International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

Technology, Environment, Agriculture

McCarthy, F.D.

IIASA Working Paper

WP-80-039

March 1980

TECHNOLOGY, ENVIRONMENT, AGRICULTURE

F. Desmond McCarthy

March 1980
WP-80-39

Presented at the FAP Task Force Meeting,
January 30 to February 1, 1980

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

This paper discusses some of the issues in the technology-environment-agriculture linkage. It indicates some of the measures which have been used to guide policy in this complex area and mentions some of the difficulties. A number of areas of research are identified which might be suitable for IIASA.

TECHNOLOGY, ENVIRONMENT, AGRICULTURE

F. Desmond McCarthy

INTRODUCTION

The study of change in various societies has attracted a wide spectrum of analysts. In certain situations socio-cultural influences exert a dominant role while in others economic forces play a critical role. The prospect that change may be modified or influenced to varying degrees by economic forces makes the subject particularly attractive to the economic analyst. In particular, the extent to which these forces may be affected by various policy measures is intriguing. In recent years the role of one of these forces, technical change, has triggered many studies. Much of this recent work was stimulated by studies of "Sources of Economic Growth" in the 1950's.

SOURCES OF ECONOMIC GROWTH

Robert Solow (1957) studied US data for the period 1909-1949. During this interval the average annual growth rate of G.N.P. was estimated at 2.9 per cent. He found that this was composed of 0.32 from capital accumulation, 1.09 from labor and 1.49 from technical progress. The magnitude of the latter contribution, about 80 per cent of per capita growth, generated considerable interest and led to further work in this area. One of the most exhaustive studies, due to Denison, seemed to corroborate Solow's findings. His decomposition of sources of growth are shown in Table 1. One notes that, of the national income per capita growth, about 33 per cent may be attributed to advances of knowledge, 13 per cent to improved allocation of resources, and 16 per cent to economics of scale. Thus, while some growth may be accompanied by depletion of resources, there are also sizeable gains to be obtained by improved productivity.

TABLE 1: *United States: Sources of Growth of Total National Income and National Income per Person Employed, 1950–62*

(Contributions to growth rate in percentage points)

Sources of growth	Total national income			National income per person employed		
	1950–62	1950–55	1955–62	1950–62	1950–55	1955–62
National income	**3.32**	**4.23**	**2.67**	**2.15**	**2.74**	**1.73**
Total factor input	**1.95**	**2.30**	**1.70**	**.79**	**.82**	**.77**
Labor	1.12	1.32	.97	.22	.19	.24
Employment	.90	1.13	.73	—	—	—
Hours of work	−.17	−.13	−.20	−.17	−.13	−.20
Age-sex composition	−.10	−.12	−.08	−.10	−.12	−.08
Education	.49	.44	.52	.49	.44	.52
Capital	.83	.98	.73	.60	.67	.55
Dwellings	.25	.26	.25	.21	.22	.21
International assets	.05	.03	.06	.04	.02	.05
Nonresidential structures and equipment	.43	.54	.35	.29	.34	.25
Inventories	.10	.15	.07	.06	.09	.04
Land	.00	.00	.00	−.03	−.04	−.02
Output per unit of input	**1.37**	**1.93**	**.97**	**1.36**	**1.92**	**.96**
Advances of knowledge	.76	.76	.76	.75	.75	.75
Improved allocation of resources						
Contraction of agricultural inputs	.25	.25	.24	.25	.25	.24
Contraction of nonagricultural self-employment	.04	.09	.01	.04	.09	.01
Reduction of international trade barriers	.00	.00	.00	.00	.00	.00
Economies of scale						
Growth of national market measured in U.S. prices	.30	.38	.24	.30	.38	.24
Independent growth of local markets	.06	.06	.06	.06	.06	.06
Irregularities in pressure of demand*	−.04	.39	−.34	−.04	.39	−.34
Adjusted Growth Rates						
National income	3.36	3.84	3.01	2.19	2.35	2.07
Output per unit of input	1.41	1.54	1.31	1.40	1.53	1.30

Sources: Tables 15-3, 15-5, 16-10, 17-3, 17-10, 18-2, 19-1, 19-3, and 20-1 except for slight differences between contributions to national income and national income per person employed due to interaction.
* Contributions of this source are excluded from adjusted growth rates.

SOURCE: Denison (1967:298)

DEVELOPMENT ECONOMICS

The study of development economics has provided another impetus to the interest in technical change besides that stimulated by growth theorists. There are many differences in the historic development paths of countries, and yet, at a certain aggregate level, broad patterns do emerge. In the early stages of development, most economies tend to be rural and agriculture based. In the process of development, the share of agriculture in total G.D.P. tends to fall while that of industry rises. See for instance, Kuznets (1966). On the expenditure side, the share going to foods tends to fall; some typical values are given in Tables 2 and 3. Changes in composition also take place, so that the primary input component falls while the processing, transportation and distribution (PTD) component rises. Two of the more evident consequences are the increase in urbanisation and the rise in agricultural productivity.

PRODUCTIVITY IN AGRICULTURE

Agriculture accounts for the greatest share of GDP in most countries in the earlier stage of development, so it is hardly surprising that the process of technical change here has attracted many researchers. The role of induced innovation was studied by Hayami and Ruttan (1971) when comparing the experiences of Japan with those of the United States. They used the concept of a meta production function [1]:

$$Y = f(A,L,K,HC,RC) \quad ,$$

where Y is the output, A land, L labor, K capital, HC human capital, RC cumulative research capital. Figure 1 shows some typical patterns.

TECHNOLOGY TRANSFER

Hayami and Ruttan also sought to incorporate the role of location specificity in agricultural technical change. Variations in cost between regions were reflected in an environmental sensitivity (ES) measure. In the transfer of agricultural technology, they found that significant barriers were presented in physical, biological and climatic differences. They proposed [2] a measure of environmental sensitivity between two regions:

$$ES_{AB} = \sum_i \alpha_i \hat{P}_i + \sum_j \beta_j \hat{Z}_j \quad ,$$

where, $\hat{P}_i$ represents proportional price differences, and $\hat{Z}_j$ accounts for environmental factor differences, while α_i, β_j are elasticities.

TABLE 2: Expenditure shares - world wide figures.

Country	Geometric mean of family size	Food	Clothing	Housing	Misc
		Fraction spent on			
Canada[a] (1947-48)	3·0	0·31	0·13	0·11	0·45
Ceylon[a] (1953)	4·2	0·65	0·08	0·05	0·22
India, Punjab[a] (1950)	4·6	0·73	0·04	0·12	0·11
Phillipines Manila[a] (1954)	5·9	0·50	0·08	0·14	0·28
Sweden[a] (1955)	2·2	0·37	0·12	0·16	0·35
USA, all cities[a] (1950)	2·6	0·31	0·11	0·16	0·42
Brazil, Rio de Janeiro[b] (1967-68)					
Income Class: 0–40	3·9	0·60	0·05	0·23	0·12
40–80	4·6	0·44	0·06	0·23	0·27
80–100	4·0	0·29	0·06	0·22	0·43

[a] Data based on H.S. Houthakker, 'An international comparison of household expenditure patterns, commemorating the centenary of Engels Law', *Econometrica*, October 1957.
[b] Data for Brazil is based on Orcamentos Familiares-consumo alimentar, Conjunctura Economica, July 1975.

TABLE 3: Expenditure elasticities.

Country	Food	Clothing	Housing	Misc
Pakistan[a] (1968-72)				
Urban 0–40	0·83	0·91	0·96	1·75
40–80	0·79	1·03	0·81	1·74
80–100	0·66	0·80	1·49	1·31
Rural 0–40	0·73	0·53	1·67	1·88
40–80	0·74	0·63	0·54	2·40
80–100	0·73	0·89	0·97	1·70
Canada[b] (1947-48)	0·712	1·25	0·78	1·08
Ceylon[b] (1953)	0·81	1·11	1·19	1·29
India, Punjab[b] (1950)	0·811	1·16	0·76	1·39
Phillipines, Manila[b] (1954)	0·757	1·14	0·87	1·31
Sweden[b] (1955)	0·652	1·14	0·75	1·26
USA[b] (1950)	0·642	1·34	0·73	1·22

[a] Values based on Household Income and Expenditure Survey.
[b] Houthakker, 1957 – see note a Table 2. The values quoted are for expenditure changes, not quantity as for the Pakistan values. The food values are adjusted to allow for family size effects.

Source: Mc Carthy (1977)

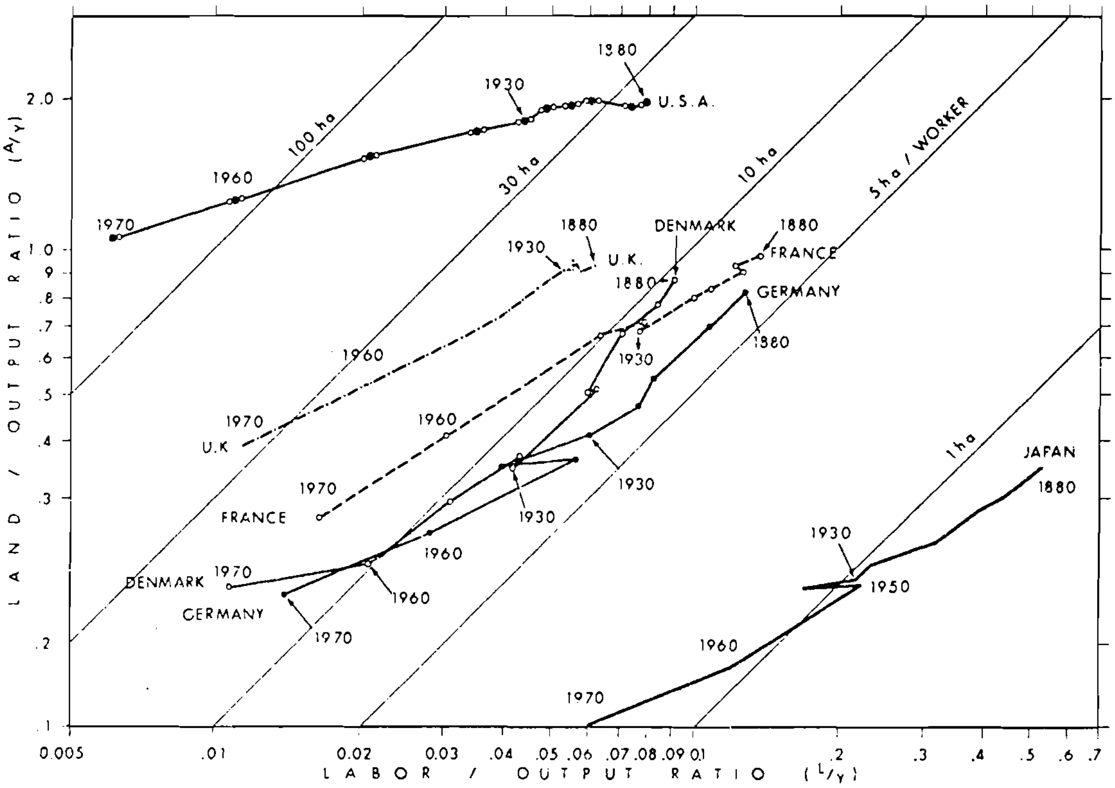


Figure 1. Input-output ratios for six countries, 1880-1970. (In logs; data from appendix 3-2. Diagonals are land-labor ratios.) (Source: Ruttan in Binswanger, Ruttan et.al. 1978:55)

ENVIRONMENT

This concept of environmental sensitivity may be extended to include any non economic factors. Thus the ES measure may give some indication of the relative importance of salient features in the adoption of a technology in a particular region. There has been a marked increase in interest in recent years in most countries in the broader impact of technology on the environment. Much of the problem arises because many key resources are perceived of as free goods--typically, air and water. In order to "protect" these resources, there are two broad approaches (besides the "choice" of doing nothing); either legislative or economic controls.

In order to devise economic controls one is again faced with the problem of assigning an environmental value. Those working in this area seem to feel that the concept of augmented GNP is the best currently available, although they are aware of its shortcomings. This requires estimating changes in public goods and services, including those provided by the environment. Commoner (1977) has estimated that most of the impact on the environment has been caused by technical changes. He used an environmental index I, given by

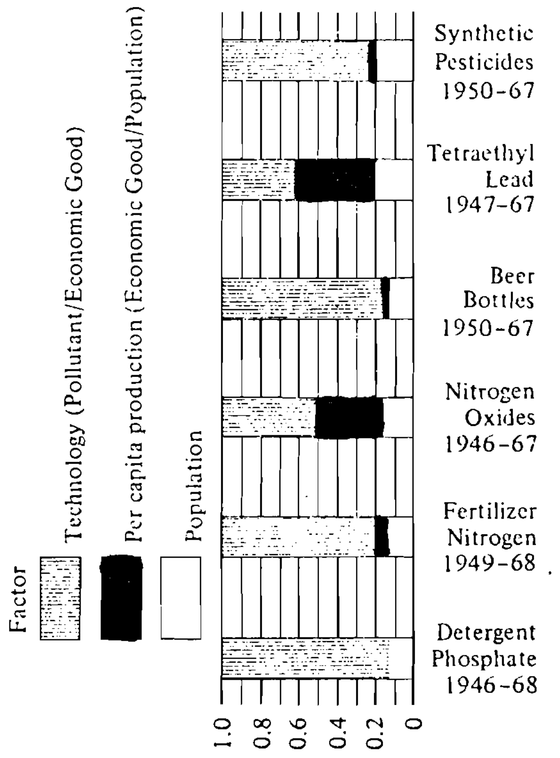
$$I = \text{Population} \cdot \frac{\text{Economic Good}}{\text{Population}} \cdot \frac{\text{Pollutant}}{\text{Economic Good}}$$

This allowed him to separate the three effects shown in Figure 2. He proposes the development of massive new technologies to essentially undo the harm caused by the technical transformation since 1946. [3)]

INTERNATIONAL ENVIRONMENTAL PROBLEMS

At the international level the problems become even more complex. Typically they are divided by the type of linkage effect involved, either physical or social. The former has problems such as vector borne diseases, highly toxic agricultural pesticides. In the social category one may include natural or historical gifts controlled by one country or region but valued by others, as for instance, Egyptian civilisation, wild life. Here again, one may devise measures--the problem is a difficult one--should a country such as Kenya faced by food shortages "develop" its game parks to feed its people with obvious detrimental effect on wild life? If not, then one needs to know for how much and by whom they should be compensated.

Some countries do not worry too much about ecological impact and the concomitant costs. This may give them some advantage in international trade. Should trade agreements take this into consideration? An examination of current patterns evolving in international trade and changes in comparative advantage could be enriched by consideration of concomitant envisioned implication (Balassa 1979).



Relative contributions of several factors to changes in environmental-impact indices. The contributions of population size, production per capita, and technological characteristics (amount of pollutant released per unit of production) to the total environmental-impact indices were computed as shown in the text. Each bar is subdivided to show the *relative* contribution, on a scale of 1.0, of each factor to the change in the environmental-impact index between the earlier year and the later year.

Figure 2. Relative Contribution to Ratio of Total Environmental Impact Indices. (Source: Commoner 1977:350)

POSSIBLE AREAS OF INTEREST FOR IIASA

Depletion of Resources vs. Improved Productivity

When a resource becomes scarce the typical economic effect is that its price rises and often a substitute evolves. The role of wood in Britain in the last century is a particular case. Here the imminent shortage forced the railroads to develop new technology to handle other fuels. The US was wood abundant at that time and so the process of technical change for railroads there was delayed.

Can this type of experience be generalized? In particular what demand and supply factors determine technical change?

Role of Research Institutions in Development

The evidence currently available[2] suggests that countries which have a domestic research capability can generally make much better use of technical advances in other parts of the world.

What strategy should countries follow at different stages of development for their various sectors?

Criteria for Introducing New Technology

On what basis should a country favor the introduction of new technology? Examples:

1. Currently in Egypt there is considerable emphasis on animal power, growth of berseem--yet the country is a major food importer.
2. Brazil is a major oil importer. There is a current proposal to place 3 million hectares under sugar cane for gasoline production. What are the implications?

International Environmental Problems

Many of the problems may be classified as externalities. What is needed to handle such issues--economic, legal, institutional approaches?

Structural Change

This should be one of the better fields for IIASA and the FAP group in particular, given its current work in this area.

The study should focus on historic patterns of change by country for:

- -- Production.
- -- Demand both within the country and imposed from outside.
- -- Export-import structure--for instance Brazil has now an efficient auto industry; what happens when it enters world markets traditionally controlled by other countries?

In particular the interaction within technology at various transitions in the growth process could be analyzed. How should development and investment be guided in the light of the analysis?

CONCLUSION

This Working Paper touches on a number of areas which impinge on the technology-agriculture-environment triad. Technical change clearly plays a major role as economies develop. It accounts for over half the growth. Interesting questions are: how should it be measured and then, if possible, directed? This will require a different answer for countries at varying stages of development. In particular, it should be possible to identify both economic and environmental benefits and costs at both the national and international level.

NOTES

1. Griliches (1968) sought to separate productivity into growth in area per worker and yield per unit area.

$$Y/L = (A/L)(Y/A) \quad ,$$

where,

$$Y = \text{output},\ L = \text{labor},\ A = \text{area}.$$

Increases in A/L are termed mechanical technology, while increases in Y/A (after allowing for changes in L) are termed biological technology.

2. One of the earlier attempts to do this was a 1973 study by Evenson and Kislev (1975). They studied wheat and maize yields for 64 countries over a period of 21 years. They used counts of Plant Breeding Abstracts for indigenous research and a dummy variable to pick up intercountry variations.

3. In the Soviet Union one also finds similar concern expressed. Goldman (1970) quotes Nikolai Popov, an editor of Soviet Life: "Why, in a socialist country, whose constitution explicitly says the public interest may not be ignored with impunity, are industry executives permitted to break the laws protecting nature?"

REFERENCES

Balassa, B. 1979. Export Composition and Export Performance in the Industrial Countries 1953-1971. The Review of Economics and Statistics.

Binswanger, H.P., V.W. Ruttan, et.al. 1978. Induced Innovation. Baltimore and London: The Johns Hopkins University Press, p.55.

Commoner, B. 1977. The Environmental Costs of Economic Growth. Economics of the Environment, edited by Robert Dorfman and Nancy S. Dorfinon. New York: W.W. Norton and Company, p.350.

Denison, E.F. 1967. Why Growth Rates Differ. The Brookings Institution, Washington, D.C., p. 298.

Evenson R., and Y. Kislev. 1975 Agricultural Research and Productivity. New Haven: Yale University Press.

Goldman, M.I. 1970. The Convergence of Environmental Disruption. Science.

Griliches, Z. 1968. Agriculture: Productivity and Technology. International Encyclopedia of the Social Sciences 1: 241-245.

Hayami, Y., and V.W. Ruttan. 1971. Agricultural Development: An International Perspective. Baltimore: The Johns Hopkins University Press.

Kuznets, S. 1966. Modern Economic Growth. Yale University Press.

McCarthy, F. Desmond. 1977. Food Consumption, Income Distribution and Quality Effects. Food Policy.

Solow, R. 1957. Technical Change and the Aggregate Production Function. Review of Economics and Statistics 39.