# THE CHANGING DYNAMICS OF GLOBAL AGRICULTURE

## A Seminar/Workshop on Research Policy Implications for National Agricultural Research Systems

DSE/ZEL Feldafing
Germany
22-28 September 1988



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## A Seminar/Workshop on Research Policy Implications for National Agricultural Research Systems

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**Germany**
**22-28 September 1988**

**Sponsors:**

International Service for National Agricultural Research (ISNAR)
The Hague, The Netherlands

German Foundation for International Development (DSE)
Feldafing, Federal Republic of Germany

The Technical Centre for Agricultural and Rural Cooperation (CTA)
ACP-EC Lom Convention
Wageningen, The Netherlands

# A Global Evaluation of National Agricultural Research Investments: 1960-1985[1]

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The overall contribution of agricultural research to the process of long-run economic growth is well documented. But agricultural research is a risky business and research-output linkages are complex. Agricultural research is also time-intensive, and the site-specific characteristic of much agricultural technology contributes to relatively long lags in the diffusion of this technology, both within and between countries. Conventional wisdom is that 15 years or so are required to exhaust fully the output-enhancing effects of agricultural research, although recent evidence for the US suggests these effects may persist for as long as 30 years.

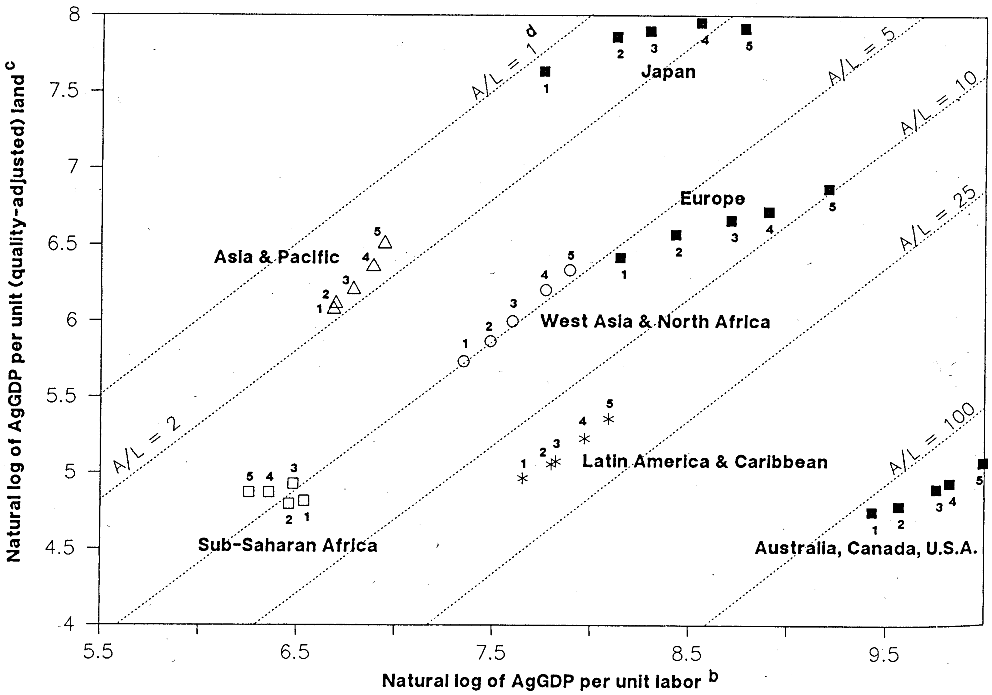
This all points to the need for an appreciation of the historical pattern of commitment to agricultural research in order to comprehend current developments in agriculture, as well as improve predictions concerning the course of future events in the sector.

## Partial Productivity Indices

Before turning to some basic indicators of national agricultural research activity, it is instructive to review briefly the productivity shifts in global agriculture over the last 25 years. Average land and labor productivity gains in agriculture for four developing country regions and three developed country groupings over the 1960-1985 period are summarized in Figure 1.

For those conversant with the work of Yujiro Hayami and Vernon Ruttan (1985: 118-125), this diagram is no doubt familiar, yet differs from their earlier work in several important respects. Most significantly, the country coverage has been substantially expanded from 44 countries (27 developing) to 110 (90 developing). Agricultural output is measured here in value-added terms in contrast to the gross output –

**Figure 1. Value-added productivity indices of (quality-adjusted) agricultural land and labor, regional averages, 1960-64 through 1980-85[a]**




1 = 1960-64; 2 = 1965-69; 3= 1970-74; 4 = 1975-79; 5 = 1980-85

a) Sample consists of 16 Asia & Pacific countries; 20 Developed countries; 26 Latin America & Caribbean countries; 35 Sub-Saharan African countries; and 13 West Asia & North African countries
b) Labor is economically active agricultural population
c) Agricultural land is arable land and permanent crops plus permanent pasture (hectares of quality adjusted land)
d) A/L = Quality adjusted land per unit labor

Source: Authors' own calculations based on FAO and UN data

adjusted for intermediate inputs produced on-farm – measure constructed by Hayami and Ruttan. Also, the land variable has been adjusted here for country-specific variations in land quality. Land quality differences are taken to reflect variations in soil characteristics driven by long-run differences in average rainfall, plus differences in the percentage of agricultural land under irrigation.[2] In quality-adjusted terms there was consequently 40% more agricultural land in Asia and 24% less agricultural land in sub-Saharan Africa during 1980-85. Unfortunately, similar quality adjustors, which account for both over-time and cross-country differences in the human capital component of agricultural labor, are not presently available.

The regional productivity patterns in Figure 1 are quite revealing. Both land and labor productivity gained in West Asia and North Africa, Europe, and Australia, Canada, and the US as a group. Similar patterns of productivity gains occurred in Asia and the Pacific, and Latin America and the Caribbean, although both partial productivity ratios appear to stagnate during the 1960s in Asia, and the late 1960s to early 1970s in Latin America. Japan demonstrated steady growth in both partial productivity ratios until the mid-1970s. Thereafter, a slowdown in land productivity gains accompanied an increasing labor productivity ratio as the size of its agricultural labor force continued to decline steadily.

The pattern of productivity gains for sub-Saharan Africa is dramatically different from all other regions. The general picture is one of a stagnating ratio of output per unit of land and an erosion in the ratio of output per unit of labor. Relatively high population growth rates coupled with a low rate of labor absorption by the nonagricultural sector means that sub-Saharan Africa has not only lost significant ground in terms of labor productivity, but the production regime in its agricultural sector has, on average, increasingly substituted labor for land.

Figure 1 also maps long-run shifts in land-labor ratios at the regional level. West Asia, North Africa, and Latin America appear to have increased their labor productivity ratios largely through "yield increasing" technologies, with no discernible shifts in land-labor ratios over this 25-year period.[3] Japan has nearly tripled its average land-labor ratio over this same period, while Europe has doubled its ratio from 5 to 10 ha per unit labor. Australia, Canada, and the US have continued to substitute land for labor to the point that by 1980-85 they averaged 130 ha per unit labor. Meanwhile, for the Asian and Pacific region, gains in labor productivity have been smaller than gains in land productivity by an amount equal to the decline in the land-labor ratio.

## Agricultural Research Expenditures and Personnel: A Regional Overview

The primary source for the agricultural research data presented here is a forthcoming ISNAR publication, which is a fully sourced and extensively documented set of research personnel and expenditure indicators for national agricultural research systems (NARS), where possible, for the 27-year period from 1960 to 1986 (Pardey and Roseboom, *in press*). The time-series data reported in this paper include estimates for 151 countries – but omit nearly all nonmarket economies, in particular China, Cuba, and Eastern Europe, for which plausible time-series data were unattainable. The country coverage is substantially larger than the 110 countries reported in the recent Judd et al. (1983, 1986) publications, and the 51 countries included in the earlier ISNAR/IFPRI report by Oram and Bindlish (1981). The data reported here therefore include observations on numerous small NARS which hitherto have been excluded from such global series, as well as completely revising and updating previously available country-level data.

Most significantly, all expenditure data were collected in current local currency units. This enabled us to minimize or at least standardize currency conversions. In particular, any currency manipulations of research expenditure data which were made represent a practical compromise to applying country-specific agricultural research deflators and agricultural research purchasing power parity indices. Inappropriate treatment of such matters can have non-trivial quantitative and qualitative impacts on the data (Pardey and Roseboom, 1988).

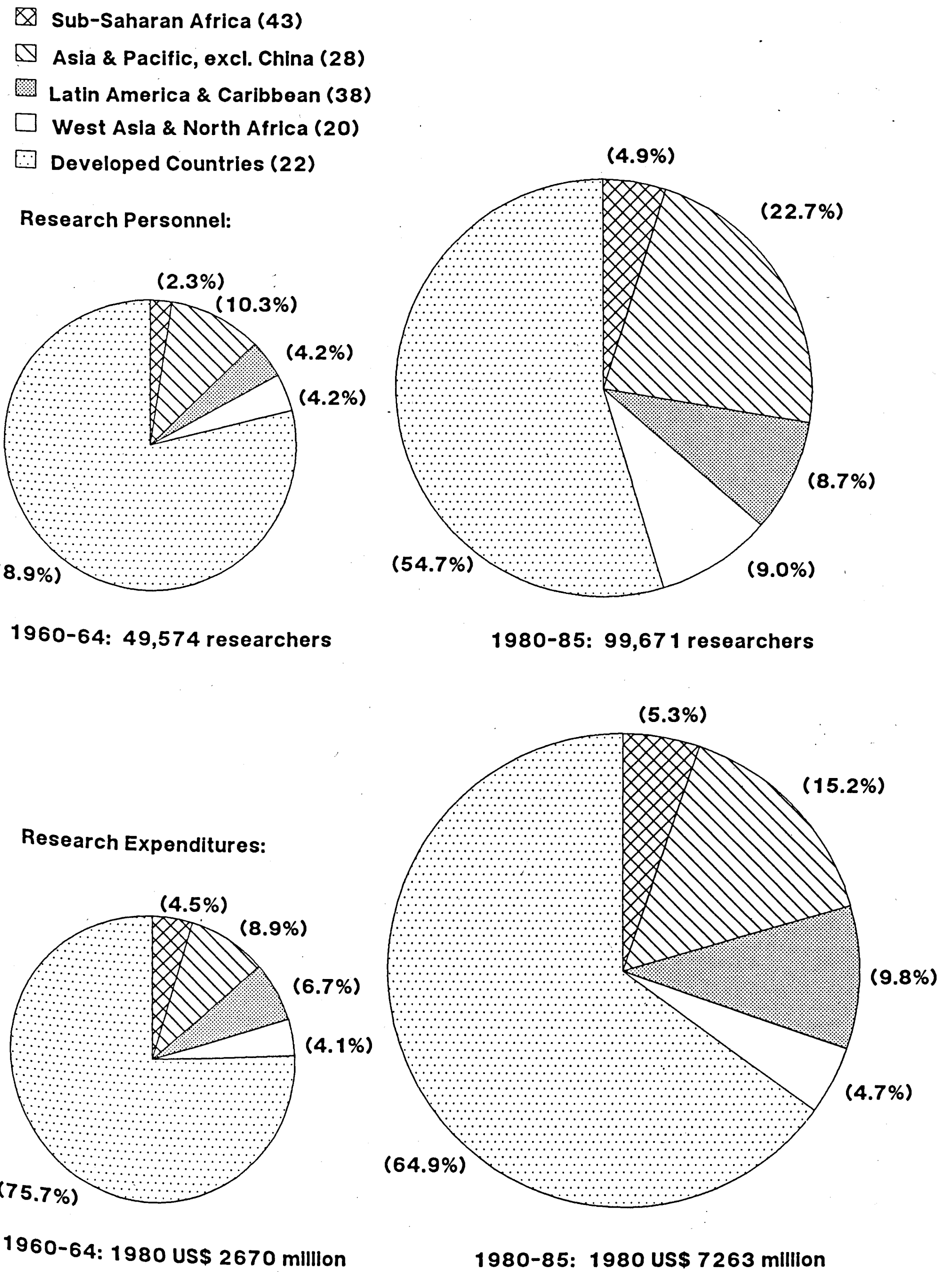
While we maintain that the over-time, cross-country commensurability of our research expenditure figures represents an improvement over previously available series, one should not underestimate the difficulties of ensuring consistency in such a series. To minimize the influence of spurious variability and missing observations, we chose to present all the indicators developed in this paper as quinquennial averages. While this may artificially dampen variability for data with strong trends, we would argue that five-year averages offer more realistic global comparisons than the point estimates used by many previous analysts.

## *Regional research expenditure and personnel shares*

Figure 2 indicates that the total global number of public-sector agricultural researchers, measured in full-time equivalent units, has approximately doubled since 1960, from 49,574 to a current level of 99,671, while "real" expenditures have increased by a factor of 2.7, from US$ 2.67 billion to US$ 7.26 billion. These impressive gains in global agricultural research capacity nevertheless represent significantly lower rates of growth than the Judd et al. (1986) estimates of a 3.14-fold increase in research scientists – measured in scientist person-years – and a 3.68-fold increase in real spending over the 1959 to 1980 period. The substantially broader coverage of public-sector agricultural research institutions included in the present series, particularly for the earlier years, plus our attempts to maintain consistency in institutional coverage over time, probably go a long way to explaining these differences.

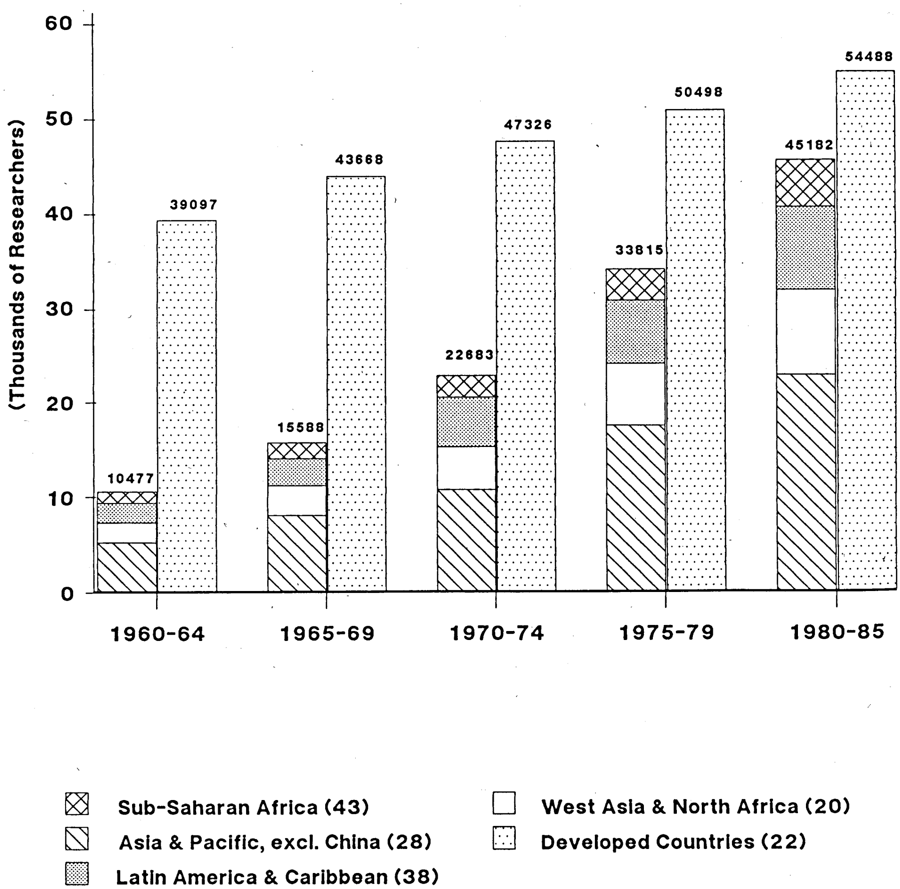
The 26-year period from 1960 to 1985 has experienced a marked shift in the developing countries' share of public-sector researchers. In 1960-64 developing countries, as a group, accounted for only 21% of the global agricultural researcher total, but by the 1980-85 period, this share had doubled to around 45% of the global total. The pattern of increase in research personnel for developing countries is similar across different regions, with all regions approximately doubling their share of the global total.

**Figure 2. Regional shares of agricultural research personnel and 'real' expenditures (1980 PPP US dollars)**



The overall result (Figure 3) is that the total number of research personnel in the developed countries has increased steadily, in a linear fashion, from 39,097 researchers in 1960-64 to 54,488 in 1980-85. By contrast, the total number of research personnel in the developing countries has grown exponentially from a mere 10,477 researchers in 1960-64 – approximately equal to two-thirds the size of the US public-sector research system at the time – to a 1980-85 average of 45,182 researchers.

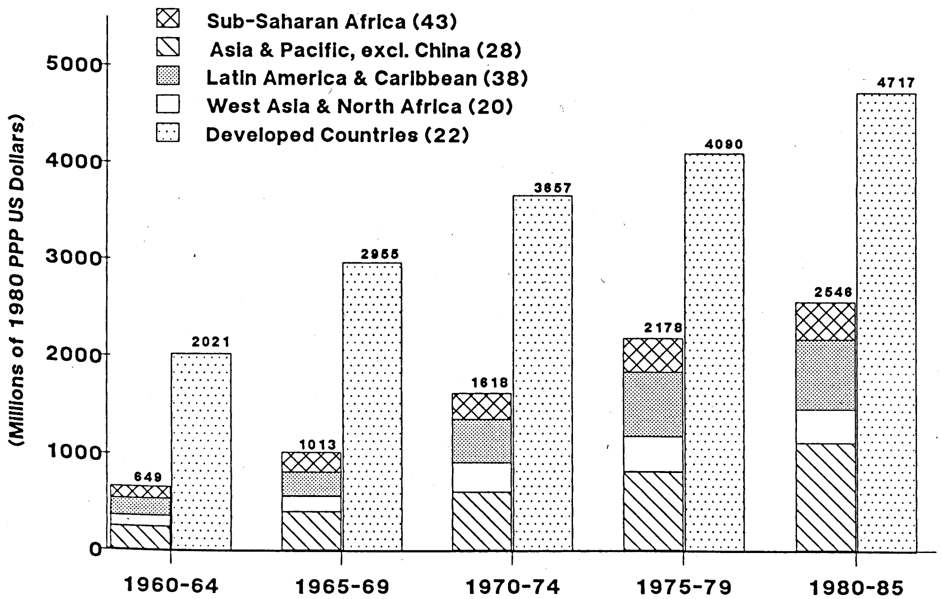
**Figure 3. Regional development of the number of researchers (in full-time equivalent units)**



China is a conspicuous omission from these figures, particularly when an attempt is made to assess agricultural research activity in Asia. It is difficult to obtain data on research personnel or expenditures for China which are commensurable with those reported for other countries. Nevertheless, we have pieced together a time series for the years following the cultural revolution which shows a rapid increase in research personnel from around 19,000 researchers in 1978 to a 1985 estimate of approximately 33,000.

The developing countries' share of the "real" expenditures of public-sector research agencies exhibits more modest gains compared with the research personnel figures (Figure 4a), increasing from around 25% of global expenditures to a 1980-85 average of only 35%. In contrast with the regional growth in research personnel, both developing as well as developed countries experienced a linear growth in real research expenditures. The asymmetry of these shifts in regional personnel and expenditure shares over time have direct implications for spending-per-scientist ratios, which will be discussed later in this paper.

**Figure 4a. Regional development of 'real' research expenditures (1980 PPP US dollars)**



## *"Real" research expenditures: A measurement problem*

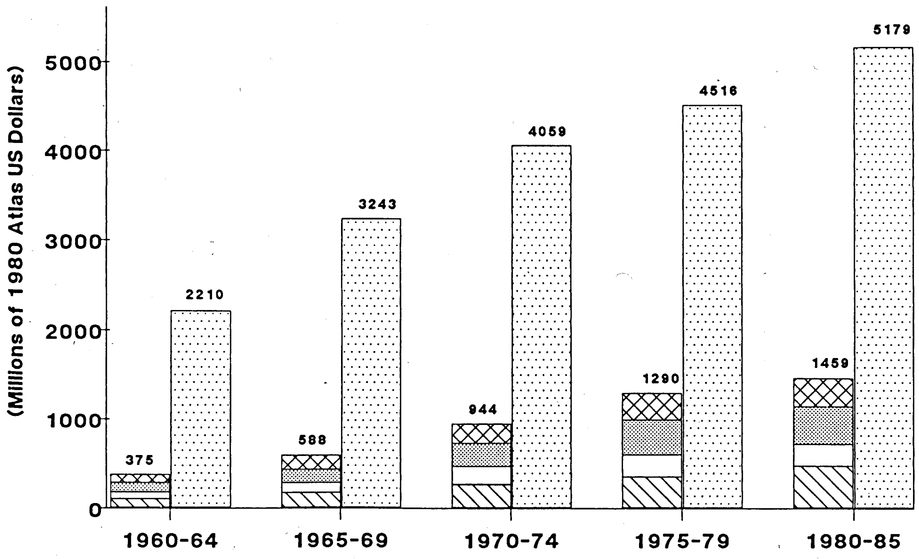
There are numerous problems associated with obtaining measures of real research expenditures that yield meaningful cross-country comparisons over time. Within a country, the rate of increase over time in the price of various inputs used by national research systems may not be well represented by a price index measuring more general rates of inflation in the national economy. The mix of inputs – such as labor, land, buildings, equipment, and miscellaneous operating expenses – varies during the life cycle of a national agricultural research system. A recent study in the US, for example, showed that while the state agricultural experiment stations currently spend only 8% of total expenditures on (physical) capital items, this figure peaked at nearly 29% of total expenditures in 1912, some 25 years after the formal establishment of the experiment station system (Pardey et al., *in press*).

There are also substantial differences in the average level of prices across countries. A great deal of effort by agencies such as the World Bank, the United Nations, and the Statistical Office of the European Community have recently been directed toward measuring the extent of these price differences in terms of purchasing power parity (PPP) indices. PPPs, by definition, measure the domestic cost of buying a bundle of goods and services in a particular country at its own prices relative to the corresponding cost in, say, dollars of the same bundle in the United States. When using PPPs to measure relative price levels, there is clear evidence that, as expected, average price levels are positively associated with per capita income. Moreover, there is overwhelming evidence that exchange-rate-converted research expenditure figures vary from PPP-converted figures in a significant and systematic manner.

Figure 4b uses World Bank atlas exchange rates to convert agricultural research expenditures into US dollars, and clearly implies a dramatically different regional pattern of real expenditures from the PPP-converted figures given in Figure 4a. In general, the atlas-converted figures appear to understate the level of real expenditures in developing countries relative to the PPP-converted figures, while overstating the level of real expenditures in developed countries. During the 1980-85 period, for instance, the PPP-converted figures suggest that real research expenditures in developing countries were 54% of the level of expenditures incurred by developed countries, while the atlas-converted figures put the ratio of developing to developed country real expenditures at only 28%.

Figure 5 decomposes the atlas- and PPP-converted expenditure figures to the regional level. PPPs suggest that average price levels in sub-Saharan Africa are not dramatically lower than those implied by Atlas exchange rates, so that measuring real research expenditures in terms of PPP rather than Atlas-converted dollars does not substantially increase the estimated volume of resources committed to research in the region. By

**Figure 4b. Regional development of 'real' research expenditures (1980 Atlas US dollars)**



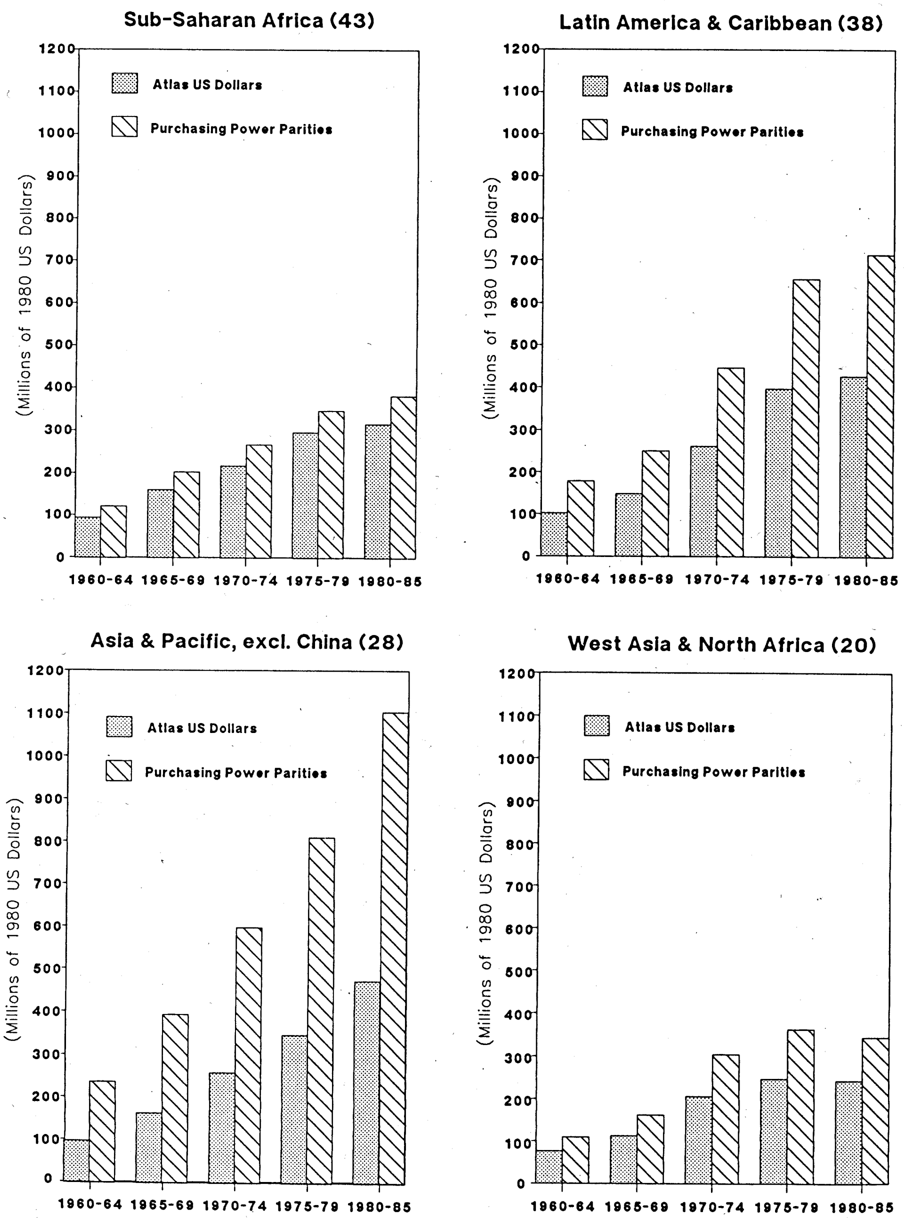

contrast, the Asia and Pacific PPP-converted expenditures suggest that real research expenditures in the region may be significantly higher than has hitherto been assumed if the relatively lower prices of domestic goods and services are factored into the conversion procedure.

The implications of these measurement issues are far-reaching, not only in the way we perceive the relative development of national agricultural research systems at a regional level, but also in terms of the implied rates of return to research and the like.

## *Real expenditures per researcher*

Figure 6 consolidates the real expenditure and research personnel data by region over time into a series of ratios of real spending per scientist. With real expenditures measured in 1980 PPP terms, the relative ratio of spending per scientist for developed countries as a group exhibits a steady increase from around US$ 52,000 in 1960-64 to approximately US$ 86,500 in 1980-85. Meanwhile, the developing countries, on average, spent US$ 62,000 in 1960-64 – 19% more per researcher than developed

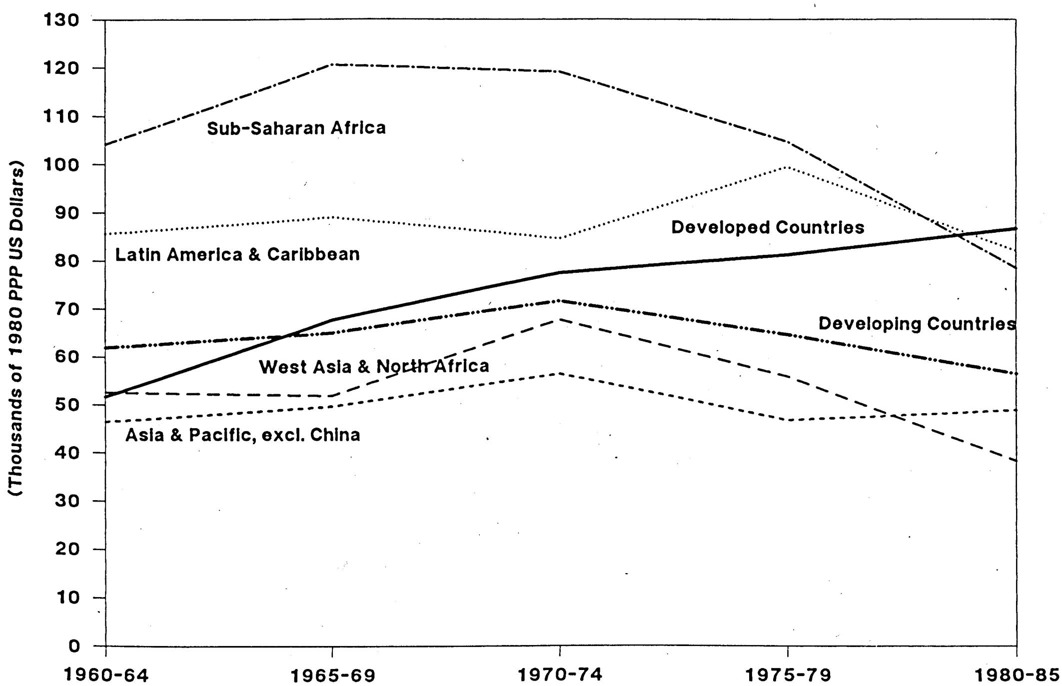
**Figure 5. 'Real' research expenditures expressed in constant 1980 US dollars using either an Atlas exchange rate or a PPP index**



countries for the same period – then peaked in their support per researcher during the early 1970s at around US$ 71,000, followed by a fairly steady decline to US$ 56,000 by the 1980-85 period.

Thus, the developed countries appear to have been moving steadily towards a more capital-intensive – both human and physical – research system over the past 25 years. Evidence based on detailed data from the US state agricultural experiment stations on the changing factor mix of their research systems points to a significant increase in human rather than physical capital over this period. By contrast, a sustained pattern of capital deepening does not appear to have materialized for many national agricultural research systems in developing countries. There has been an erratic, but nevertheless slight, drift upwards, on average, in spending per scientist in the Asia and Pacific

**Figure 6. 'Real' research expenditures per researcher (thousands of PPP US dollars per full-time equivalent)**



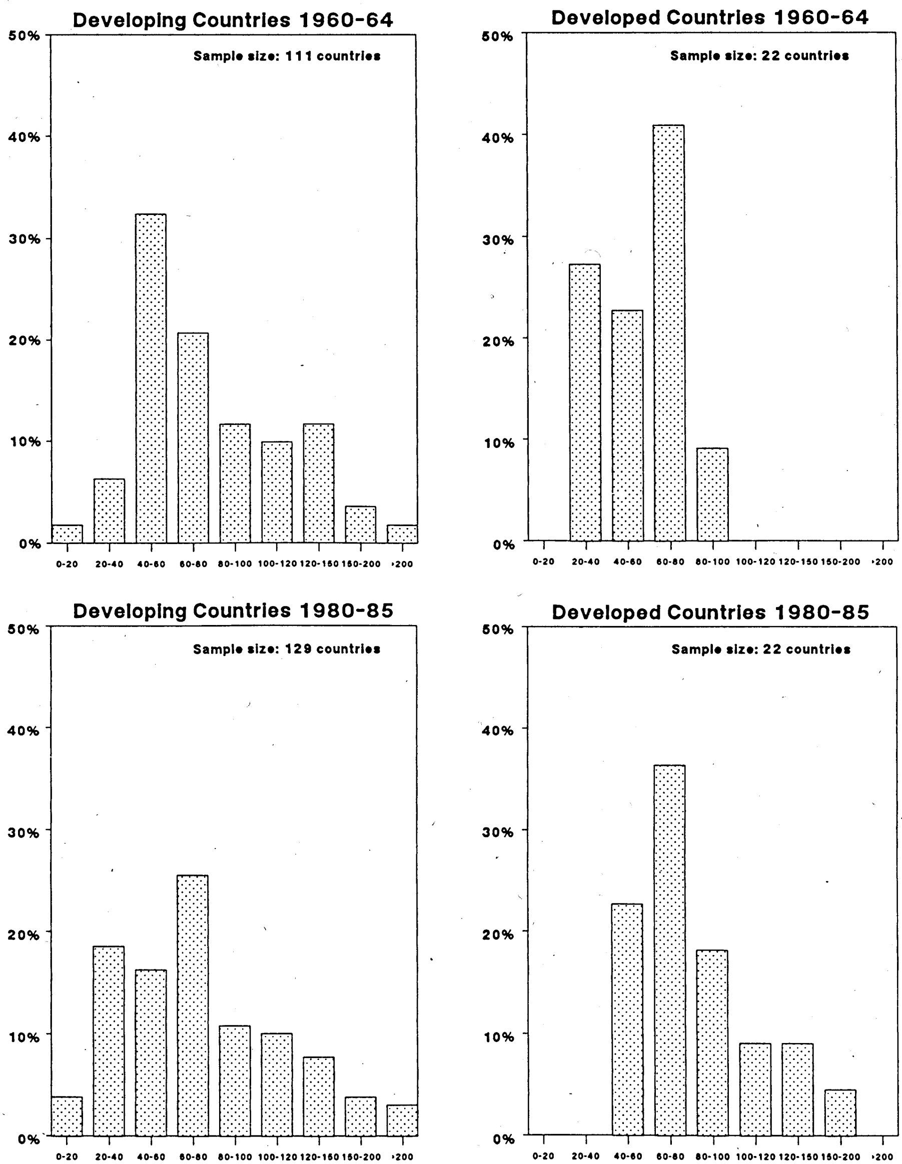
region. For the Latin America and Caribbean region, real spending per scientist remained fairly stable from the early 1960s through to the 1970-74 period, then rose during the later part of the 1970s to around US$ (PPP) 99,500 per scientist, only to fall back to earlier levels during the first half of the 1980s.

The pattern of real spending per scientist in sub-Saharan Africa over the last 25 years is again quite different from the other regions. Although average price levels in sub-Saharan Africa appear somewhat lower than developed countries, real spending per scientist on research performed during the 1960-64 period in sub-Saharan Africa was around US$ 104,000 in 1980 PPP terms, approximately double the corresponding developed country average. This ratio of real costs per scientist rose to around US$ 120,500 during the 1965-1974 period, followed by a rapid decline thereafter.

Figure 7 shows the frequency distribution of these expenditure ratios for 133 national agricultural research systems averaged over the 1960-64 period, and 151 systems averaged over the 1980-85 period. During the early period, 55% of all systems spent in the range of US$ 40,000-80,000; during the later period, 44% spent in this range. Interestingly, none of the developed countries in the sample spent more than US$ 100,000 per scientist during the 1960-64 period, while nearly a quarter of the sample spent in excess of this level in the later sampling period. There appears to be greater diversity in the pattern of real spending per scientist in the developing versus developed countries, which if anything, shows a tendency to increase rather than decrease over time. This development does not seem to be a function of the 18 new NARS that established research systems since the 1960-64 period, and are included in the later 1980-85 sample. Their ratios of spending per scientist were fairly evenly distributed across different cost ranges.

Explanations for the different patterns in spending per scientist, both over time and among regions, are varied, complex, and presently the focus of empirical study at ISNAR. They include a set of issues that are essentially internal to the research process, and a further set that are external to the process. This latter category relates to the political and economic forces that shape public support for agricultural research and are discussed in some detail in Pardey et al. (1988). Forces internal to the research proces influence, among other things, ratios of spending per scientist and include issues on economies of size, including the degree of fragmentation of national research systems; the stage in the life cycle of a research system; the relative price of research inputs, which directly influence the factor mix of the research process itself; and the very nature of the research problem under study.

Figure 7. Frequency distribution of average 'real' expenditures per scientist per country (thousands of 1980 PPP US dollars)



## Conclusion

Disaggregating this regional data will help us understand the factors that influence the shifting patterns of support for national agricultural research systems that the data have revealed. Sharpening our estimates of the resource commitment to agricultural research – in both quantitative and qualitative terms – will also allow us to understand with greater precision the links between these growth-promoting investments, and the cross-country variation in agricultural productivity over time which we observed at the outset of this paper.

## Notes

1. All figures presented in this paper are preliminary and may be subject to change as the primary data and/or conversion procedures are revised. Nonetheless, we expect that the general quantitative picture presented here will remain intact.

2. The methodology used to construct this international land quality index is a derivative of the procedure described in Peterson (1986).

3. Although Brazil increased the land under agriculture over this period by 85.6 million ha (58%), this was offset by the relatively rapid regional growth in the economically active population in agriculture.

## References


Hayami, Y., and Ruttan, V. 1985. Agricultural Development: An International Perspective. Baltimore, Maryland: Johns Hopkins University Press.

Judd, A.M., Boyce, J.K., and Evenson, R.E. 1983. Investing in Agricultural Supply. Economic Growth Center Discussion Paper No. 442. New Haven, Connecticut: Yale University, Economic Growth Center.

Judd, A.M., Boyce, J.K., and Evenson, R.E. 1986. Investing in Agricultural Supply: The Determinants of Agricultural Research and Extension. Economic Development and Cultural Change 35 (1):77–113.

Oram, P.A., and Bindlish, V. 1981. Resource Allocations to National Agricultural Research: Trends in the 1970's. A Review of Third World Systems. The Hague and Washington, DC: ISNAR (International Service for National Agricultural Research) and IFPRI (International Food Policy Research Institute).

Pardey, P.G., and Roseboom, J. 1988. An International Yardstick for Value-Based Indicators: An Application to National Agricultural Research Expenditures. ISNAR Staff Note No. 88-10. The Hague: ISNAR (International Service for National Agricultural Research).

Pardey, P.G., and Roseboom, J. *In press.* ISNAR Agricultural Research Indicator Series: A Global Data Base on National Agricultural Research Systems. Cambridge, UK: Cambridge University Press for ISNAR (International Service for National Agricultural Research).

Pardey, P.G., Craig, B., and Hallaway, M.L. *In press.* U.S. Agricultural Research Deflators: 1890-1985. Research Policy 18.

Pardey, P.G., Kang, M.S., and Elliott, H. 1988. The Structure of Support for National Agricultural Research Systems: A Political Economy Perspective. ISNAR Staff Note No. 88-11. The Hague: ISNAR (International Service for National Agricultural Research).

Peterson, W. 1986. Land Quality and Prices. American Journal of Agricultural Economics 68 (4):812-819.