the impression that consumer's surplus and producer's surplus are easily applied concepts. That is not so. The validity of consumer's surplus as a welfare measure remains a controversial matter. [45, pp. 350-366]. Even its advocates [4, 27, 42, 57] admit that it can be used only if the demand curve D in figure 9 has the special property that along this curve real income is held constant. The demand curve $D_A$ in figure 9 was drawn under the assumption that money income remained constant. A downward movement along that curve decreases $P_A$ and therefore increases real income. In order that real income be constant along a

demand curve, we must have compensating variations in money income. Transformation of Slutsky's equation (45, p. 240-246) into elasticity form yields

30) $e^M_{q_A} = e^U_{q_A} - S_A E^M_A$

where

$e^M_{q_A}$ = the price elasticity of demand for $Q_A$ with money income held constant

$e^U_{q_A}$ = the price elasticity of demand for $Q_A$ with real income (or "utility") held constant

$E^M_A$ = the income elasticity for $Q_A$

$S_A$ = the share of consumer's income M spent on $Q_A$

Statistical investigation of consumer's expenditure behavior typically yield estimates of the first, third and fourth parameters listed above. Using 30 we can easily calculate the price elasticity of demand for $Q_A$ with real income held constant. If either $S_A$ or $E^M_A$ is small, the difference between the uncompensated and compensated price elasticity will be small. In our model $Q_A$ represents "food". Consequently, neither $S_E$ or $E_A$ will be small, and 30 must be used to calculate a compensated price elasticity of demand. Given this, we advocate the use of consumer's surplus in calculating the welfare implications of the export tax.

We do not recommend the use of producer's surplus, because the area to the left of the supply curves $S_A$ and $S_B$ in figures 8 and 9 do not represent producer's surplus. The arguments against using producer's surplus were developed in a previous paper [53]. Factor rents exist, because factor units are heterogeneous to users or suppliers [44]. The use of a single representative production function in the first sector of this paper implicitly assumes

that the factor is homogeneous to the firms in the industry. On account of this, there can be no rents accruing to the industry.

If we assume the factor to be heterogeneous in use to firms outside the industry, then the factor supply curve would rise, and the industry would earn rents [39]. Also, if the factor is heterogeneous in use to the suppliers of that factor, then the factor supply curve will rise. The area to the left of the compensated factor supply curve then measures rents. The industry would earn quasi-rents if all factors can be assumed to be economically immobile, i.e. if the factor supply elasticity equals zero. This assumption underlines much of incidence analysis in a general equilibrium setting. Finally, the factor supply curve of a homogeneous factor will also rise if that factor is scarce to the economy, but the area to the left of such a curve does not measure rents to the industry in which it is employed. In this paper, we emphasize the scarcity, rather than the heterogeneity, of the composite factor X. Because of this, the area to the left of the factor supply curve carries no significance for economic welfare.

The area to the left of the food supply curve in figure 8 cannot be interpreted as producer's surplus, because along that supply curve the price of exports and factor supplies are variables. There is a different marginal cost curve for each point on this equilibrium adjusted supply curve (53, p. 41). Only if $e_{q_B} = \infty$ and $e_X = 0$ will the food supply curve represent a proper marginal cost curve. But the same argument applies pari passu to the area to the left of the export supply curve, where we must assume $e_{q_A} = \infty$. The resulting pooled set of assumptions is not of general interest. We must, therefore, dispense with the concept of producer's surplus in calculating the welfare incidence of an export tax.

## 15.7 First order and second order welfare effects

The shaded areas in figure 8 summarize the welfare incidence of an agricutural export tax. In the upper diagram we assume $(\sigma^* + e_X) < 0$. Under this assumption, the price of food $P_A$ must decrease. Consumer's surplus of food increases by the shaded trapezoidal area $A_1$. Because food, by assumption, is neither exported or imported, all of $A_1$ will be appropriated domestically. Consumer's surplus in export production will decrease by the area $B_1$. If all of $Q_B$ is exported, as assumed, $B_1$ will be borne by consumer abroad. Agricultural income decreases by the sum of areas $X_1$ and $X_2$. Total tax revenue collected equals the sum of areas $B_1$ and $B_2$. Because no distortion of the marginality conditions occurs in the food and factor supply market, the dotted triangle in the export good market measures all of the tax induced efficiency loss in this model [16, p. 790].

In the following pages we develop the appropriate algebraic expressions for the changes in consumer's surplus for food $\Delta CS_A$, changes in consumer's surplus for exports $\Delta CS_B$, tax revenue collected TR, the change in agricultural income $\Delta(P_X X)$ and the efficiency loss $\Delta EL$. The increase in consumer's surplus $\Delta CS_A$ in figure 8 equals

30) $\Delta CS_A = (Q_A + 1/2\ \Delta Q_A)\Delta P_A$

From the definition of $e_{q_A}$, we have along the demand curve for food

31) $\Delta Q_A = e_{q_A} \cdot \frac{Q_A}{P_A} \cdot \Delta P_A$

By definition

32) $\Delta P_A = E_{P_A \cdot t}\ P_A \cdot t$

Substitution of 32 and 31 in 30 yields a money measure for $\Delta CS_A$ as a fraction of pre-tax income from food production.

33) $\Delta CS_A = [t \cdot E_{P_A \cdot t} + 1/2\ t^2 \cdot (E_{P_A \cdot t})^2] \cdot P_A Q_A$

The change in consumer's surplus $\Delta CS_A$ consists of a first order effect, i.e. the first term within square brackets, and a second order (or squared) effect, i.e. the second term within brackets. It follows that for small tax rates ($t < 1$) and a modest cross price effect ($E_{P_A} \cdot t < 1$) the second order effect will be quite small relative to the first order effect. Total tax revenue TR equals

34) $TR = (Q_B - \Delta Q_B)(P_B^* - P_B)$

By definition along the demand curve for the export good

35) $\Delta Q_B = e_{q_B} \cdot \frac{Q_B}{P_B^*} \cdot \Delta P_B^*$

The change $\Delta P_B^*$ in the f.o.b. price of the export good equals

36) $\Delta P_{B \cdot t}^* = E_{P_B^* \cdot t} \cdot P_B^* \cdot t$

Substitution of 35 and 36 in 39 yields tax revenue TR as a fraction of pre-tax income from export production

37) $TR = [t - t^2 \cdot e_{q_B} \cdot E_{P_B^* \cdot t}] P_B \cdot Q_B$

The loss in consumer's surplus borne by consumers of exports Q as a fraction of tax revenue equals

38) $\frac{\Delta CS_B}{TR} = \frac{(Q_B - \Delta Q_B) \cdot \Delta P_B^*}{(Q_B - \Delta Q_B)(P_B^* - P_B)}$

Recalling that $P_B = (1-t)P^*$ above expression simplifies to .

39) $\Delta CS_B = E_{P_B^* \cdot t} \cdot TR$

Substitution of 37 into 39 yields an expression for $\Delta CS_B$ similar to that for $\Delta CS_A$ in 34. The loss in factor income $\Delta(P_X X)$ consists of a compounded factor price and factor supply effect.

40) $\Delta(P_X X) = X \cdot \Delta P_X + P_X \cdot \Delta X + \Delta P_X \cdot \Delta X$

This loss as a fraction of pre-tax factor income equals

$$41)\quad \frac{\Delta(P_X X)}{P_X X} = p_X + x + p_X \cdot x$$

Substituting the factor supply function 5 into 41, we obtain

$$42)\quad \frac{\Delta(P_X X)}{P_X X} = (1 + e_X + e_X p_X) p_X$$

The proportional rate of change in the shadow price $P_X$ is given by 15. Hence,

$$43)\quad \Delta(P_X X) = [t\cdot(1+e_X)E_{P_X \cdot t} + t^2 \cdot e_X^2 (E_{P_X \cdot t})^2] \cdot P_X X$$

The efficiency loss $\Delta EL$ associated with the export tax equals

$$44)\quad \Delta EL = 1/2\ \Delta Q_B (P_B^* - P_B) = 1/2\ \Delta Q_B \cdot t \cdot P_B$$

Substituting 35 in 44 yields the efficiency loss as a fraction of pre-tax income from export production

$$45)\quad \Delta EL = (1/2 \cdot t^2 \cdot e_{q_B} \cdot E_{P_B^* \cdot t}) \cdot P_B^* Q_B$$

It will be observed that the efficiency loss $\Delta EL$ is a second order effect only. All other welfare measures consist of a first order and a second order effect.

Numerical values for above expressions are easily calculated. In the following paragraph we assume that the government imposes a ten percent ad valorem tax on exports $Q_B$. All of the required parameters have been discussed or derived in section 15.3. There we assumed $e_{q_A} = -.7$, $e_{q_B} = -1.5$, $\sigma^* = -1.0$, $e_X = .2$, $k_A = .7$, $k_B = .3$. We calculated $E_{P_A \cdot t} = -.147$, $E_{P_B \cdot t} = -.700$, $E_{P_B^* \cdot t} = .300$ and $E_{P_X \cdot t} = -.313$. Substitution of these parameters in 33, 38, 39, 43 and 45 can be used to calculate the incidence of the 10 percent ad valorem export tax in terms of an arbitrarily adopted common denominator agricultural income $P_X X$. In these calculations we distinguish between first order effects, i.e. terms in t, and second order effects, i.e. terms involving t . The results are presented in Table 4.

Table 4: The incidence of a 10 percent ad valorem export tax expressed as a fraction of pre-tax factor income $P_X X$.

| Measure | terms in t | terms in $t^2$ | total effect |
|---|---|---|---|
| $\Delta CS_A$ | +.0103 | -.0001 | +.0102 |
| $\Delta CS_B$ | -.0090 | -.0004 | -.0094 |
| $\Delta P_X X$ | -.0376 | -.0002 | -.0378 |
| TR | +.0300 | +.0014 | +.0314 |
| $\Delta EL$ | 0 | -.0023 | -.0023 |

A comparison of first order effects and second order effects for each measure shows that the second order effects are very small relative to the first order effects. This proposition will always be true for small changes in the tax rate t. If, however, a 200 percent ad valorem tax were to be imposed, then the second order effect (the term in $t^2$) may outweigh the first order effect (the term in t). The efficiency loss $\Delta EL$ in this example is very small as a proportion of agricultural income $P_X X$. Its absolute size of course depends on the magnitude of $P_X X$. Nevertheless, for small changes in tax rates, policy decision makers may well want to ignore efficiency losses.

## 15.8 Social benefit-cost analysis of a tax on agricultural exports

In section 15.6 we showed that for small ad valorem tax rates the second order effects are likely to be of negligible importance in the social valuation of the incidence of the tax. The remaining first order effects measure changes in real income. The change in real income of domestic consumers of food is measured by the first order term of $\Delta CS_A$. The change in real income of foreign consumers of this country's exports is measured by the first order term of $\Delta CS_B$. The change in real income of domestic producers is measured by the

first term of $\Delta(P_X X)$. The tax revenue collected is in first instance proportional to the value of agricultural exports prior to the imposition of the export tax. The appropriate algebraic expressions for these effects are very simple. They are derived from equations 33, 37, 39, and 43 by deleting terms in $t^2$. We then find

46) $\Delta CS_A = t \cdot k_A \cdot E_{P_A} \cdot t(P_X X)$

47) $\Delta CS_B = t \cdot k_B \cdot E_{P_B^*} t(P_X X)$

48) $\Delta P_X X = t(1+e_X) E_{P_X} t \cdot (P_X X)$

49) $TR = t \cdot k_B \cdot (P_X X)$

Let us assume that above four measures are the only relevant ones in evaluating the desirability of the export tax. Implicitly we assume, therefore, that the country's exchange rate is such that we are indifferent to a loss in foreign exchange earnings. Between above first order effects exists an approximate relationship

50) $TR \approx -[\Delta(P_X X) + \Delta CS_B + \Delta CS_A]$

The amount of revenue generated by the tax TR equals approximately the negative of the sum of the changes in factor income $(P_X X)$ and consumer's surpluses $CS_A$ and $CS_B$. From this follows that if those who gain because of the export tax (domestic consumers, the treasury) would compensate those who lose (consumers abroad, domestic producers), then the net social benefit associated with the imposition of this tax would be approximately zero. <u>There is then no apparent social justification for imposing the export tax!</u>

In above calculation we have simply added different money measures of economic welfare, i.e. we have assumed that all changes are to be weighted equally. If policy makers think in terms of national welfare rather than

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1/ Substitution of 46, 47, 48, 49 in 50 yields $-k_B = k_A E_{P_A} t + k_B E_{P_B^*} t + E_{P_X} t$ Substitution for the supply elasticities in this expression using 12, 13 and 15 proves the proposition for $\sigma^* = e_X = 0$. The equality holds approximately if $\sigma^* \to 0$, $e_X \to 0$.

global welfare, then the loss in income $\Delta CS_B$ suffered by consumers abroad would be assigned a zero weight. Assuming equal weights for the remaining measures, the net social benefit, as a fraction of pre-tax agricultural income now equals

51) $[\Delta CS_A + \Delta(P_X X) + TR] = .0027\ P_X X$

Imposition of the tax is socially advantageous, if domestically incurred income changes are all weighted equally. Equal weighting of income changes by policy makers in the exception rather than the rule. Export taxes in first instance are imposed to generate tax revenue and in second instance because they are thought to increase food production. The resulting decrease in agricultural income is rarely given much emphasis. If then the change in agricultural income $\Delta(P_X X)$ is to be given a zero weight, it follows that the net social benefit of the export tax now equals

54) $(\Delta CS_A + TR) = .0479\ P_X X$

Under these social accounting considerations the export tax is clearly socially advantageous. It is, of course, a simple matter to construct a counter-example which shows that an export tax is not socially advantageous. Concern about rural poverty, imbalance between rural and urban income levels and low productivity of public sector expenditures reflects itself close to zero weights for $\Delta CS_A$ and TR, with the effect that the export tax is no longer socially advantageous.

Agricultural statistics make reference to market prices, not social accounting prices. Nevertheless, equating the two is widely practiced by policy analysts. Under that assumption, as shown above, the net social benefit of any tax will be zero or close to zero when $\sigma^*$ and $e_X$ are close to zero. Under these circumstances the efficiency loss $\Delta EL$ becomes of major interest, i.e. with the factor employment distortions brought about by ill advised public sector policies, etc. The position taken here is that the policy analyst can

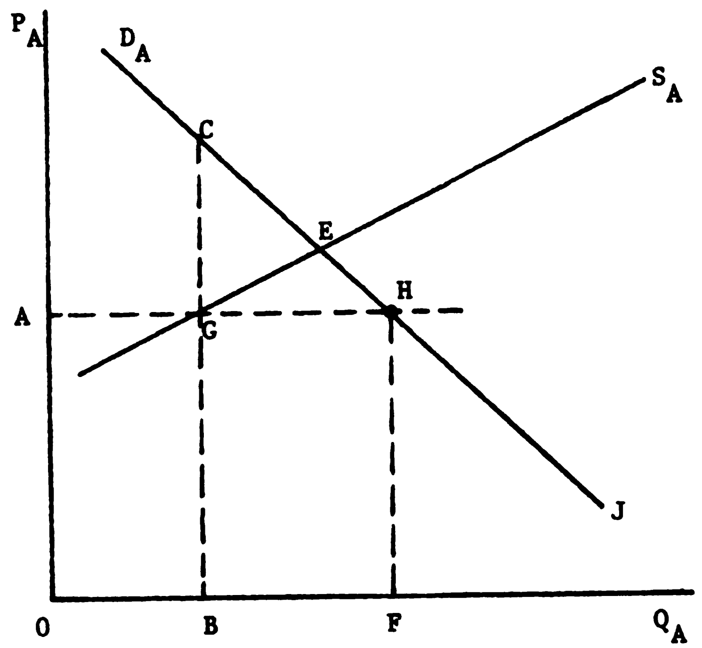
make a very significant contribution in explaining the incidence of an export tax to the policy decision makers. On the other hand, the policy analyst cannot take a strong position on the desirability of an export tax unless the political authorities provide him with sufficiently specific guidelines as to the social valuation of economic change.

15.9 Policy interdependence: much to do about nothing?

We argued in section 4 that the effect of a policy X on a chosen objective Y may be influenced by the existence of other policies or simultaneously occurring autonomous changes such as income and population growth. In what follows we will not analyze the incidence of pari passu changes in autonomous variables. Analytically they constitute shift variables added to the six structural equations of the model outlined at the beginning of section six. To study the incidence of such changes, we can avail ourselves of the same solution techniques as used for the study of tax incidence. It involves the solution of a system of simultaneous equations as in matrix equation 9.

A tax on agricultural exports must take into account the existence of other policies. We will focus on one obvious possibility, i.e. food price controls. We assume that such controls are effective. In the case of food price controls we may therefore take the price of food $P_A$ as a policy instrument. It follows that $P_A$ is no longer determined by the interaction of commodity and factor markets but that $P_A$ must be taken as a politically determined parameter. We must therefore modify our supply and demand diagram as in figure 10. Let OA be the controlled price $\overline{P}_A$ of food. This will result in an excess demand GH for food. Such an excess demand is not substainable, i.e. it must disappear. Since $\overline{P}_A$ is to remain constant, the government must

Figure 10: The demand and supply for food products with food price controls



must either import the excess demand GH or else it can resort to rationing domestic production AG. If consumers are allowed to resell among each other, the observed price actual consumers will pay equals BC. Rationing allows consumers who have a low priority for food to capture the consumer's surplus of those who assign a high priority of food.[1/]

Producers, however, always receive the legally stipulated price $\overline{P}_A$. At that price producers can sell a quantity AH.[2/] The effective demand curve facing the producers of food is kinked. It consists of the horizontal segment AH and the lower part HJ of the original demand curve for food $D_A$. With food price controls the demand for food is in effect infinitely price elastic, i.e. $e_{q_A} = -\infty$.

In order to calculate the incidence of a tax on exports, we must substitute this value for $e_{q_A}$ where appropriate. Substitution for $e_{q_A}$ in simplified the expression for the price elasticity of supply of $Q_B$ to[3/]

$$E_{Q_B \cdot P_B} = -k_A\sigma^* > 0$$

The determinant $\Delta_3$ of our system of structural equations in now appears as

$$\text{10B)} \quad \Delta_3 = -(e_{q_B} + k_A\sigma^*)e_{q_A} < 0$$

The incidence formulas related to product and factor prices are modified such that

$$\text{11B)} \quad E_{P_B \cdot t} = \frac{-e_{q_B}}{(e_{q_B} + k_A\sigma^*)} < 0$$

$$\text{12B)} \quad E_{P_B^* \cdot t} = \frac{(k_A\sigma^* - k_Be_X)}{(e_{q_B} + k_A\sigma^*)} > 0$$

---

1/ See section 14 for discussion on the incidence of food price controls.

2/ We assume a concomitant reduction in food imports should they exist.

3/ If $e_{q_A} = -\infty$, it will dominate all other finite parameters or combinations of parameters not containing $e_{q_A}$.

13B) $E_{P_A \cdot t} = 0$

15B) $E_{P_X \cdot t} = \dfrac{-k_B e_{q_B}}{(e_{q_B} + k_A \sigma^*)} < 0$

Using the numerical assumptions of section 15.3 we can calculate Table 5. A comparison of the two columns shows that the existence of food price controls does not drastically affect the major parameters that characterize the incidence of the tax. It follows that the welfare measures discussed in section 15.6 will also be relatively little affected, except for those terms involving $E_{P_A \cdot t}$. The export tax by assumption cannot affect the price of food, since it is fixed by the government. Consequently, the increase in consumer's surplus from food $\Delta CS_A$ is also zero. Farm income $\Delta(P_X X)$ will decline less than before. On the other hand, consumer's surplus $\Delta CS_B$ will be larger. Food price controls permit a relatively larger share of the export tax to be shifted abroad.

Above numerical example demonstrates that the interdependence of economic policies may not have to receive the attention planners think it should receive. Nevertheless, further numerical experimentation and analysis of other policies is required before we should arrive at a firmly held opinion in this matter.

15.10 Statistical estimation of the underlying parameters

In order to apply the model in this section we need to obtain estimates of five parameters.

1) The price elasticity of demand for agricultural exports, i.e. $e_{q_B}$.
2) The price elasticity of demand for crops grown concurrently with agricultural exports, i.e. $e_{q_A}$.
3) The price elasticity of supply of the factors of production used in producing $Q_A$ and $Q_B$, i.e. $e_X$.

Table 5: Supply and tax incidence elasticities with and without food price controls

| | $P_A$ free | $P_A$ controlled |
|---|---|---|
| $E_{Q_A \cdot P_A}$ | .381 | .381 |
| $E_{Q_B \cdot P_B}$ | .642 | .700 |
| $E_{P_B \cdot t}$ | -.700 | -.680 |
| $E_{P_B^* \cdot t}$ | .300 | .320 |
| $E_{P_A \cdot t}$ | -.147 | 0 |
| $E_{P_X \cdot t}$ | -.313 | -.205 |

4) The elasticity of commodity substitution between export crops and crops grown concurrently with it, i.e. $\sigma^*$.

5) The ratio between agricultural income derived from exports and crops grown concurrently for domestic consumption, i.e. $k_A/k_B$.

Time series on production and prices received can be used to establish the parameters $k_A$ and $k_B$. The estimation of the remaining four parameters is more difficult. Before estimating the remaining parameters, it is advisable to execute a sensitivity analysis. The purpose of this is to detect as to whether one or more parameters dominate the numerical results obtained. In section 13.9 we observed that the price elasticity of demand $e_{q_A}$ of crops grown concurrently with exports did not materially affect the welfare incidence of the tax. Given this, proportionately little effort should be spent on estimating such a parameter.

Price elasticities of demand for crops grown concurrently with export crops are usually unavailable. Assume, however, as is often true, that human consumption accounts for a very large share of domestic disappearance. Given the availability of a household expenditure survey, the income elasticity (expressed in primary product equivalent) for $Q_A$ and remaining expenditure items can be calculated [35]. Given certain a priori assumptions as to the underlying representative consumer's utility function, the same information can be used to derive a complete scheme of direct and cross price elasticities [5, 36], from which we can derive an estimate of $e_{q_A}$.

The price elasticity of demand for agricultural exports, such as sugar, coffee, bananas, etc., has been studied extensively [14]. The price elasticity of demand for a single country is influenced by its share in world-wide exports of that commodity. Adjustments for this can be made, resulting in a provisional estimate of $e_{q_B}$.

No studies are available on the expected value of the elasticity of commodity substitution. It must, therefore, be estimated ab initio. The coefficient $\sigma^*$ can be estimated statistically on basis of the indices of production $Q_A$, $Q_B$ and their corresponding price indices $P_A$, $P_B$. Let $Y = (Q_B/Q_A)$, and $Z = (P_A/P_B)$, then estimate by the method of ordinary least squares[1/] $Y = a + bZ$ where a is the intercept and b the slope of the inverse line in figure 11. Then calculate $\sigma^*$ for the expected ratios $(Q_B/Q_A)$, $(P_A/P_B)$ to prevail at the time (or year) the export tax is to be applied. Observe that $\sigma^*$ is not a constant, i.e. it can vary over time. We previously observed that typically variations in Z are much larger than the variations in Y. We therefore expect the slope coefficient b of the regression line $Y = a + bZ$ to be quite small. Because of this, the estimated value of $\sigma^*$ may well be close to zero.

The price elasticity of factor supply $e_X$, as a first approximation, can also be estimated by the O.L.S. method. The supply curve to be estimated takes the following form:

$$P_X = c + dX$$

where c may be the positive or negative intercept of $S_X$ in figure 1, and where d is the positive slope of that supply curve. Given estimates for c and d, we calculate $e_X$ as follows:

$$e_X = {}^{\Delta X}/{\Delta P_X} \cdot {}^{P_X}/X$$

$$e_X = 1/d \cdot {}^{P_X}/X$$

where the ratio $(P_X/X)$ must be chosen so as to correspond to the situation prevailing at the time the export tax is to be applied. The problem with above procedure is that reliable data on factor prices $(P_X)$ and factor employment

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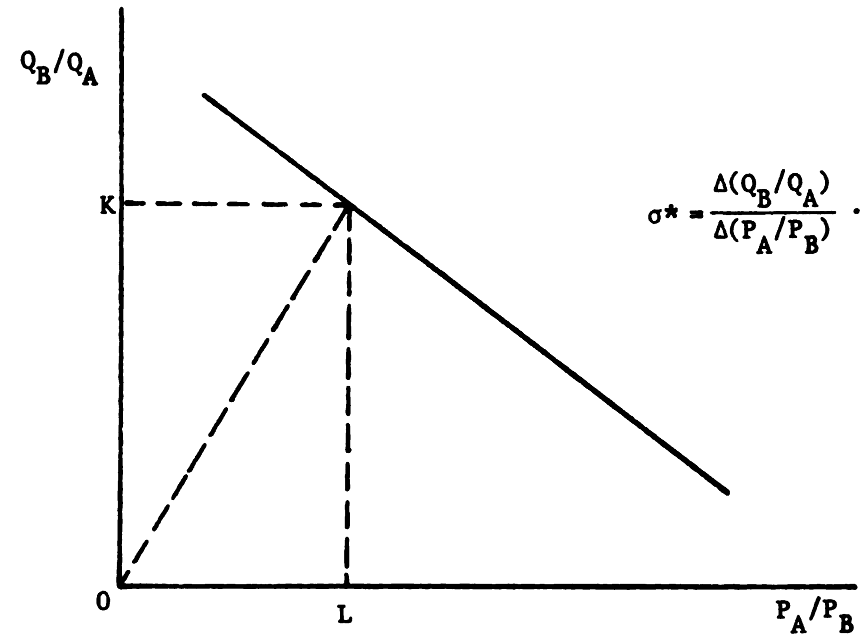
[1/] For details on the use of the ordinary least squares method, the reader may consult the module on statistical estimation by Kenneth McCormick in this series.

Figure 11: The elasticity of commodity substitution σ*




$$\sigma^* = \frac{\Delta(Q_B/Q_A)}{\Delta(P_A/P_B)} \cdot \frac{(P_A/P_B)}{(Q_B/Q_B)}$$

(X) are rarely available. We previously observed that

$$P_X X = P_A Q_A + P_B Q_B$$

Consequently, an index of agricultural income ($P_X X$) is available. If we were to have a reliable index for aggregate factor employment X, then we can derive a reliable index of factor prices $P_X$ by dividing $P_X X$ by X. The problem then is to construct either a reliable index of factor prices $P_X$ or of factor employment X. Assume that the factors of production employed in the production of $Q_A$ and $Q_B$ can be classified into two categories: owned resources ($X_0$) and purchased resources ($X_p$). For any single period we then have the following accounting identity:

$$P_X \equiv P_{X_p} \cdot X_p + P_{X_0} \cdot X_0$$

Partial information is usually available on the price farmers pay for purchased inputs like seed, chemicals, labor, interest rates paid on short term credit, etc. A lesser amount of information will be available on the quantum of purchased inputs, particularly labor and credit. Disaggregation by subsectors is rarely available even when reliable estimates are available on the sector's total use of seed and chemicals. Annual statistics on the use of an owned resource like land are available, but statistics on owner-employment of labor in agriculture are not available. Nor do we have information about the renumeration these resources earn in agriculture.

From this follows that the construction of a time series representing the right hand side in above equation must of necessity involve a great deal of guess work. Once such a right hand side has been completed, we can construct either an index of factor prices $P_X$ or a quantum index X of resources used. However, errors made in constructing $P_X$ automatically reflect themselves in errors in the quantum index X. The final result is that neither $P_X$ or X can be considered as very reliable. The ordinary least squares method may then have to be replaced by an estimating technique that allows for correlated errors in

the variables [24]. In the final analysis we will probably have to admit that no reliable estimate of $e_X$ can be obtained. Nevertheless, one should resist the temptation of setting $e_X$ arbitrarily equal to zero as is commonly practiced. This because different values of $e_X$ lead to substantially different results as to the incidence of the export tax.

In the foregoing pages we have suggested that the four critical parameters $e_{q_A}$, $e_{q_B}$, $\sigma^*$ and $e_X$ be estimated separately. Figure 1 indicates that the prices and quantums of commodities and factors of production are determined simultaneously. This raises the questions as to whether one could or should estimate all parameters simultaneously. The answer to both questions is in the affirmative. We nevertheless do not pursue that possibility here. The interested reader may consult texts on econometric methods, such as 24.

## 16. The incidence of technological progress

### 16.1 What is technological progress?

Much of agricultural policy is concerned with measures that affect the improvement or preservation of the quality of agriculture-related outputs, inputs and services. Such measures are thought to bring about technological progress in agriculture. Prior to measuring the changes induced by technological progress, the analyst must be aware of the following aspects.

1. Description: what does technological progress change in first instance
    - 1.1 technological progress changes the marginal physical products of one or more resources
        - 1.1.1 at some initial point of equilibrium [Hicks]
        - 1.1.2 such that the marginal product of that resource increases by a constant amount for all levels of that input [Ricardo's improvement of the first kind]

1.1.3 such that the increase in the marginal product is proportional to the level of that input [Mill's improvement of the first kind]

1.2 technological progress increases the effective supply (or efficiency) of one or more resources [Harrod's factor augmentation]

1.3 technological progress changes the marginal resource requirements of one or more outputs

1.3.1 such that the marginal resource requirement decreases by a constant amount for all levels of that output [Ricardo's improvement of the second kind]

1.3.2 such that the marginal resource requirement decreases proportionately to the level of that output [Mill's improvement of the second kind]

1.4 technological progress changes the elasticity of factor substitution

1.5 technological progress changes the elasticity of product substitution in case of joint production

1.6 technological progress changes the elasticities of production

2. The production function

2.1 the production function is homogeneous of degree one with all resources measured in natural units [Hicks]

2.2 the production function is homogeneous of degree one with all resources measured in efficiency units

2.3 the production function is homogeneous of degree one with labor measured in efficiency units and capital measured in natural units [Harrod].

2.4 the production function is non-homogeneous in capital, labor and land [Ricardo, Mill]

3. Incidence

Depends on the specification of the environment, i.e., the model. Two pairs of relevant dimensions are static vs. dynamic; partial equilibrium vs. general equilibrium. The incidence of a given type of technological progress [1.1 through 1.6] is very different between the type of model chosen. The standard matching in the literature is as follows

| model | static | dynamic |
|---|---|---|
| partial equilibrium | Hicks | |
| general equilibrium | Hicks | Ricardo, Mill, Harrod |

Definitions 1.4, 1.5 and 1.6 are not systematically explored in the literature.

4. Neutrality

Technological progress of a specified type, given a specified model, may leave certain key performance variables or ratios thereof unchanged. Hicks' neutral technological progress for constant factor prices will leave the functional distribution of income unchanged. Harrod neutral technological progress, given the one sector neoclassical growth model, will leave the real rate of interest and the capital-output ratio unchanged.

5. Continuity

In static models one typically analyzes technological progress as a discrete event. In dynamic models technological progress typically is assumed to be continuous, e.g., the effective supply of a constant amount of labor increases at a constant exponential rate.

6. Endogeneity vs. exogeneity

Technological progress may be assumed to occur as an exogenous phenomenon or as an endogenously determined process. In the latter case it may be price guided or linked to the allocation of resources provided for the generation of technological progress.

7. Embodiment

Technological progress is said to be disembodied if it affects all units of a given resource equally, i.e., independent of the time when such units first came into use. Technological progress is said to be embodied if it affects only those units of a given resource which come newly into use.

8. Fundamental problem

Research and innovation are not aimed directly at those concepts which are most tractable for the purposes of economic analysis, e.g., we do not know a priori how improved seed will change the marginal productivity of labor and other resources. As to whether technical progress was of type 1.1 - 1.6 must be deduced from observed incidence.

But one set of data may be consistent with more than one model, and one model may be consistent with more than one type of technological process. Observations, therefore, may be used to disprove an assumed hypothesis as to the type of technological progress that took place. It cannot in general prove that technological progress was of a certain type.

16.2 Hicksian disembodied technological progress

1. The production function is homogeneous of degree one with all resources measured in natural units.

2. Technological progress is disembodied.

3. Technological progress changes the marginal physical products of one or more resources at some initial point of equilibrium.

4. Technological progress is exogenous to the firm.

5. "Model": that of a firm in a competitive industry trying to minimize costs for a given output.

Assume that the firm produces output Q by means of two factors of production $X_1$ and $X_2$, where $Q = f(X_1, X_2)$ is homogeneous of degree one. Assume given factor prices $P_1$ and $P_2$ and a given product price P. For given output $\overline{Q}$, costs will be minimized if

$$1)\quad P \cdot f_1 = P_1$$

$$2)\quad P \cdot f_2 = P_2$$

Or in terms of proportionate rates of growth

$$3)\quad p_1 = \frac{\Delta f_1}{f_1} + p$$

$$4)\quad p_2 = \frac{\Delta f_2}{f_2} + p$$

Considering that the marginal physical product $f_1$ of the first factor of production is also a function of time, total differentiation yields

$$5)\quad \Delta f_1 = f_{11} \cdot dX_1 + f_{12}\, dX_2 + f_{1t} \cdot dt$$

Division by $f_1$ yields

$$6)\quad \frac{\Delta f_1}{f_1} = \frac{f_{11} \cdot X_1}{f_1} \cdot x_1 + \frac{f_{12} \cdot X_2}{f_{11}} \cdot x_2 + \frac{f_{1t}}{f_1} \cdot dt$$

where $r_1$ is the percentage increase in the marginal physical product of the first factor due to technological progress during a specified interval of time

$$7)\quad r_1 = \frac{f_{1t}}{f_1}\,dt$$

For a linear homogeneous function

$$8)\quad X_1 \cdot f_{11} + X_2 \cdot f_{12} = 0$$

$$9)\quad X_1 \cdot f_{21} + X_2 \cdot f_{22} = 0$$

Substitution for $f_{11}$ in 6 yields

$$10)\quad \frac{\Delta f_1}{f_1} = -\frac{f_{12}X_2}{f_1} \cdot x_1 + \frac{f_{12}X_2}{f_1} \cdot x_2 + r_1$$

We previously defined the elasticity of substitution $\sigma$ as

$$11)\quad \sigma = \frac{f_1 \cdot f_2}{Q \cdot f_{12}}$$

Substitution of $\sigma$ in 10 yields

$$12)\quad \frac{\Delta f_1}{f_1} = (x_2 - x_1)\frac{k_2}{\sigma} + r_1$$

It also can be shown that

$$13)\quad \frac{\Delta f_2}{f_2} = (x_1 - x_2)\frac{k_1}{\sigma} + r_2$$

If the production function is homogeneous of degree one, then

$$14)\quad P \cdot Q = P_1X_1 + P_2X_2$$

Taking log-differentials, we have

15) $p + q = k_1[p_1 + x_1] + k_2[p_2 + x_2]$

Because $k_1 + k_2 = 1$, we can rewrite above expression

16) $q = k_1[(p_1 - p) + x_1] + k_2[(p_2 - p) + x_2]$

From 3 and 4 follows that we can substitute for $(p_1 - p)$ and $(p_2 - p)$ using 12 and 13, which yields

17) $q = k_1[x_1 + r_1] + k_2[x_2 + r_2]$

Substituting 12 and 13 into 3 and 4 and retaining 17, we obtain the following matrix equation

17)

| $x_1$ | $x_2$ | $p$ | $p_1$ | $p_2$ | $q$ | $r_1$ | $r_2$ |
|---|---|---|---|---|---|---|---|
| $k_1/\sigma$ | $-k_1/\sigma$ | +1 | 0 | 1 | 0 | 0 | -1 |
| $-k_2/\sigma$ | $k_2/\sigma$ | +1 | 1 | 0 | 0 | -1 | 0 |
| $k_1$ | $k_2$ | 0 | 0 | 0 | 1 | $-k_1$ | $-k_2$ |

The solutions of this equation are tabulated in Table 5. The coefficients to the left of the dotted line are identical to the coefficients of derived factor demand determined earlier in this manual.

Table 6. The Impact of Hicksian Technological Progress on Factor Employment and Cost of Production

| | $p_1$ | $p_2$ | $q$ | $r_1$ | $r_2$ |
|---|---|---|---|---|---|
| $x_1$ | $-k_2\sigma$ | $k_2\sigma$ | 1 | $-k_1+k_2\sigma$ | $-k_2\sigma-k_2$ |
| $x_2$ | $k_1\sigma$ | $-k_1\sigma$ | 1 | $-k_1-k_1\sigma$ | $k_1\sigma-k_2$ |
| $p$ | $k_1$ | $k_2$ | 0 | $-k_1$ | $-k_2$ |

Technological progress is said to be $X_1$ saving (and $X_2$ using) if for constant factor prices ($p_1 = p_2 = 0$) and constant output ($q = 0$), the $X_1/X_2$ ratio decreases, i.e. if $(x_1 - x_2) < 0$. From Table 6 we obtain for $p_1 = p_2 = q = 0$.

18) $(x_1 - x_2) = \sigma(r_1 - r_2)$

For an innovation to be $X_1$ saving the increase $r_1$ in the marginal physical product of that factor must be less than the increase $r_2$ in the marginal physical product of the remaining factor of production. If $X_1$ represents labor, and if $X_2$ represents capital, we may infer that a Hicks labor saving innovation increases the capital-labor ratio at prevailing factor prices.

Technological progress in either factor reduces the average (= marginal) cost of production proportional to the corresponding factor shares $k_1$ and $k_2$. Technological progress limited to a given factor for a given output will increase the employment of that factor relative to the remaining factor. However, the absolute employment of that factor will increase only if $(-k_1 + k_2\sigma) > 0$ if technological progress is restricted to the first factor, and $(-k_2 + k_1\sigma) > 0$ if restricted to the second factor. Employment of both factors for given output will decrease under technological progress if the elasticity of substitution equals zero. If technological progress occurs at equal rates for both factors, then the ratio of factor employments remains unchanged, and both factor employments will decrease at a rate equal to the common rate of technological progress.

When considering technological progress in the context of the economy, rather than the firm, it is natural to take the factor supplies $X_1$ and $X_2$ as given. Competition for these limited resources will then establish the factor prices $P_1$ and $P_2$. It is also natural to take the price of output as numéraire. Consequently, in Table 1, $p_1$, $p_2$ and q become endogenous variables, and $x_1$, $x_2$

and p become exogenous variables. Resolving matrix equation 17, we obtain Table 7.

Table 7. The incidence of Hicksian technological progress on factor prices and output

| | $x_1$ | $x_2$ | p | $r_1$ | $r_2$ |
|---|---|---|---|---|---|
| $p_1$ | $-k_2/\sigma$ | $k_2/\sigma$ | 1 | 1 | 0 |
| $p_2$ | $k_1/\sigma$ | $-k_1/\sigma$ | 1 | 0 | 1 |
| q | $k_1$ | $k_2$ | 0 | $k_1$ | $k_2$ |

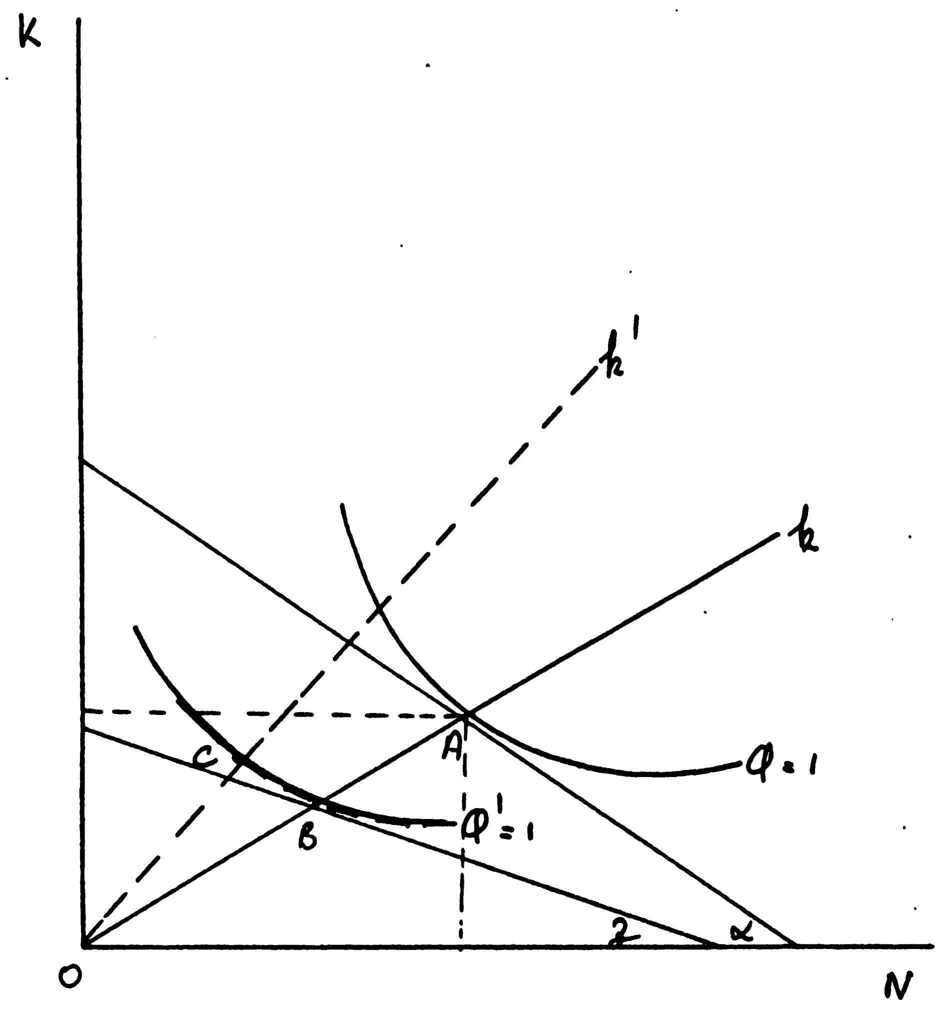
Technological progress is said to be $X_1$ saving if for a given $X_1/X_2$ ratio the price of the factor saved $X_1$ decreases relative to the price of the factor used $X_2$, i.e., if $(p_1 - p_2) < 0$. From Table 7, we have for $x_1 = x_2 = p = 0$.

19) $(p_1 - p_2) = (r_1 - r_2)$

As before, we find that for an innovation to be $X_1$ saving, the increase $r_1$ in the marginal product of that factor must be less than the increase $r_2$ in the marginal product of the remaining factor. If $X_1$ is labor and $X_2$ capital, then a labor-saving innovation will decrease the wage-rental ration $(P_1/P_2)$.

The foregoing is represented by Figure 12. The original unit isoquant is represented by Q = 1. With technological progress, we obtain a new unit isoquant Q' = 1. The original capital-labor ratio is given by the ray Ok. The initial wage-rental ratio is given by tg$\alpha$. Given technological progress, a constant capital-labor ratio k and cost minimization the economy will move from point A to point B. At point B the wage-rental ratio is less than at point A. The innovation is labor saving. Alternatively with technological progress, constant factor prices and cost minimization, the firm would move from point A to C. As a consequence, the capital-labor ratio increases from Ok to Ok'. The inno-

Figure 12: Labor saving technological progress



vation is labor saving. Should the innovation be Hicks neutral, then for given k tgz = tgα, or for given tgα, we would have Ok = Ok'.

Hicks [19 , p. 122] defines a labor saving invention as one that will diminish the relative share of labor. By definition

$$20)\qquad k_1 = f_1 \cdot \frac{X_1}{Q}$$

The proportionate rate of change in the relative share of the first factor, therefore, equals

$$21)\qquad \frac{\Delta k_1}{k_1} = \frac{\Delta f_1}{f_1} - \frac{\Delta(Q/X_1)}{(Q/X_1)}$$

or

$$22)\qquad \frac{\Delta k_1}{k_1} = r_1 - r$$

where r measures for constant $X_1$ and $X_2$ the proportionate rate of increase in average factor productivities. Consequently technological progress will be "$X_1$ saving" if $r_1 < r$, i.e., if the marginal productivity of $X_1$ increases by less than the average productivity of $X_1$.

Because of Euler's theorem we have at any moment of time

$$23)\qquad Q = X_1 f_1 + X_2 \cdot f_2$$

For constant $X_1$ and $X_2$ output Q can increase due to technological progress assumed to increase autonomously at a constant rate through time. Hence,

$$24)\qquad dQ = X_1 \cdot f_{1t} + X_2 f_{2t}$$

Therefore,

25) $q = k_1r_1 + k_2r_2$

But for given $X_1$ and $X_2$ the proportionate rate of increase in output Q also equals the proportionate rate of growth in average factor productivities $Q/X_1$ and $Q/X_2$. Hence,

26) $r = k_1r_1 + k_2r_2$

It follows that if technological progress is "$X_1$ saving" (i.e., $r_1 < r$) it must be "$X_2$ using" (i.e., $r_2 > r$). Defining the technological bias coefficients $z_1$, and $z_2$ as the proportionate rates of change in relative factor shares we have

27) $\Delta k_1/k_1 = z_1 = r_1 - r$

28) $\Delta k_2/k_2 = z_2 = r_2 - r$

we find on substitution

29) $k_1z_1 + k_2z_2 = 0$

For technological progress to be $X_1$ saving $z_1 < 0$ or $z_2 > 0$.[1/] Given $r_1$ and $r_2$ we find

30) $z_1 = k_2(r_1 - r_2)$

31) $z_2 = -k_1(r_1 - r_2)$

From this follows that "$X_1$ saving" technological progress increases the marginal product of $X_1$ less than the marginal product of $X_2$ [Hicks, 19,

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[1/] If $r_1 < 0$ then technological progress is very "$X_1$ saving." With economies of scale an invention can be "factor saving" with respect to all factors of production [Meade, 33, p. 23].

p. 122]. If $r_1 = r_2$ then $z_1 = z_2 = 0$, and technological progress is said to be Hicks neutral. Such technological progress leaves the factor ratio $X_1/X_2$ and the relative shares $k_1$, $k_2$ unchanged.

## 16.3 Hicks technological progress and the one product-two factor model of the competitive industry

To analyze the impact of technological progress for a competitive industry we must postulate commodity and factor prices as endogenously determined variables. For each of these variables we must introduce a new equation, i.e., commodity demand and factor supply equations.

32) $q = e_q \cdot p$

33) $x_1 = e_{X_1} \cdot p_1$

34) $x_2 = e_{X_2} \cdot p_2$

Substitution for $x_1$, $x_2$ and q in Table 5 yields the following matrix equation:

| | $p_1$ | $p_2$ | $p$ | $r_1$ | $r_2$ |
|---|---|---|---|---|---|
| | $(e_{X_1} + k_2\sigma)$ | $-k_2\sigma$ | $-e_q$ | $-k_1 + k_2\sigma$ | $-k_2 - k_2\sigma$ |
| 35) | $-k_1\sigma$ | $(e_{X_2} + k_1\sigma)$ | $-e_q$ | $-k_1 - k_1\sigma$ | $-k_2 + k_1\sigma$ |
| | $k_1$ | $k_2$ | $-1$ | $k_1$ | $k_2$ |

The determinant of the coefficients of the endogenous variables in 35 can be

36) $\Delta = (e_q - E_{QP})(k_1 e_{X_2} + k_2 e_{X_1} + \sigma) < 0$

or alternatively

$$37)\quad \Delta = (e_{X_2} - E_{X_2P_2})[-k_2(\sigma + e_q) + (e_q - e_{X_1})] < 0$$

$$38)\quad \Delta = (e_{X_1} - E_{X_1P_1})[-k_1(\sigma + e_q) + (e_q - e_{X_2})] < 0$$

Solving matrix equation 35 for p in terms of $r_1$ and $r_2$ we obtain by Cramer's rule

$$39)\quad E_{P} \cdot r_1 = \frac{k_1(1 + e_{X_1} \cdot E_{P_1P})}{e_q - E_{QP}} < 0$$

$$40)\quad E_{P} \cdot r_2 = \frac{k_2(1 + e_{X_2} \cdot E_{P_2P})}{e_q - E_{QP}} < 0$$

Hicksian technological progress lowers the equilibrium price P of output Q. It follows immediately that

$$41)\quad E_{Q} \cdot r_1 = e_q \cdot E_{P} \cdot r_1 > 0$$

$$42)\quad E_{P_1r_1} = \frac{-[E_{PP_1} + E_{X_1P_1}]}{e_{X_1} - E_{X_1P_1}} \gtrless 0$$

An increase in the marginal productivity of factor $X_1$ may shift the derived demand curve for $X_1$ such that its equilibrium adjusted employment and price increase. For this to happen $|E_{PP_1}| < |E_{X_1P_1}|$, or in terms of Cramer's determinantal equation, where $\Delta < 0$

$$43)\quad E_{P_1} \cdot r_1 = \frac{k_1(\sigma + e_{X_2})(1 + e_q) - k_2\sigma(e_{X_2} - e_q)}{\Delta} \gtrless 0$$

A sufficient condition for $E_{P_1} \cdot r_1$ to be positive is that $e_q < -1$, i.e., the demand for commodity Q must be price elastic. It can also be shown that

44) $$E_{P_1} \cdot r_2 = \frac{k_2(\sigma + e_{X_2})(1 + e_q) + k_2\sigma(e_{X_2} - e_q)}{\Delta} \gtrless 0$$

If $e_q > -1$ then an increase in the marginal productivity of the second factor will shift the derived demand curve for the first factor such that the equilibrium adjusted employment and price of the first factor decrease.

With neutral technological progress $r_1 = r_2 = r$. Hence

45) $$p_1 = (E_{P_1r_1} + E_{P_1r_2})r$$

The term in parentheses equals

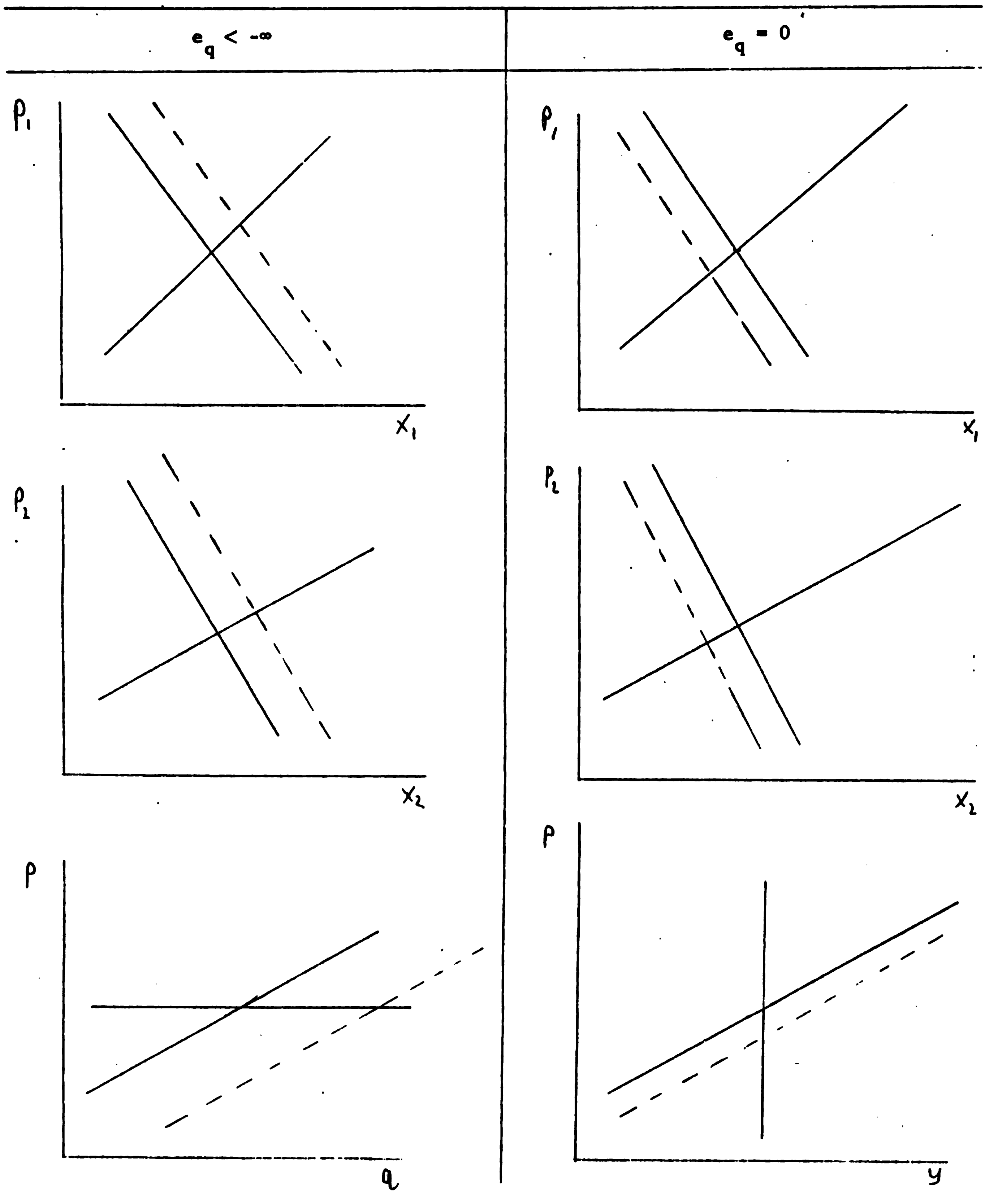
46) $$E_{P_1r_1} + E_{P_1r_2} = \frac{(\sigma + e_{X_2})(1 + e_q)}{\Delta}$$

Neutral technological progress will increase the factor employment and price of a given factor if the demand for the commodity is price elastic, i.e., $e_q < -1$. This conclusion also holds for biased technological progress provided both rates of factor augmentation are positive. In case of for example "very $X_1$ saving" technological progress we have $r_1 < 0 < r_2$, and in that case

47) $$p_1 = E_{P_1r_1} \cdot r_1 + E_{P_2r_2} \cdot r_2 \gtrless 0$$

From the foregoing follows that knowledge about the price elasticity of the demand for the industry's output is generally sufficient to arrive at an a priori qualitative conclusion about the impact of technological progress on factor employment and prices. The results for $e_q = -\infty$ and $e_q = 0$ are illustrated in figure 13. More precise estimates depend on the knowledge about the parameters discussed in this section.

Figure 13: The Impact of Factor Augmenting Technological Progress in Both Factors on the Equilibrium Values of the Competitive Industry One Output-Two Factors of Production Model



Given that the demand for the commodity is price inelastic (i.e., $e_q > -1$) then neutral technological progress will increase the price of the first factor relative to that of the second factor provided the elasticity of supply of the first factor is greater than the elasticity of supply of the second factor.[1/]

$$48)\quad (E_{P_1r_1} + E_{P_1r_2}) - (E_{P_2r_1} + E_{P_2r_2}) = \frac{(e_{X_2} - e_{X_1})(1 + e_q)}{\Delta} \gtrless 0$$

If the demand for the commodity is price elastic the opposite conditions as to factor supply elasticities must hold. With price inelastic factor supplies, such that $e_{X_2} = e_{X_1} = 0$ neutral technological progress will not affect relative factor prices.

For biased factor augmenting technological progress $r_1 \neq r_2$. The exponential rate of change in the factor price ratio $(P_1/P_2)$ then equals

$$49)\quad d\log(P_1/P_2) = E_{P_1r_1} \cdot r_1 + E_{P_1r_2} \cdot r_2 - E_{P_2r_1} \cdot r_1 - E_{P_2r_2} \cdot r_2$$

The sum of the first and third term in the above expression equals

$$50)\quad (E_{P_1r_1} - E_{P_2r_1}) \cdot r_1 = \frac{[k_1(1+e_q)(e_{X_2}-e_{X_1}) - \sigma(k_1e_{X_1}+k_2e_{X_2}-e_q)] \cdot r_1}{\Delta}$$

The sum of the second and fourth term in the above expression equals

$$51)\quad (E_{P_1r_2} - E_{P_2r_2}) \cdot r_2 = \frac{[k_2(1+e_q)(e_{X_2}-e_{X_1}) + \sigma(k_1e_{X_1}+k_2e_{X_2}-e_q)] \cdot r_2}{\Delta}$$

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[1/] See Finis Welch [56, p. 168] for a similar result.

For neutral technological progress $r_1 = r_2 = r$ we obtain the result in 48 We also obtain this result for biased technological progress if the elasticity of substitution equals zero, because $k_1r_1 + k_2r_2 = r$. With inelastic factor supplies such that $e_{X_2} = e_{X_1} = 0$ biased technological progress does not affect the factor price ratio.

The effects of technological progress on relative factor shares was previously established

52) $\Delta k_1/k_1 = \beta_1 = k_2(r_1 - r_2)$

53) $\Delta k_2/k_2 = \beta_2 = -k_1(r_1 - r_2)$

"$X_1$ saving" technological progress ($r_1 < r_2$) decreases the relative cost share $k_1$ of the first factor. The absolute factor cost of the first factor equals $P_1X_1$. Its proportionate rate of increase is $(1 + e_{X_1})P_1$. If $e_q > -1$ then the cost shares $P_1X_1$ and $P_2X_2$ will increase provided both $r_1$ and $r_2$ are positive. If commodity demand is price inelastic the opposite conclusion will tend to hold.

In the above paragraphs $X_1$ and $X_2$ have been considered as purchased factors. They may also be considered as factors provided or owned by the firm itself.1/ Given this one could assume the factor supply curves of the firm (and the industry) to be perfectly price inelastic, i.e., $e_{X_1} = e_{X_2} = 0$. We then obtain

$$E_{Pr_1} = \frac{k_1}{e_q} < 0$$

1/Or one factor may be owned or provided by the firm, with the other being purchased.

54) $$E_{Pr_2} = \frac{k_2}{e_q} < 0$$

55) $$E_{P_1r_1} = \frac{k_1 + e_q}{e_q} \gtrless 0$$

56) $$E_{P_1r_2} = \frac{k_2}{e_q} < 0$$

Neutral technological progress will increase output at a rate equal to the rate of technological progress. Factor prices will increase if $(1 + e_q)/e_q$ is greater than zero, i.e., if commodity demand is price elastic. Factor employments are constant because of the assumption $e_{X_1} = e_{X_2} = 0$.

16.4 The incidence of Hicks technological progress when some other things are held constant

In section 16.2 we derived the incidence of Hicks technological progress for the competitive firm, i.e. when factor prices and output were held constant. In section 16.3 we derived the incidence of Hicks technological progress when factor prices and output were variable so as to clear all factor and commodity markets. These are but two possible model configurations. What, for example, is the incidence of technological progress if the price of labor is controlled by the public sector? What is the incidence of technological progress if the price of a commodity is controlled by the public sector? What is the incidence of technological progress if the quantity employed of a factor of production is held constant or if output is rationed among producers? The answers to above questions involve the adaptation of the core model in section 16.3 so as to conform with the existing structure of policies in place. Analytically, some of the endogenous variables will then have to be specified as exogenous variables. Given the large number of possibilities, we do not pursue that

topic here. The reader is referred to (51, pp. 48-50) for a list of 39 of such possibilities.

One must expect, however, that the impact of technological progress is significantly different between model specifications. Consequently, the benefits and costs of programs that improve the quality or conservation of resources used in agricultural production will depend on the remaining package of policies in effect with respect to the agricultural sector.

17. Induced innovation and agricultural growth

Hayami and Ruttan[1/] calculated average land and labor productivities for 43 countries for 1950, 1960 and 1965. The results are plotted in Figure 14 Visual inspection of that figure reveals the following stylized facts:

1) In virtually all countries, output per hectare as well as output per worker increased simultaneously.
2) There are substantial differences between countries as to the absolute and percentage increase in output per hectare, or output per worker or both of these measures.
3) There is no evidence that LDCs have smaller percentage increases in output per hectare or output per worker than MCDs.
4) The pattern of growth between countries is very heterogeneous, some register a very substantial increase in yield per hectare with virtually no change in output per worker, the converse of this, or a situation which is intermediate between these extremes; i.e. the slope of the arrows is very different between countries.

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[1/] Yujiro Hayami and Vernon W. Ruttan, Agricultural Development: an international perspective, Johns Hopkins, Baltimore, 1971.

## Figure 14: Agricultural Productivity Gap among Countries

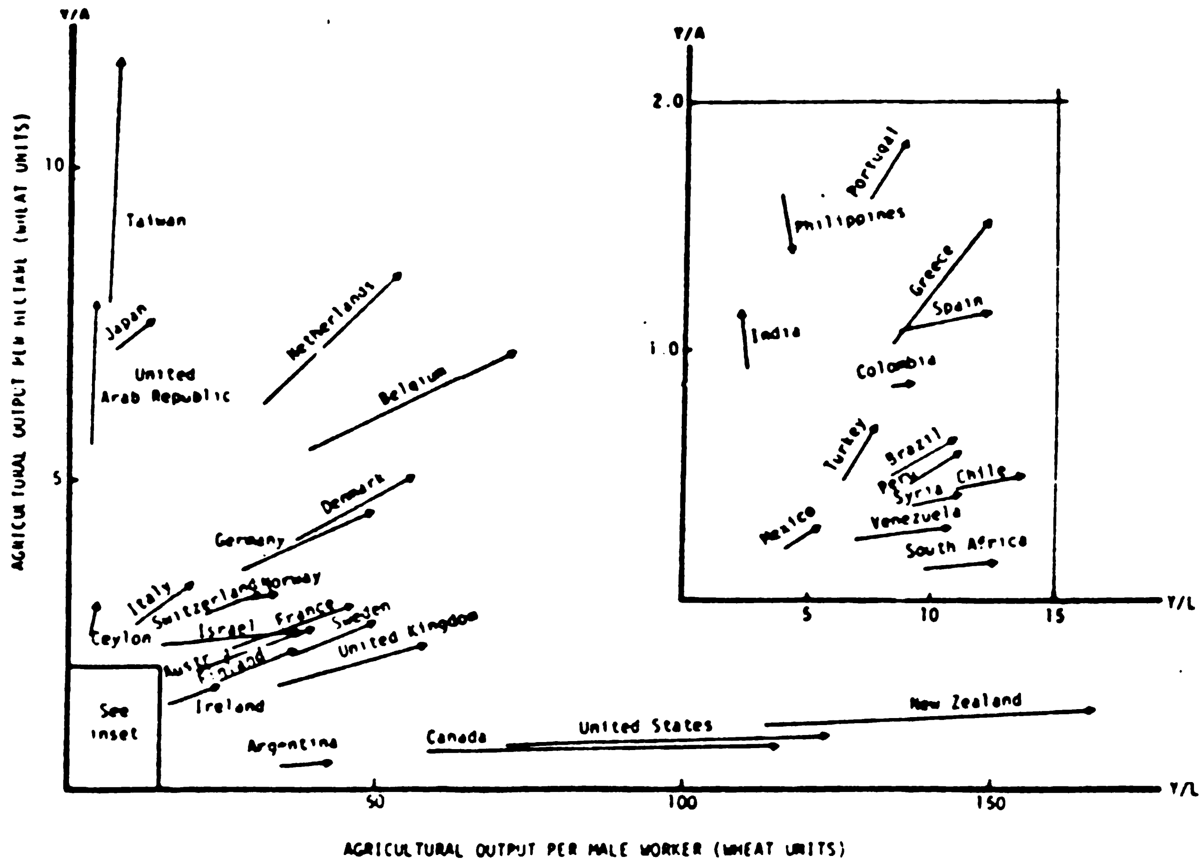


FIGURE 4-3. Intercountry cross-section comparison of changes in agricultural output per male worker and in output per hectare of agricultural land, 1955–65. (Data from Appendix Table A-5.)

5) The slope of the arrow for most countries is such as to yield a positive intercept. This indication that the land-labor ratio $(X_2/X_1)$ increases[1/] Hence, $(x_2 - x_1) > 0$. It follows that $(x_2 - q + q - x_1) > 0$, or $(q - x_1) - (q - x_2) > 0$. Consequently, the percent increase in output per man exceeds the percent increase in output her hectare.

6) The 1955 land-labor ratios are very high in countries such as Argentina, Canada and the U.S.. They are very low in Ceylon, Taiwan and Japan. MDCs do not necessarily have high land-labor ratios, nor do LDCs have necessarily low land-labor ratios.

Is it possible to explain this diversity of growth paths by means of a single core model? Is it possible, furthermore, to give a logical explanation for the almost universal increase in the land/labor ratio given the predominant opinion that agricultural research has been land saving $(r_1 > r_2)$, which would lead one to believe that the land-labor ratio should decrease, rather than increase according to the observed facts in Figure 14. It would also be interesting to establish the conditions under which the direction of the arrows in Figure 14 will be either preserved or changed, i.e. we would like to be able to make conditional predictions of the pattern of agricultural growth for individual countries.

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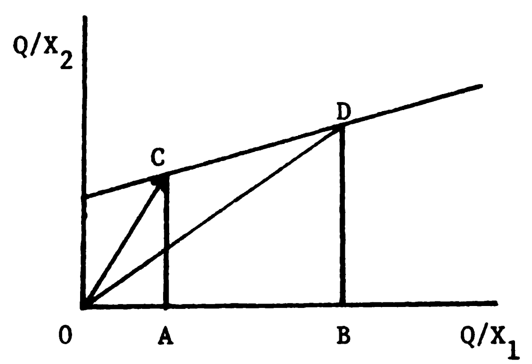
1/




tg COA = $X_1/X_2$

tg COA > tg DOB

$X_1/X_2$ decreases along CD

$X_2/X_1$ increases along CD

In the following pages, we make the assumption that technological progress in agriculture is of the Hicksian type. We assume that agriculture is a competitive industry, and that labor and land are the fundamental factors of production. New inputs or other innovations raise the marginal physical products of land and labor. We assume that agricultural production is not subject to economies of scale. Figure 15 draws the productivity function for an imaginary country A. Output per worker $Q/X_1$ almost doubled, but output per hectare increases by little. These changes were brought about by land deepening ($X_2/X_1$ increases) and technological progress. Technological progress has been Hicks labor saving, because for a constant land-labor ratio the wage rental ratio ($P_1/P_2$) declines. The following section offers an economic explanation for the movement of the agricultural sector from a point such as C to a point such as D.

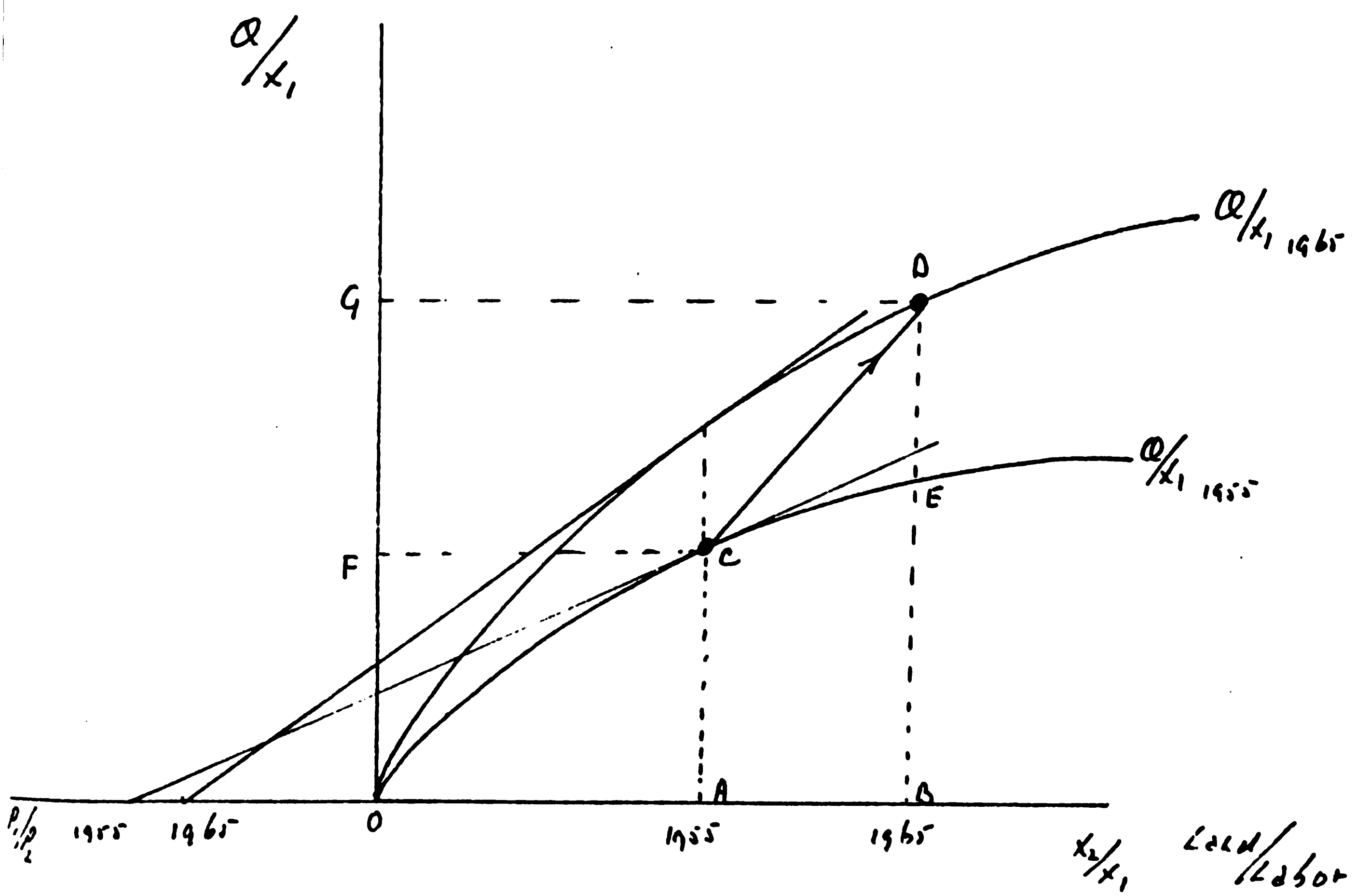
If we assume that $Q = Q(X_1, X_2)$ is homogeneous of degree one, with $X_1$ and $X_2$ measured in natural units, then technological progress must be of the Hicksian type. Given this, we can make use immediately of the factor demand and cost functions in Table 6 (section 16).

Table 6:

| | $x_1$ | $x_2$ | $p$ | $r_1$ | $r_2$ |
|---|---|---|---|---|---|
| $p_1$ | $-k_2/\sigma$ | $k_2/\sigma$ | 1 | 1 | 0 |
| $p_2$ | $k_1/\sigma$ | $-k_1/\sigma$ | 1 | 0 | 1 |
| $q$ | $k_1$ | $k_2$ | 0 | $k_1$ | $k_2$ |

The above classification of exogenous and endogenous variables is not necessarily valid at the sector level. In what follows, we will argue that $r_1$ and $r_2$ are endogenously determined. We also assume that agricultural labor is mobile between the agricultural and non-agricultural sector. Given this, there will tend to

Figure 15: The productivity function for country A



exist an equality of money wage ($p_1$) in agriculture and outside agriculture. We take $p_1$ as exogenously determined. We also assume that the demand for land equals the supply of land, and that the latter is exogenously determined. This assumption, however, is not justified for those countries with substantial areas of unused arable land which can be brought into production at virtually constant cost (e.g., Brazil and Nigeria). We assume the following simple demand function for agricultural output

1) $$q = e_q \cdot p + d$$

where d is a demand shifter related to population and income growth. Our model then consists of four structural equations. Substituting for q in Table 6, we obtain the following matrix equation.

| $p_2$ | $x_1$ | $p$ | $p_1$ | $x_2$ | $r_1$ | $r_2$ | $d$ |
|---|---|---|---|---|---|---|---|
| 0 | $+k_2/\sigma$ | -1 | -1 | $k_2/\sigma$ | 1 | 0 | 0 |
| 1 | $-k_1/\sigma$ | -1 | 0 | $-k_1/\sigma$ | 0 | 1 | 0 |
| 0 | $-k_1$ | $e_q$ | 0 | $k_2$ | $k_1$ | $k_2$ | -1 |

$$\Delta = \frac{-k_2 e_q + k_1 \sigma}{\sigma} > \sigma$$

The determinant Δ of the endogenous variables ($p_2$, $x_1$, $p$) is positive. Using Cramer's determinental equation, we can solve for $x_1$. Subtracting $x_2$, we obtain the rate of change in the labor/land ratio

2) $$(x_1 - x_2) = 1/\Delta\ [e_q \cdot p_1 - 1.x_2 - 1.d] - 1/\Delta\ [(e_q + k_1)r_1 + k_2 r_2]$$

For most countries, the real wage (in terms of industrial goods) has increased, i.e. $p_1 > 0$. Also, income and population growth have been such that $d > 0$. For most countries, the supply of land has remained the same or increased $x_2 \geq 0$. Given this, the sum of the terms within the first square bracket is negative. In the absence of technological progress, we would expect the land/labor ratio to

increase. Neutral technological progress ($r_1 = r_2$) will increase the land/labor ratio whenever the price elasticity of demand for food is inelastic, i.e. when $0 > e_q > -1$. Above considerations taken together imply that the normal pattern of agricultural growth is one where the land/labor ratio increases, i.e. an agriculture where farm units are likely to increase in size over time and one in which "population pressure on the land" decreases.

Nevertheless, the converse situation is possible. Prolonged economic depression may decrease real wages, the decline in income, population or loss of export markets may result in a leftward shift of the demand curve for food, and drought or floods may cause the supply of cultivated land to decline. A further possibility is that the bias of agricultural innovation is such as to encourage a relatively faster expansion in the demand for labor than for land.

The average increase in output per worker or hectare equals

3) $$r = k_1 r_1 + k_2 r_2$$

The bias B of Hicks technological progress is defined by the difference in the rates of increase of the marginal productivities of labor and land.

4) $$B = r_1 - r_2$$

Resolving above two equations simultaneously, we have

5) $$r_1 = 1.r + k_2 \cdot B$$

6) $$r_2 = 1.r - k_1 \cdot B.$$

Substitution in 2 yields

7) $$(x_1 - x_2) = 1/\Delta \; [e_q \cdot p_1 - 1.x_2 - 1.d - (e_q + 1)r - e_q \cdot k_2 B]$$

The first four terms within square brackets are normally negative. The remaining term is of indeterminate sign

8) $$-e_q \cdot k_2 \cdot B \gtrless 0$$

The above term will be negative for $B < 0$, i.e. for $r_1 < r_2$, i.e. for labor saving technological progress. For MDCs, for example, the U.S., technological

progress is often assumed to be labor saving. This by itself would tend to increase the land/labor ratio, a tendency reinforced by the increase in the wage rate ($p_1$), expansion of cultivated area ($x_1$) and increasing domestic or foreign demand (d). The Hicksian definition of labor saving technological progress, considered in the context of the firm,[1/] would lead to an increase in the land/labor ratio. In this instance, we observe that what happens at the firm level is also taking place at the sector level.

But such a correspondence does not necessarily exist. For LDCs, technological progress is often assumed to be a land saving (see the "Green Revolution" debate). In that case, $r_1 > r_2$, and the Hicks bias coefficient B is positive. The term in 8 is then positive. A study of equation 8 reveals that B would have to be extremely large if it is to outweigh the effect of the remaining negative terms. Consequently, even though technological progress is strongly land saving, we should still expect under most circumstances the land/labor ratio ($X_2/X_1$) to increase as in Figure 14.

Table 5 can be used to establish the movement in the wage-rental ratio ($P_1/P_2$). By subtraction, we find

9) $$(p_1 - p_2) = -1/\sigma\ (x_1 - x_2) + (r_1 - r_2)$$

Substituting for $(x_1 - x_2)$ using 101, we have

10) $$(p_1 - p_2) = {}^{-1}/\sigma\Delta\ [e_q p_1 - x_2 - d - (e_q + 1)r - k_1\sigma B]$$

Given neutral technological progress, the Hicks bias coefficient B equals zero. Given $p_1 \geq 0$; $x_2 \geq 0$; $d \geq 0$, it must follow that the wage-rental ratio will increase. This conclusion will also hold with land saving technological progress, because then $r_1 > r_2$, i.e. $B > 0$. However, with very strong labor saving technological bias, B may be sufficiently negative so as to dominate the remaining terms in 10. Under these circumstances, the wage-rental ratio may fall. Normally, however, one would expect the wage-rental ratio to increase over time.

Agricultural growth affects the functional income distribution of that sector. If $a = k_2/k_1$, then the equation of motion of the relative income shares is as follows.

11) $$\frac{\Delta a}{a} = (p_2 - p_1) + (x_2 - x_1)$$

Substitution for $(p_2 - p_1)$ yields

12) $$\frac{\Delta a}{a} = \frac{1-\sigma}{\sigma}(x_1 - x_2) - B \gtrless 0$$

The direction of change in the ratio of relative income shares is indeterminate. The variables influencing the outcome of this event are easily identified.

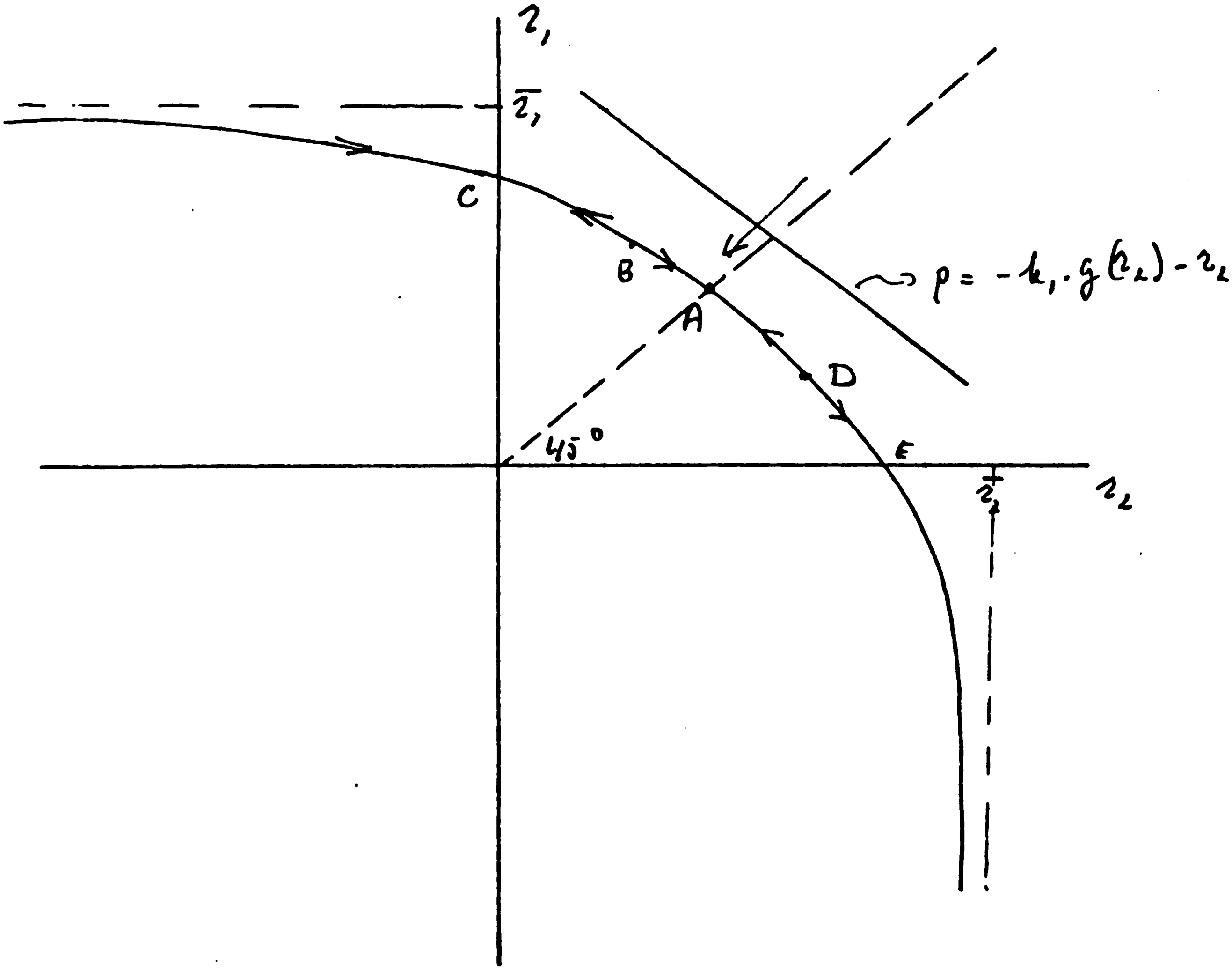
1) The factor elasticity of substitution
2) The behavior of the land/labor ratio
3) The bias of technological progress

Normally $(x_1 - x_2) < 0$, but no such normal assumption can be made as to $\sigma$ or B. Land saving technological progress (B > 0) by itself will decrease the relative income share $k_2$ of land. But this effect may be counter-compensated or reinforced given the size of $\sigma$. Only if $\sigma = 1$ will the bias of technological progress by itself determine the shift in relative income shares. A "Green Revolution", therefore, has no predetermined effect on the functional income distribution in agriculture in LDCs or MDCs.

We observed previously that both MDCs and LDCs have obtained large percentage increases in output per worker or output per hectare. We therefore believe that the "innovation possibility functions" of MDCs and LDCs may be similar, in the sense that the I.P.F.s of LDCs are not necessarily nested within those of the MDCs. Substantial percentage increases in the marginal product of labor are then equally possible in LDCs and MDCs. A similar argument would hold for potential percentage increases in the marginal physical product of land.

Figure 16 contains the innovation possibility function for country A. From a previous argument, we know that cost minimizing producers will select a particular $(r_1, r_2)$ innovation such that at that point the slope of the innovation possibility function equals the ratio a of relative income shares. A country such as the U.S. with presumably labor saving technological progress $(r_1 < r_2)$ would be located at a point such as D. For $\sigma = 1$, we then have $\Delta a > 0$, and technological progress will become increasingly labor saving; i.e. point D moves towards a point such as E. Conversely, for a country such as Taiwan, technological progress may be land saving $(r_1 > r_2)$ at a point such as B. For $\sigma = 1$, technological progress in Taiwan would then become increasingly land saving, i.e. point B moves towards a point such as C. If, however $\sigma \neq 1$, the direction of movement along the IPF no longer depends on the bias of technological progress alone. Given this, one would disavow the hypothesis that technological progress in MDCs will become (or is) increasingly labor saving, or that technological progress in LDCs will become (or is) increasingly land saving. Furthermore, there is no a priori evidence that the bias of technological progress should be considered as the main determinant of the increase in agricultural production or its distribution.

Figure 16: An innovation possibility function



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