BIAS TOWARDS THE LARGE FARM SUBSECTOR IN AGRICULTURAL RESEARCH. THE CASE OF MALAYSIAN RUBBER.

by

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ABSTRACT

The economic effects of historical research bias towards the estate subsector of the Malaysian rubber industry are examined. This bias may be expected to have induced technologies using factors appropriate to the relative input prices and other characteristics of estates. It may thus have benefitted them more than the other major subsector of smallholdings, which has had higher prices of capital.

The consequences of bias are first investigated by comparing the resource use, yields, and profitability of sampled units of the two subsectors on successive technological strata, from the early 20s to the mid 70s. In both subsectors the adoption of successive new technologies has permitted considerable savings in the land, labour, capital, and management required to achieve a given output. While these technologies have been land and labour-saving and capital-using, they have also permitted substantial factor substitution, and smallholdings have all along employed more labour and less capital than estates. The analysis denotes that up to the early 60's estates benefitted more than smallholdings in applying new technologies, but that subsequently there has been little difference.

The bias is also scrutinized by examining major features of modern rubber technology of the 80s. This indicates a wide possible substitution between labour and capital at current output levels, but shows too that the move to higher output is

strongly capital-using, with less possibility of factor substitution. The new techniques of the 80s are further highly management-using compared to previous strata.

Factor prices to estates and smallholdings now seem likely to converge in the increasingly commercialized Malaysian economy, and in these circumstances the earlier bias will no longer be a problem. The main current policy indication is to ease the adjustment of smallholdings to the emerging technology. Thus in working along the innovation possibility curve, researchers should provide somewhat more for substitution between labour and capital. At the field level extension services should be improved, so that small farmers can better handle the greater management requirements of new techniques.

BIAS TOWARDS THE LARGE FARM SUBSECTOR IN AGRICULTURAL RESEARCH. THE CASE OF MALAYSIAN RUBBER

A bias in research towards a particular subsector is defined as one leading to technologies which save factors in a manner appropriate to the prices of that subsector. In theory, at least, this may lead to less favoured subsectors being penalized (footnote 1). The development of such a bias is essentially due to various political and social pressures on the managers and scientists involved.

The existence of politically and socially inspired bias in historical rubber research has been well established (Bauer, 1948; Barlow and Peries, 1977), and is accepted here as fact. Others (de Janvry, 1973 and 1977; Grabowski, 1979; and Anderson, 1979) have elaborated this theme in different agricultural research spheres. This politico-social effect supplements factor price influences on technical change suggested by Hicks, (1932), and demonstrated in agriculture by Hayami and Ruttan (1971). Yet while it is quite apparent that such bias often exists, its allegedly adverse effects on neglected subsectors are rarely clear. A closer scrutiny of how bias towards estates in rubber research has affected the relative economics of estates and smallholdings in Malaysia (footnote 2) is thus well justified.

Background and procedure

During the British colonial period to 1957, almost the whole emphasis in rubber research was on technologies suitable for estate conditions (Rubber Research Institute of Malaya, 1932-58). Most research was organised through public institutions, notably

the Department of Agriculture (1905-25) and the Rubber Research Institute of Malaya (from 1926 onwards), and the ruling pressures on management followed what Barlow and Drabble (1983) have termed the "corporate plantation" philosophy of the regime. Although a small extension service to smallholders was organized by the Institute after an independent investigation (Federated Malay States, 1933), this involved bringing the dominant estate technology more effectively to the notice of smallholders. Bauer (1948) in relation to the early 40's quoted examples of the "one sided nature" of the Institute's activities, and the "unfamiliarity of the officers with the conditions and problems on smallholdings".

While some change occurred from the late 50's with Malaysian national independence and a new policy of developing small farm agriculture, substantial research bias towards the estate subsector is thought to have remained. This was owed to effective political pressures on the part of estate associations, matched against the lack of any body articulating the real technical needs of smallholders. It was only in the early 80's that the National Association of Smallholders began to exercise pressure in this regard (Haji Mohd. Rashid Ahmad, 1983). The persisting estate bias was also due to the educational "conditioning" of research personnel and their political masters towards large scale operations. Such conditioning engendered unduly optimistic expectations from investment in technologies for such circumstances. Thus right up to the present, researchers have concentrated on innovations relevant to the estate milieu.

The estate bias in publicly sponsored research has all along been added to by considerable private research activity, financed by individual plantation companies and directed exclusively to generating technologies for large plantations (Harrisons and Crosfield Ltd., 1944; Guthrie and Co. Ltd., 1951; Kumpulan Guthrie Sendirian Berhad, 1982; Harrisons Malaysian Plantations, Berhad, 1983). The private research groups have also acted as an important liaison with the Rubber Research Institute, facilitating information exchange and joint experimentation, and stimulating Institute staff to strengthen their links with estate rubber even more.

The economic effects of any bias towards estates and against smallholdings should become evident over time through differences in the utilization of new technology, and in consequent rates of technical and economic advance. The difficulty here is that other elements also influence these outcomes, and must be abstracted if the effects of bias per se are to be determined. Thus the estate and smallholding institutional forms differ in their capacity for rapid adjustment to changing economic conditions, and in access to information about new technologies and expected future changes in factor prices. Smallholdings are more dependent on extension services for such advice, and in Malaysia these have been poorly developed. Even where information is received, economies of scale in using it have favoured the estates (footnote 3).

In light of such complications, the procedure in reviewing differences in the utilization of technology is to focus on more

progressive independent smallholdings, which have actively taken it up and which form a major portion of the Malaysian smallholding sector (footnote 4). It may of course be argued that smallholdings which rarely adopted new technologies were rejecting them because they were inappropriate for their economic circumstances. There are grounds for believing, however, that these less progressive units were typically less "efficient", and that their non-adoption was due largely to elements other than characteristics of the new technology itself (footnote 5).

Differences in utilization

Figures of labour and capital use in the land development and production phases of rubber cultivation on estates and smallholdings (footnote 6) are given in Table 2 for specific years in the 20's, 60's, and 70's. Figures of management use are also presented for estates, but this input is subsumed within labour for the smallholdings. The respective outputs per hectare of rubber, and the nominal prices of rubber and major resources, are also detailed (footnote 7). Published information being limited, the data under each classification comes from relatively small samples. In particular, there are no figures for Malaysian smallholdings in 1922, and the gap is filled by figures referring to similar conditions in South Sumatra in 1981 (footnote 8). In addition, it is only possible to secure overall average input and output figures for estates and smallholdings in each year, and distributions around these means are not available. The data of Table 2 are nonetheless believed to reflect broad economic trends quite well.

In order to facilitate comparisons between years and subsectors, the nominal values of Table 2 are normalized in 1978 dollars in Tables 3 and 4. Production costs are quoted in isoproduct terms in Table 4, and the isoproduct curves for labour and capital are plotted in Figure 2.

The 1920's

In 1922, with large areas of accessible unexploited jungle and heavy previous immigration, land and labour were cheap and similar in price for both subsectors. Thus labour was under half, and land under one sixteenth, its value in 1978 (Table 3). The main price difference was for capital, which was much cheaper to estates. While these units had access to formal sector credit and further benefitted from pecuniary economies, smallholdings operated in a semi-subsistence, capital-scarce environment. Both subsectors used essentially the same primitive technology based on unselected seedlings (footnote 9).

Technically efficient means of land development had barely been investigated by research workers, and this helps to explain the exceedingly high labour and management inputs per hectare in this activity on estates, despite abundant and cheap land (Tables 2 and 3). Taking into account the frequent need to duplicate workforces owing to health problems, the estate management with its "scientific" bent still required inordinately intensive approaches to maintaining cleared land. It was only in the later 20's that the counterproductive disease-encouraging effects of this were realised (Barlow, 1978). While the detailed planting activities of Malaysian smallholdings in this period are not

known, they certainly used less labour than estates and achieved yields which were just as high (Bauer, 1948). Thus the South Sumatran smallholders, with their primitive technology and land-abundant situation (but admittedly better health, much longer learning experience, and probably greater efficiency) of 1981, used less than one eighth the labour and one fifth the capital per hectare in a system which subsequently produced higher average yields than early Malaysian estates.

The production technology of estates was more sophisticated, following the classic tapping research of Thomas Ridley in the late nineteenth century (Wycherley, 1959). Even in this phase, however, South Sumatran smallholdings in their labour-intensive approach appear to have made better use of resources (Tables 2 and 4), although with higher land prices their approach would have become unprofitable in later years. A similar situation may well have obtained on early Malaysian smallholdings. Thus the relatively good yields of the latter in years without output restrictions (footnote 10) denote that the tapping techniques of smallholders were not so damaging as often alleged by contemporary observers (Agricultural Bulletin, 1920-22).

Transition to the 1960's

Important changes occurred over the period to the 60's. The real price of labour almost doubled with the burgeoning development of other parts of the economy in the postwar years, and the price of land rose far more as accessible areas were developed and legal constraints placed on new cultivation (Table

3). The cost of capital to smallholdings declined, however, as the rural economy became more commercialized, and the wage: interest ratio widened greatly, indicating that the price of capital in terms of labour was being lowered. In the late 20's and the 30's the technologies generated through research began to be adopted and have practical impact, and although the output restriction schemes of those years may have delayed economic adjustment (Whittlesey, 1931; Bauer, 1948), substantial resource reallocation towards greater efficiency nonetheless took place. Large reductions in labour and management inputs in land development were achieved without reducing productivity.

From the mid 50's, wide areas were replanted with high-yielding trees under the stimulus of government grants (footnote 11). Once investment credit was provided in this way, most estates and a substantial proportion of smallholdings obviously found replanting with the new cultivars a profitable avenue of improvement (footnote 12). The new cultivars represented an immense advance over unselected seedlings, and often enabled yields to be more than quadrupled. They and their complementary inputs embodied a land saving but capital-using technology, which nonetheless accommodated some substitution between labour and capital in both development and production phases.

The adoption of these new technologies is reflected in the cost structures of the two sectors (Table 3). In estate land development, the total cost per hectare of labour, management, and capital was over 40 per cent lower in 1963 than in 1922, although the absolute cost of capital rose. In estate production, the total cost per hectare rose due to added labour

and capital requirements for harvesting a higher yield, but the cost of production per kg dropped by almost two thirds. A similar lowering in unit production costs probably occurred in the smallholding sector, although the use of efficient 1981 South Sumatran figures to represent 1922 Malaysian smallholdings indicates otherwise (Table 4). The smallholdings used more labour-intensive and land-extensive techniques than estates, but due to lower yields their unit costs were substantially higher. It should be noted that these and subsequently quoted costs do not include land, whose addition in the calculations much reduces the profitability gains indicated by Tables 3 and 4 and Figure 2. This item impacts similarly on estates and smallholdings, however, and its inclusion does not affect the relative assessment.

Transition to the 1970's

From 1963/64 to 1975/78 real wages do not appear to have changed much (Table 3), although with the quickening development of manufacturing and services in the seventies (Fisk and Osman-Rani, 1982) expectations of further relative wage increases must have existed. Nominal interest rates to estates advanced considerably in line with international trends, but their value in real terms probably remained constant. The rate to smallholdings continued to decline. Thus the wage: interest ratio for smallholdings continued to widen, and to approach the estate figure. Land prices again rose greatly. Further improved technologies were introduced, and a new generation of trees was planted on the estates and progressive smallholdings represented

in the samples of this study. These trees gave some increase in yield, albeit minor compared to that of the first generation.

Total estate land development costs per hectare fell slightly over the period, but the usage of capital increased even further. Total estate production inputs per hectare also declined although management costs remained constant, and with the parallel increase in yield, unit costs dropped by almost 20 per cent. Total smallholding production inputs fell more considerably, and unit costs moved down to the same level as that of estates. The smallholding input of capital was reduced, although this could be an aberration owed to the small size of sample.

Subsequently in the 80's, the main change has been a large real wage rise, reflecting the availability of far wider employment opportunities (Malaysian Rubber Research and Development Board, 1984). Absolute labour use has reportedly declined in both rubber subsectors, but considerably more amongst smallholdings where big areas of residual low-yielding rubber owned by less progressive farmers (footnote 5) have been virtually abandoned in face of more remunerative possibilities elsewhere. The increased employment opportunities have nonetheless improved the cash flow of progressive smallholder families, and to this extent further reduced their costs of capital. While no large scale survey data from smallholdings are yet available, such changes may be expected to have influenced the resource use of progressive farmers towards that employed by estates.

These changes in resource use with technological advance are broadly confirmed by various econometric studies (Pee, 1977; Mohd, Yusoff, 1977; and Chew, 1981). On the other hand, Yee (1981), who made a comprehensive production function analysis covering the transition by estates of three technological strata, found that embodied changes involving the "implicit" factors applied during land development (types of trees, planting densities, and cultivation inputs) had shifted the estimated producton surface neutrally between strata. This analysis only covered the period from the early 60's, however, by which time much of the alteration in factor use would have already taken place. In contrast and in direct agreement with the present study, disembodied changes involving "explicit" factors applied during production (tapping and cultivation inputs) had shifted the estimated surface non-neutrally. Here both management and capital-using change occurred in phases preceding the highest technological stratum. None of these other studies attempted to specifically compare estate and smallholding situations.

These changes in Malaysian rubber parallel to some extent those sketched by Ishikawa (1981) for labour absorption in the later "backward-rising" phase of the East Asian rice sector, when inputs were progressively more labour and land-saving. Ishikawa's earlier "forward-rising" phase of enhanced labour absorption was associated with the period before World War I, when prices of labour were low in relation to those of other inputs.

The indications of the estate-smallholding analyses just discussed are not conclusive, especially in light of their small

database. Since there are no further figures to broaden the comparison, other angles on the orientation of rubber technology must be explored. In this next section the detailed characteristics of modern rubber technology are scrutinized for major resource-using characteristics and the ongoing directions of research.

Characteristics and profitability of technology

Some major features of modern land development and production technology are set out in Table 5, which distinguishes between the basic "elements" of cultivars and their planting density, and the major "practices" of land clearing and preparation, propagation and planting, tapping, and cultivation. One of the cultivars at a given density must be incorporated within each of the practices if output is to be achieved. Unselected seedlings are included as a cultivar, even though they are not part of current Malaysian technology; this is because they provide a benchmark as the original element in all practices. Indeed, such seedlings are still predominant in the vast smallholding area of Indonesia. Each practice is a general head covering various methods, as where propagation and planting may be undertaken over a range from "seed at stake" to "nursery budded stumps". Within each method there are again several distinct techniques.

Table 5 illustrates the complexity of the broad technology, and serves to demonstrate the wide possible substitution between labour and capital within each practice. Under the all-important head of tapping, for example, the proportion of labour in the

total value of labour and capital required to achieve a normal yield per hectare is estimated to range from 60 to 45 per cent, as capital in the form of stimulant and fertilizer is progressively substituted for it (footnote 13). An even wider capital-labour substitution can occur within other practices detailed. Such possibilities explain the substantial gap between average estate and smallholding positions on the isoquants of Figure 2. Individual farm observations would be spaced more widely. With the undoubted pro-estate research bias, this broad selection of available techniques may be attributed to the variety of conditions spanned by estates themselves. Such variety was particularly true in earlier years, and accordingly encouraged research over a fair range of the innovation possibility curve.

It is also evident from Table 5, however, that output response above typical levels under each head is largely to added capital items, with less substitution becoming feasible. Thus in propagation and planting, reducing the time to maturity involves turning towards nursery methods with proportionately greater material inputs. Again, getting higher yields from selected seedlings and budgrafts chiefly means using more fertilizer. With this capital-using bias, the move to higher output may be contained somewhat for smallholdings over the next decade or so, until capital markets are more fully developed.

It is clear too from Table 5 that the move to higher output is skill and management-intensive. While the 50 per cent of Malaysia's independent smallholders defined as progressive may be

judged able to cope with all current technology, they are still likely under currently imperfect information markets to require a longer learning time than estate operators to achieve technical efficiency (footnote 3). They will accordingly suffer a relative lag in the stream of benefits following adoption. Here the teaching role of extension services is important, but unfortunately not performed adequately under present arrangements (footnote 14). It may be noted that for this kind of situation "robustness" in technology, which connotes its ability to be applied profitably in a transition from poorly-managed low inputs to well-managed high inputs, is a very suitable characteristic (footnote 15). This is because such robustness enables smallholders lacking initial information and experience to reap progressively more economic advantage from improving their skills, as well as benefitting directly through applying further inputs as enhanced cash flows become available.

With the current research focus on achieving higher output (Table 5), the trends just discussed are naturally emphasized. Thus new technological strata are likely to be capital- and management-intensive and labour- and land-saving, probably with diminished possibilities of substitution. While this thrust is basically appropriate to the emerging relative prices and endowments of both subsectors, the adjustment difficulties noted above are wont to persist.

Conclusion

The real prices of labour and land increased considerably during the sixty years reviewed, in a trend to be expected with

economic growth. Although these prices were all along similar for the two rubber subsectors, the cost of capital was initially much higher for smallholdings but then fell gradually in a slow convergence with the cost for estates.

While this convergence was taking place, both subsectors benefitted from lowered costs brought about by their adoption of new technologies. The gains from technical change were greater for the estates, however, as indicated by their substantially more rapid reduction in unit costs, at least until the 60's. This may be partly attributed to the factor-using bias in their favour. In addition, the estates showed themselves better capable of perceiving gains from the adoption of new technologies, as well as superiority in the acquisition and processing of new information.

The moves of both estates and smallholdings to successive technological strata were land and capital-saving. In estate land development they were also quite strongly labour and management-saving throughout (Table 2). Yet the technologies also permitted considerable factor substitution, where smallholdings all along used more labour and less capital than estates, as relative prices would denote. One current problem for smallholdings is the pronounced capital-using bias in the newest technologies, but the probable further convergence of prices will reduce any adverse effects of from this. The management-intensive character of these technologies posesanother immediate difficulty.

The chief indication for future technology policy in respect of smallholdings is the need to ease their adjustment to the

emerging stratum. First, in working along the innovation possibility curve, researchers should be constrained to continue to providing possibilities for substitution between labour and capital. Second, field level extension services should be improved, so that small farmers are helped more in handling more sophisticated management requirements. This latter was a recommendation of a recent Rubber Industry Enquiry (Malaysian Rubber Research and Development Board, 1984), which also proposed substantial restructuring of the less progressive smallholding sector to make it more amenable to technical change.

It should finally be noted that the converging capital prices true of the Malaysian estate-smallholding nexus are likely to take far longer to achieve in the important Indonesian natural rubber sector. In that context the argument for generating a capital-saving and robust technology specific to smallholding condition is much more weighty (Barlow and Jayasuriya, 1984).

FOOTNOTES

1. Thus the research undertaken between period t and t + 1 moves the isoproduct curves from I_t to I_{t+1} (Figure 1), where the capital-labour price ratio for the privileged "estate" subsector (towards which the bias is exhibited) is $P_E P_E$. This subsector then operates at the capital-labour combination E. The unprivileged "smallholding" subsector, whose capital-labour price ratio is $P_S P_S$, operates at S. In

fact, however, with the innovation possibility curve IPC_{t+1}, it would have been more appropriate for the smallholding sector if the production function generating I^*_{t+1} had been developed, enabling it to operate at S*. Because this is not done, an economic loss is incurred.

2. Estates are enterprises of at least several hundred planted hectares, operated by a hierarchical organisation of managers, supervisors, and paid workers, and often coordinated and serviced in large groups by central managing agencies. Smallholdings are mainly independent farms of 1-5 planted hectares, operated by single farming households and often with little access to information and advice. These contrasting institutional arrangements emerged at the first planting of rubber early this century, and have remained important ever since (Table 1). Since the early 60's, the independent smallholdings have been joined by a new class of "group" smallholdings in new land settlement schemes organized by government. These consist largely of individually operated parcels under central managerial guidance, with common processing and marketing facilities (Lim, 1976). The main focus in this paper is on comparing estates and independent smallholdings, however.

3. The specialized hierarchical structure of estates means that data can be effectively sought, assessed, and where relevant applied at field level. Part of this procedure may be field experimentation, which is easily feasible in a big unit and involves little penalty in failure. Such information economies do not apply to individual

smallholdings, where difficulties of communication remain even in the presence of special extension services, and where received information may not be properly assessed or applied. Field experimentation is either impossible or considered too risky within the limited confines of tiny parcels of smallholding land.

This deficiency of smallholdings may be largely overcome, however, by the development of an active extension service where experimentation by the service is undertaken on representative farms, and where a climate of enquiry and dialogue is promoted amongst small farmers. Such a service would nonetheless add a 'management' cost to the smallholding subsector.

4. Progressive independent smallholdings were estimated by Malaysian Rubber Research and Development Board (1984) to cover about half the total area of 800,000 hectares under all independent smallholdings.

The estates for which sample figures are presented are also likely to be more progressive, although not so distinct a sub-group as the progressive smallholdings.

5. The operators of these smallholdings are essentially at "the right-hand tail" of the frequency distribution of management ability, and unable to manage the new technology. In a normal process of agricultural development, they would sell out their holdings to more progressive neighbours and migrate to wage employment where they would secure better

returns. In fact, their children have done the latter en masse, but they themselves have rarely sold their land owing partly to legal problems of transfer.

6. "Land development" includes the clearing of land and planting and maintenance of young rubber trees over six years to maturity, while "production" involves tapping mature trees thereafter.

7. The very similar prices of labour indicated for estates and smallholdings may seem to contradict the conventional understanding that smallholding wage rates are lower. This conventional understanding refers to the average smallholding, while the figures presented here refer to "progressive" elements, whose yields (and consequent share tapping rates) are above average.

8. The technology of South Sumatran rubber smallholdings appears to have altered little since the early plantings from 1910, and is based on unselected seedlings (footnote 9). The efficiency of using this technology has almost certainly improved over time, however, and by 1981 was probably far superior to that of Malaysian smallholdings in the 20's.

9. These are seedlings grown from seed gathered by farmers themselves from the better surrounding trees. They are robust to poor conditions (Table 5), but rarely yield more than 500-550 kg. per ha.

10. Restriction schemes which severely limited the output of Malaysian rubber producers were in force from 1922-28

(Stevenson Scheme, applying to the British Empire only) and 1934-41 (International Rubber Regulation Agreement, incorporating all major producing countries). Both schemes were operated so as to restrict smallholding output relatively more than that of estates (Lim, 1977; Bauer, 1948).

11. These were set to cover the total cost of replanting on smallholdings, and a major part of the cost on estates (Barlow, 1978). The smallholding grants were funded by a special export tax.

12. No data is available on the rate of adoption of particular techniques, although there are broad figures on the adoption (planting) of high-yielding trees.

13. Such substitution involves shifting from 12-15 days half-spiral tapping per month to an approach involving a quarter cut used in association with stimulant once a week. Half-spiral alternate daily tapping is a common system, where a cut is made around half the circumference of the tree on every other day. Owing to rain interference, the tappings on this system average about 12 days per month. A cut around one quarter of the circumference once a week is much less labour intensive, but the labour may be mainly substituted for by chemical stimulant applied to the bark.

14. It was found in a recent official investigation (Malaysian Rubber Research and Development Board, 1984) that extension services to independent rubber smallholders were poorly developed, and that progressive smallholders in particular

could benefit greatly from a more adequate flow of information.

15. Robustness is defined as the ability of a technology to be used profitably at a wide quality and range of input levels. Thus selected seedling materials will survive well and yield considerably more than unselected seedlings under poor management, with minimal inputs of capital in particular (Table 5). They will also give profitable responses to better management and greater capital inputs. Such robustness does not characterize budgrafts, the other improved planting material, which although allowing considerable factor substitution only do this above quite high thresholds of input quality and quantity. Below these thresholds such trees will not survive.

REFERENCES

Abdullah bin Sepien (1978). Technical and allocative efficiency in Malaysian rubber smallholdings: a production function approach. Rubber Research Institute of Malaysia, Kuala Lumpur.

Abdullah bin Sepien, Lim, F.H., and Koh, M.H. (1982). "Production cost of rubber on estates - an ex post analysis." Proceedings of the Rubber Research Institute of Malaysia Planters' Conference, 1982, 247-272.

Agricultural Bulletin (1920-22). Agricultural Bulletin of the Federated Malay States, Vols. 8-10. Kuala Lumpur.

Anderson, K. (1979). Public agricultural research investment in developing countries: towards a politico-economic theory. Unpublished paper, Department of Economics, Research School of Pacific Studies, Australian National University.

Arndt, T.M., Dalrymple, D.G., and Ruttan, V.W. (1977). Resource allocation and productivity in national and international agricultural research. University of Minnesota Press, Minneapolis.

Barlow, C. (1978). The natural rubber industry: its development, technology, and economy in Malaysia. Oxford University Press, Kuala Lumpur.

Barlow, C. (1983). "The natural rubber industry". Outlook on Agriculture, 2 (1), 2-11.

Barlow, C. and Drabble, J.H. (1983). Government and the emerging rubber industries in the Netherlands East Indies and Malaya, 1900-40. Paper presented to the Conference on Indonesian Economic History in the Dutch Colonial Period, December. Australian National University, Canberra.

Barlow, C. and Jayasuriya, S.K. (1984). "Problems of investment for technological advance. The case of Indonesian rubber smallholdings". Journal of Agricultural Economics, XXXIV, 1, 1-14.

Barlow, C. and Peries, O.S. (1977). "On some biases in the generation of technologies by rubber research institutes". Journal of the Rubber Research Institute of Sri Lanka, 54, 445.

Bauer, P.T. (1948). The rubber industry. A study in competition and monopoly. Longmans and Green and Co., London.

Chew, T.A. (1981). The economics of production in Chinese rubber smallholdings in Peninsula Malaysia. Unpublished Ph.D thesis, Universiti Pertanian Malaysia.

de Janvry, A. (1973). "A socio-economic model of induced innovation for Argentinian agricultural development". Quarterly Journal of Economics, 87, 410-435.

de Janvry, A. (1977). "Inducement of technological and institutional innovation. An interpretative framework". Chapter 26 in Arndt et al (1977).

Edwards, C.T. (1970). Public finances in Malaya and Singapore. Australian National University Press. Canberra.

Federated Malay States (1933). Report of the Commission of Enquiry into the constitution, administration, and working of the Rubber Research Institute. Government Press, Kuala Lumpur.

Figart, D.M. (1925). The plantation rubber industry in the Middle East. Trade Promotion Series, No. 2, Department of Commerce, Washington, D.C.

Fisk, E.K. and Osman-Rani (Eds.) (1982). The political economy of Malaysia. Oxford University Press, Kuala Lumpur.

Grabowski, R. (1979). "The implications of an induced innovation model". Economic Development and Cultural Change, 27(4), 723-734.

Guthrie and Co., Ltd. (1951). Guthries. Singapore.

Haji Mohd. Rashid Ahmad, (1983). Structural changes in the Malaysian smallholder sector. Paper presented to the International Rubber Marketing Conference, October. Malaysian Rubber Exchange and Licensing Board, Kuala Lumpur.

Harrisons Malaysian Plantations, Berhad (1983). Annual Report, 1983. Kuala Lumpur.

Harrisons and Crosfield, Ltd. (1944). One hundred years as East India merchants, 1844-1943. London.

Hayami, Y., and Ruttan, V.W. (1971). Agricultural development: an international perspective. The Johns Hopkins Press, Baltimore.

Hicks, J.R. (1932). The theory of wages. Macmillan and Co. Ltd., London.

Ishikawa, S. (1981). Essays on technology, employment and institutions in economic development: comparative Asian experience. Economic Research Series No. 19, Hitotsubashi University, Tokyo.

Kumpulan Guthrie Senderian Berhad (1982). Natural rubber today. Kuala Lumpur.

Lim, S.C. (1976). Land development schemes in Peninsular Malaysia: a study of benefits and costs. Rubber Research Institute of Malaysia, Kuala Lumpur.

Lim, T.G. (1977). Peasants and their agricultural economy in colonial Malaya, 1874-1941. Oxford University Press, Kuala Lumpur.

Lim, K.P. and Chai, W. (1981). "Cocoa-coconuts and oil palm as possible alternatives in replacing old rubber - an economic

appraisal". Proceedings of the Rubber Research Institute of Malaysia Planters' Conference 1980, 368-381.

Malaya (1934). Bark consumption and bark reserves on rubber smallholdings in Malaya. Economic Series No. 4, Department of Agriculture, Kuala Lumpur.

Malaysia (1932-82). Rubber statistics handbooks, 1930-80. Department of Statistics, Kuala Lumpur.

Malaysia (1971-83). Annual statistical handbook of Malaysia. Department of Statistics, Kuala Lumpur.

Malaysia (19779-80). Monthly statistical bulletins, Peninsular Malaysia. Department of Statistics, Kuala Lumpur.

Malaysian Rubber Research and Development Board (1984). The Malaysian Natural Rubber Industry, 1983-2000. Report of the Task Force of Experts, Volume One. Kuala Lumpur.

Mohd. Yusoff (1977). An econometric analysis of the world natural rubber industry. Unpublished Ph.D. thesis, Iowa State University, Ames.

Ng, C.S. (1969). Economic aspects of replanting on rubber estates. Unpublished M.Sc thesis, University of Malaya, Kuala Lumpur.

Pee, T.Y. (1977). Social returns from rubber research in Peninsular Malaysia. Unpublished Ph.D thesis, University of Michigan.

Planters' Bulletins (1970-83). Quarterly publication. Rubber Research Institute of Malaysia, Kuala Lumpur.

Rubber Research Institute of Malaya (1932-58). Annual reports, 1931-57. Kuala Lumpur.

Rubber Research Institute of Malaya (1966). Annual Report, 1965. Kuala Lumpur.

Rubber Research Institute of Malaya (1969).

Whittlesey, C.R. (1931). Governmental control of rubber. Princeton University Press, Baltimore.

Wycherley, P.R. (1959). "The Singapore Botanic Gardens and rubber in Malaya". Gardens' Bulletin, XVII, II, 175.

Yee, Y.L. (1981). Technological change in the Malaysian rubber growing industry. Unpublished Ph.D thesis, University of Queensland.

Yee, Y.L., Lim, F.H. (1982). "Financial performance of rubber estates in 1979". Planters' Bulletin, No. 171, 50-63.

Table 1. Rubber in Peninsular Malaysia, 1900-80.

	Rubber					
	Av RSSI Price[a] M$/kg,fob)	Area ('000 ha)		Production ('000 t)		
		Estates	Smallholdings	Estates		Smallholdings	
1900	6.00	2		-			
10	9.70	219		6		(n.a.)[b]	
20	1.50	883		177		(280)	
30	0.42	763	483	238	(424)[b]	218	(562)[b]
40	0.83	843	547	337	(463)	217	(426)
50	2.38	795	643	382	(341)	322	(507)
60	2.39	783	766[c]	420	(738)	298	(521)
70	1.24	647	1,077[c]	621	(1,140)	595	(787)
80	3.12	492	1,206[c]	609	(n.a)	877	(n.a)

Notes: a. Nominal, for the year shown. For 1900-20 prices are for London market and for 1900 are for crude rubber.

b. Figures in brackets are average yields in kg/mature hectare.

c. For these years areas figures also include group smallholdings in new land settlement new schemes (1960 = 23,000 ha; 1970 = 171,000 ha; 1980 = 391,000 ha).

Sources: (of rubber prices): Malaysia (1971-83).
(of rubber areas and production): Malaysia (1932-82).
(of rubber yields): Barlow (1978).

Table 2. Usage of resources in land development and production, 1922-78.[a]

	Estates			Smallholdings[b]		
	1922	1963	1978	S. Sumatra, 1981	1964	1975
Land development[c]						
Cost, $/ha, nominal	[56][d]	[74]	[n.a.]	[250]		
Labour	842 (63)[e]	1,475 (52)	2,222 (48)	105[f] (93)	[n.a.]	[n.a.]
Management	321 (24)	519 (18)	555 (12)	-		
Capital	175 (13)	835 (30)	1,853 (40)	7 (7)		
Total	1,338 (100)	2,829 (100)	4,630 (100)	112 (100)		
Mandays labour/ha[g]	1,203	362[h]	251	140		
		1964				
Production						
	[12]	[53]	[46]	[250]	[495]	[85]
Yield, kg/ha	300	1,308	1,448	518[i]	1,173	1,345
Cost, $/ha, nominal[j]						
Labour	106 (58)[e]	636 (65)	948 (62)	86[f] (97)	859 (82)	1,062 (86)
Management	43 (24)	113 (11)	216 (14)	-	-	-
Capital	32 (18)	234 (24)	358 (24)	3 (3)	183 (18)	170 (14)
Total	181 (100)	983 (100)	1,522 (100)	89 (100)	1,042 (100)	1,232 (100)
Mandays labour/ha	151	141	107	115	191	166
Prices				Malaysia, 1922		
Labour, $/day[k]	0.40 [0.70][l]	$3.15 [4.50]	$6.20 [8.86]	0.70-0.80[m]	4.50[m]	6.40[m]
Capital, %	6-7	8-10	12-15	30-40[n]	25-30[n]	20-25[n]
Land, $/hectare	100-200	2,000-2,500	10-20,000	100-200	2,000-2,500	8-15,000
Rubber, RSS1, $/kg, fob	0.31[o]	1.60	2.30	0.31	1.50	1.36

(Cont'd over)

Table 2 (Cont'd)

Notes:
a. Figures are averages for each group. Values in this and succeeding tables are in Malaysian $.
b. All data refer to "independent" smallholdings, outside development schemes.
c. Resources used in developing land to commencement of tapping at maturity, including share of management, but excluding infrastructure such as buildings and roads.
d. Figures in brackets [ ] in this row are numbers of companies/estates/smallholdings from which cost/labour input/yield figures are taken.
e. Figures in brackets ( ) are proportions of the total cost per hectare.
f. "Labour" is valued here at an estimated 1922 average total rate in Malaysia of 0.75 cts/day, and the value attributed to "other" is determined according to its proportion in the total cost.
g. At the total wage rates shown.
h. Average wage per tapper in 1963 was $2.85 per day, giving a total payment of 2.85 ÷ 0.7 = $4.07.
i. A comparable Malaysian smallholdings yield from unselected seedlings was 539 kg/ha (Malaya, 1934).
j. Costs are to farm gate level only.
k. For tappers.
l. Wages are quoted in terms both of the cash wage actually paid to tappers, and of the total value of the wage including perquisites (in [ ] brackets). Except in 1922 when there were substantial extra recruitment costs, cash wages are estimated as 70%, and perquisites as 30%, of total wages.
m. Return to share tappers getting 50% of the crop at the yields shown, at concurrent task sizes, and at relevant farm gate prices.
n. Smallholder loans are also limited in amount with a quick repayment period. No interest is charged on the replanting grant.
o. For thin pale crepe. RSS 1 sold at about 1 ct/kg discount to this.
p. Source data is not completely adequate for the above classification, and some estimates have been made.

Sources:[p] (of estate 1922 data): Figart (1925) (informed estimates for land development, and sample of sterling companies for production).
(of estate 1963 land development data): Ng (1969).
(of estate 1964 production data): Rubber Research Institute of Malaya (1969) (estates yielding over 1,104 kg/ha).
(of estate 1978 land development data): Lim and Chai (1981).
(of estate 1978 production data): Abdullah, Lim, and Koh (1982). A guide to the relative contributions of labour, management and other resources is given by the detailed figures of Yee and Lim (1982).
(of smallholding South Sumatra data): Barlow (1983).
(of smallholding 1964 production data): Rubber Research Institute of Malaya (1966)
(of smallholding 1975 production data): Abdullah (1978) (holdings from 1.00 - 2.00 ha only).
(of tappers' wages): Figart (1925), and Malaysia (1932-82).

Table 3. Normalized usage of resources in land development, 1922-78[ab] and 1978 equivalent prices.[c]

	Estates			Smallholdings		
				S. Sumatra		
Land development	1922	1963	1978	1981	1964	1975
Costs, 1978 $/ha						
Labour	5,072	2,509	2,222	632		
Management	1,933	883	555	-	[n.a.]	[n.a.]
Capital	1,054	1,420	1,853	42		
Total	8,059	4,812	4,630	674		
1978 prices				1922		
Labour, $/day[d]	4.22	7.65	8.86	4.52	7.74	7.22
Land, $/hectare[e]	904	3,827	15,000	904	3,872	12,979
Rubber, $/kg fob	1.87	2.72	2.30	1.87	2.58	1.53
Wage : interest rate ratio	64.9	85.0	65.6	12.9	28.1	32.1

Notes a. Samples for each year are as in Table 2.
b. Values of each input in 1922, 1963, 1964, and 1975 (Table 2) converted to 1978 $ by using specially constructed consumer price index with 1978 = 100; 1922 = 16.6; 1963 = 58.8; 1964 = 58.1; 1975 = 88.6 (for sources see below).
c. 1978 equivalent prices secured through inflating actual prices for particular years (Table 2) by index noted under 'b' above.
d. Totals, including perquisites, for estates.
e. Taking mean values quoted in Table 2.

Sources: (of basic data): Table 2.
(of consumer price index): figures quoted by Barlow (1978) (Appendix Table 1.2) up to 1973; Malaysia (1978-80) for 1973-78.

Table 4. Normalized usage of resources in production, 1922-78[a]

	Estates			Smallholdings		
Production	1922	1963	1978	S. Sumatra, 1981	1964	1975
Costs, 1978 $/ha						
Labour	638	1,082	948	518	1,478	1,199
Management	259	192	216	-	-	-
Capital	193	398	358	18	315	192
Total	1,090	1,672	1,522	536	1,793	1,391
Labour, mandays/ '000 kg.ha	503	108	74	222	163	123
Costs, 1978 $/'000 kg/ha						
Labour	2,127	827	655	1,000	1,260	891
Management	863	147	149	-	-	-
Capital	643	304	247	35	269	143
Total	3,633	1,278	1,051	1,035	1,529	1,034

Note: a. Notes for Table 3 refer.

Table 5. Features of land development and production technology, 1980's

Elements and practices	Characteristics[a] and constraints	Research focus
Cultivars[b]		
Unselected seedlings [USS] (grown from unimproved seed collected by farmers from better-performing trees)	Low yielding. Some possible substitution[c] away from predominately L input possible in land development (by C in mechanical clearing and agrocides), but not in production. Very little output response[d] to added L or C. Robust[e] to poor conditions.	No research.
Selected seedlings [SS] (produced by controlled hand pollination, after systematic selection of outstanding mother trees)	High-yielding. Wide possible substitution in land development (L in hand clearing and weeding; C in mechanical clearing, agrocides, fertilisers, and covers), but more limited in production (L in tapping cannot go above d/3[f], although C can be substituted as fertilizer and stimulant). Considerable output response to added C in land development and in production. Quite robust to poor conditions involving indifferent management and minimal C inputs, and here will yield more than USS (though yield still low at about 700 kg/ha). Not officially recommended for smallholdings, owing to easy confusion of seed with USS.	On developing higher-yielding and environmentally better adapted SS, especially under C - using conditions.
Budgrafts [BG] (derived by cloning selected seedling material).	High-yielding. Limited possible substitution in land development (L in hand clearing and weeding; C in mechanical clearing, agrocides, fertilisers and covers) with substantial L and C threshold below which plants (which are not robust) may not survive. Wider possible substitution in production (L in tapping and maintenance; C in fertiliser and stimulants). Considerable output response to added C in both land development and production. Generally higher maximum yield than SS.	As for SS.[g] Major focus is on BG rather than SS, however, and a far wider range of BG is accordingly available now.
Land clearing and preparation		
(of jungle or old rubber trees, and preparation of ground for planting. Methods range from exclusive use of hand tools to that of large scale machines, with a further technique involving use of tree poisons).	"Output" alters between methods, with mechanical clearing generally producing clean ploughed ground which eliminates disease. Very wide possible substitution where whole range of tehniques is taken into account, with two extremes of purely hand clearing (95%[h] L, with C as a few hand tools) and purely mechanical clearing (30% L as drivers and a few other C - implementing tasks; C as bulldozers and tractor cultivators). Intermediate L-C mixes also possible, and C may also be in form of tree poisons. C - using mechanical methods cannot be applied in blocks less than 2-3 ha.	On developing more effective C - using methods.

(Cont'd over)

Table 5 (cont'd)

Propagation and planting[h]		
(of seed. Methods range from seed planted "at stake" in field [and subsequently budgrafted if this is needed] to "advanced" methods involving the production in separate "nurseries" of budded stumps, stumped buddings, or seedlings in polybags. Such advanced materials are then planted in the field, reducing immaturity by 1.5-2.0 years with substantial economic benefit).	"Output" alters between methods, with extremes of seed-at-stake taking 6 years to maturity compared to stumped holdings taking 4 years. Wide possible substitution where whole range of techniques is taken into account, with 2 extremes of seed-at-stake using hand methods (95% L, with C as hand tools) and nursery methods with emphasis on material inputs (50% L, with C as hand tools, fertilizers, agrocides, and transport items). Considerable substitution also possible within each method, whose output in terms of time to maturity is responsive to added C as fertilizers and agrocides. Scale economies mean that nurseries for individual smallholders are uneconomic, and here centrally organized facilities must be provided. Special risks of loss exist in establishing budded stumps and stumped buddings in the field.	On advancing maturity even further, and on reducing establishment risk with budded stumps and stumped buddings, both goals involving C - using changes.
Density of planting		
(of trees in the field. Methods range from initial planting density of 400 trees/ha [reducing to 300 trees in mid-maturity] to 600 trees/ha [reducing to 450 trees in mid-maturity]).	Average densities 350 trees in tapping/ha on estates, and 450 trees on smallholdings. In terms of associated inputs, higher smalholding density essentially substitutes L in production (in activity of tapping) for C (in fertilizers and stimulants). At constant level of C inputs, density increase from 350 to 450 trees in tapping/hectare adds about 10% to output, with parallel rise in L. Further though diminishing output rises result from densities even higher. Higher densities also provide safeguard against risk of undue absolute tree loss, but increase time to maturity and produce smaller trees with thinner bark.	On measuring effect of initial densities ranging from 300-400 trees on yield and associated characteristics.
Tapping[h]		
(of trees in the production phase. Methods range from S/4[i] once a week with stimulant, to daily S/2. Commonest approach is S/2 alternate daily, with stimulant often being applied to renewed bark on estates. Task size ranges from 250 to 600 trees/tapper/ tapping, depending to some extent on nature of cut and stimulant policy.	Output of rubber alters between methods, with extremes of S/4 once a week with stimulant yielding about 80% of S/2 alternate daily. Tapping is essentially L - using, but there is considerable possible substitution as hand approaches are reduced in favour of stimulants and fertilizers, and task sizes are raised (60% L to 45% L). Limited extra output beyond that given by S/2 alternate daily for added C (stimulants and fertilizer) in tapping, with physiological constraints meaning that dryness usually arises from excessive long-term efforts in this regard.[j]	On comparing wide variety of methods using many clones and seedlings in each treatment. Particular concentration on use of stimulant and L - saving tapping techniques. Better tapping tools also being developed.

(Cont'd over)

Table 5 (cont'd)

Cultivation[h]		
(of land during both land development and production phases. Methods involve hand weeding, legume covers [land development only], fertilizers, and agrocides).	Output of rubber alters between methods, with fertilizers in particular (in both land development and production) increasing output by up to 20%. Wide possible substitution where whole range of techniques is taken into account, with 2 extremes of hand weeding (95% L, with C as hand tools) and heavy use of fertilizers and agrocides (20% L in C - complementing activities. Substantial output response to all cultivation inputs, especially fertilizers.	On developing more effective C - using methods.

Notes: a. Of the existing (early 80s) production function associated with each element and practice.

b. Average output of cultivars, and average associated usage of L and C in land development and production, detailed in Table 2 (where USS = 1922 and S Sumatra '81 data; SS and BG = 1963 and 1978 data).

c. Between labour (L) and capital (C) at typical input and output levels.

d. Over typical output from typical resource combinations.

e. In the sense of being profitable at a range of input levels, including the low L and C inputs characterizing poor conditions (see footnote 15).

f. Third daily tapping, to which predominantly labour input in this activity is crucially limited.

g. In fact, SS and BG are complementary, in that clonal selection and generative breeding alternate regularly in systematic breeding programmes.

h. Percentages quoted here are of total value of L and C, excluding management and land. These percentages are not quoted under "cultivars" heading, owing to insufficient data.

i. S/4 represents a "quarter spiral" cut, and S/2 a "half spiral" cut. Most suitable method also varies with number of years for which trees have been in tapping.

j. With SS, dryness arises at tapping intensities over d/3.

Source: (of technical information): Planters' Bulletins (1970-83).

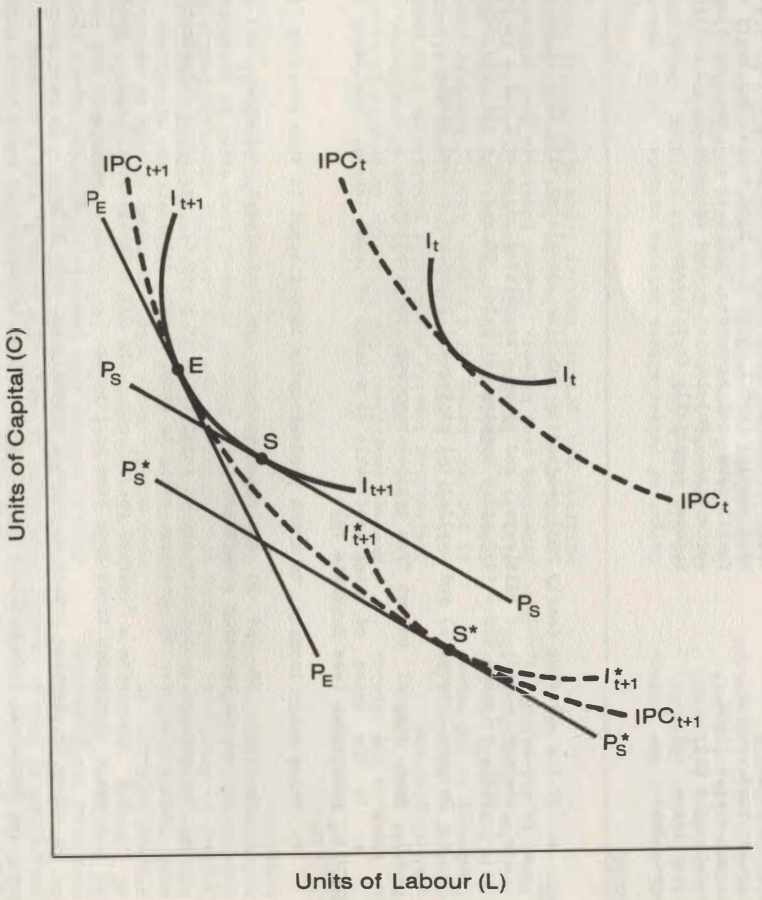

Figure 1. Technology generation biassed towards estates.

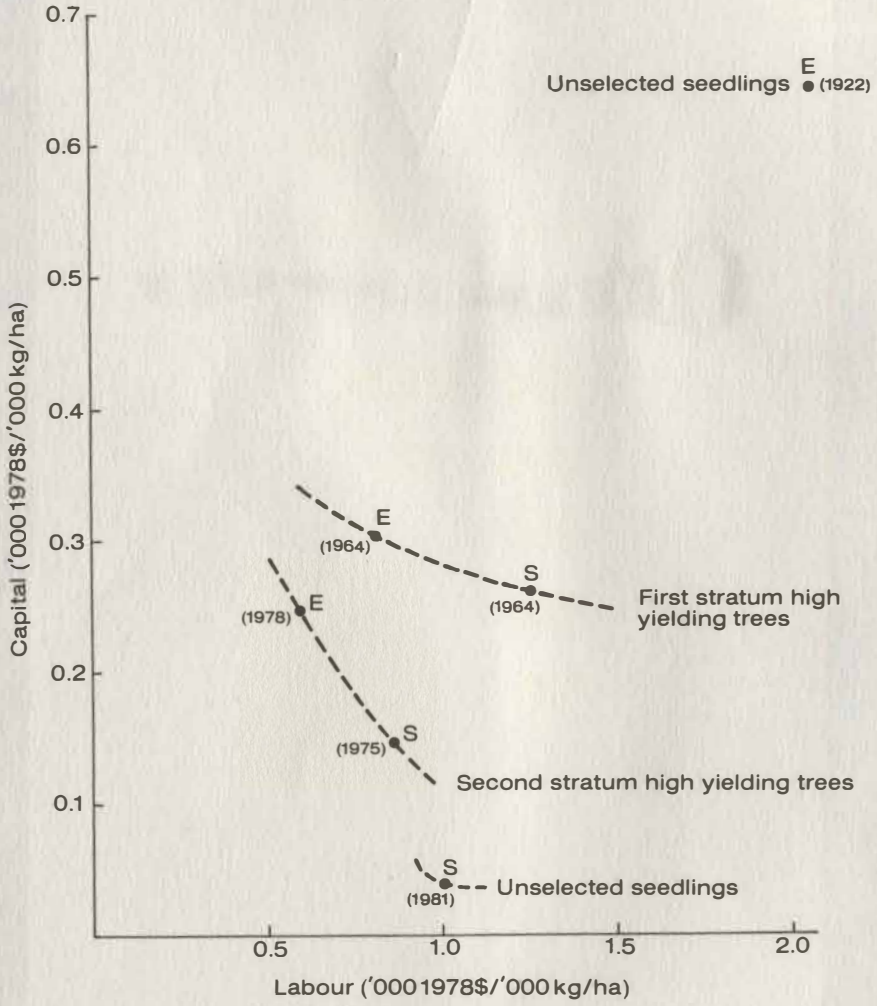

Figure 2. Normalized labour and capital combinations in production 1922-1975 (... = isoproduct curve; E and S = respective estate and smallholding C-L combinations; ( ) = relevant year to which data applies).

Source: Table 4.