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Technological Capacitation and International Division of Labor

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This paper was presented at the International Conference on the Pacific Community and Latin America, Easter Island, Chile, 18-23 October 1979.

I. Introduction: - the OPTAD in a perspective for industrial and technological cooperation

This paper is intended to deal with certain theoretical aspects of the perspectives for industrial and technological cooperation among the countries sympathetic with the notion of "OPTAD" - an Organization for Pacific Trade and Development or an inter-governmental forum for mutual policy coordination in the style of OECD but with its members consisting of both developed and developing countries in and around the Pacific Basin.

The author believes that international cooperation can be made more effective through a pragmatic and locally focused approach than through the formalistic "common efforts" characterizing the contemporary activities of global institutions like the United Nations and the OECD. However, the author wishes to disassociate himself from the particular version of the OPTAD which is centered on the five industrialized countries (U.S., Canada, Japan, Australia and New Zealand) with invitation opened to developing countries as associate members.

Thus in this paper, after a preliminary reflection upon the advantages and disadvantages of "late comers" (in Section II), it will be demonstrated that the OPTAD as a closed "Technology Club" would leave little room for technologically less advanced countries. (Section III). It will be further shown that the world technology market, imperfect as it is, can be described essentially as one for oligopolistic competition rather than a collusion of oligopolists and that it is important to distinguish between the short-run economic effects and the long-run impact on technology diffusion in regard to the innovator's pricing of technology. (Section IV).

The Pacific Community is comprised of a large number of countries at widely different levels of development. If it should function primarily as a club for cooperation and policy coordination among its members at a level practical enough to resolve concrete real-world problems, it will require a multiplex-structured framework of cooperation that can respond to different types of problems envisaged between LLDCs, MSACs, ADCs and DCs. Apart from its organizational implications, the effectiveness of its intended function would depend on the availability of a reasonably firm vision and evaluation criteria regarding the dynamics of international division of labor. Particularly important for relatively advanced countries would be how to cope with the need for industrial adjustments to constant shifts in their edges of comparative advantage. For less advanced industrializing countries a central concern would be what development paths are visible for their structural transformations and how to accelerate the process of technological capacitation along such paths.

Such a precondition would not be fulfilled without a collaborative system of forward planning, equiped with firm insight into the very speed at which a given country is catching up with other technologically more advanced ones.

By way of an illustration of the nature of the problem, the remainder of this paper focuses on relatively skill- and technology intensive capital-goods sectors, rather than labor-intensive consumer-goods sectors. This is not because the latter sectors are unimportant in the perspective of technological capacitation, but simply because little attention has been paid so far to the catching-up process in the former sectors. A retrospective analysis is attempted in Section V of the historical experience of Japan in the electricity-generating machinery industry. The final section of this paper takes up some of the policy implications of this retrospection with a viw to hinting at an agendum for collaborative research to be initiated as a substantive groundwork for the realization of the OPTAD type policy coordination forum.

II. Experiences in the narrowing of technology gaps: - advantages and disadvantages of "late comers"

The fact that countries like Fed. Rep. Germany and Japan, both having started as late comers, succeeded in rapid growth and structural transformation is often alluded to as an evidence of late comers' advantages. It is generally accepted that this sort of advantage pertains to diffusion of technology at relatively mature phases of its life cycle, rather than to the development of new technologies.

Central in the conventional technique of forecasting the rate of adoption of new innovation is the familiar S-shaped curve:

$$A(t) = \frac{A(\infty)}{1 + EXP[\ -b(t-t_0)\ -c]}$$

where A designates the rate of adoption at given point of time (t) and the initial condition (at $t = t_0$) is given by $A(\infty)/[1+EXP(-c)]$; b represents the speed of diffusion.

It has been empirically demonstrated , e.g. by Mansfield (1961) referring to the U.S. industries, that parameter b was an increasing function of the profitability of the new technology adoption or the rate of growth of production in the adopting industry. It was also shown that b tended to be the larger, the smaller the amount of capital investment needed to adopt new technologies, and the later the year when the new technology was first adopted. Late comers' catching-up performances at higher speeds than early adopters are supported by various later studies. E.g., Bundgaad-

Nielsen (1973 and 1976) demonstrated a few industries for which the relationship below proved statistically significant:

$$b_i = \alpha + \beta t_{0i} + \gamma g_i$$

where t_{0i} stands for the year when given new technology was first introduced in i-th country and g the rate of growth of the maket facing the industry in that country. Generally it is likely that $\beta > 0$; $\gamma > 0$ if g refers to the period <u>after</u> t_o but $\gamma < 0$ if g refers to the period <u>before</u> t_o. (1)

Late comers's advantage in terms of economic gains would be even more obvious in view of the existence of substantial time lags between basic research and first adoption of its outcomes for commercial applications via development. Thus. a country (like Japan up to the 1960s) which happens to acquire leading edges in international competition by mastering and minor improvements of imported technologies will be able to enjoy a larger sum of economic gains than the country from which she first imported the base technology, even when she has not quite caught up technologically with the latter.

However, this advantage will have to disappear sooner or later unless the rate of new innovation in technologically leading countries is sustained at a high level. (2)Narrowing technological gaps vis-a-vis followers would put a squeeze on the leaders's room for income earning through product trade, thus compelling them to impose severer conditions for transfer of their technology. Late comers thus eventually faces a new task of technology generation with their own basic and applied research and development: - situation facing countries like Japan today.

Doesn't the late comers' advantage hold for catching up in basic and applied research as well?

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(1) For example, oxygen converters were first introduced in Sweden in 1956; it was not until 1963 in France and 1966 in Italy. To reach the point of "half-time" ($A(t)/A(\infty) = 50$ %), Sweden took 6 years while Italy and France needed only one year and three years respectively. See Bundgaad-Nielsen (1976).

(2) In this connection one may note Paul Krugman's theoretical treatment of the theme that "higher Northern per capita income depends on the quasi-rents from the Northern monopoly of new products, so that North must continually innovate not only to maintain its relative position but even its real income in absolute terms. (P. Krugman, 1979)

There have been controversies on the Schumpeter-Galbraith contention that the efficiency of technology generation increases with the size of R and D organization. (E.g. see Fisher and Temin, 1973.) Indeed, there is a strong possibility, both theoretical and empirical, that given particular R and D group enjoys a phase of increasing return only after having continued its exploration in a particular direction for some years. But Nelson (1977) warns about the propensity of researchers to stick to their old lines of search longer than they should. Fluctuations in the rate of innovation in given industry may be attributed at least partly to such behavioral pitfalls since a single trajectory of R and D efforts falls eventually into a phase of decreasing return.

Countries which have decades of experience in R and D are usually aware of this danger and make an effort of diversification of R and D projects. The problem for late comers is then how to gain access to signals of increasing return to research out of the on-going activities in advanced countries, and to avoid pulling themselves on to the parallel-oil-fields-digging type inefficiencies of R and D competition.

Institutional development suited to the generation of own technology is likely to differ in many respects from the one which has happened to be effective in absorption and assimilation of foreign technology. Also it is doubtful that late comers should be able to secure collaboration in R and D with advanced countries through formation of an economic community.

This last point is examined further with the help of "economics of club formation" in the next section.

III. Economics of "Technology Club" formation: - a case against an advanced nations-centered OPTAD

There exists always scope for technological cooperation in a closed "club" style for countries which are capable of learning from others' R and D and at the same time whose own R and D offer something for others to learn from. The theory of "Invention Market" of the kind put forward by Nordhaus (1969) will find a useful application in this context.

Suppose that each i-th country's productivity $(X/L)_i$ is a function of the following form:

$$(X/L)_i = h_i(R_1, \ldots, R_i, \ldots, R_n)$$
$$= \sum_{j=1}^{n} \lambda_{ij} h_j(R_j) , \qquad (i, j = 1, \ldots, n)$$

where λ_i stands for the extent to which i-country enjoys the "spill-over" effects of other countries' R and D.

It is likely that $\lambda_{ii} \geq 1$ and hence $\mu_i = \sum_{j=1}^{n} \lambda_{ij} > 1$. And for simplicity's sake assume that

$$h_i(R_i) = kR_i^{\alpha} .$$

If the total demand for the products of technology is given exogenously, the optimization criterion may be stated simply as minimizing the collective cost of production including R and D costs:

$$\text{Min.}C = w\sum_i L_i + r\sum_i R_i$$

where w and r stand, respectively, for wage rate and the annual rate of expenditure corresponding to the required level of R.
The optimum number of countries ($\tilde{n}$) and the corresponding total R and D ($\tilde{R}$), compared to what would obtain if free entry were permitted all the way till excess profits disappear (n* and R* respectively), are:

$$\tilde{n}/n^* = \left(\frac{\mu-\alpha}{1-\alpha}\right)^{-\alpha}, \quad \text{and} \quad \tilde{R}/R^* = \frac{\mu-\alpha}{1-\alpha},$$

Work by Minasian, Mansfield, etc. lets us expect α to take a value around 0.1.

Apparently there would be no club formation if any country's productivity improvement depended soley on her own R and D: namely $\lambda_{ij} = 0$ for $j \neq i$, hence $\mu \approx 1$.
For given $\mu(>1)$, the larger the value of α(elasticity of productivity with respect to R and D), the smaller the optimum number of countries ($\tilde{n}$) and yet the larger the Club's total R and D expenditures. A similar story applies to the value of λ(ease of cross-country diffusion of R and D results).

μ might decrease as the number of Club members increases for some reasons or others; then $\tilde{n}$ would be even smaller, and $\tilde{R}$ would be still larger, than otherwise.

This simplified general model is static in nature but is still good enough to hint at what parameters are more essential than others for a Technology Club to be a cost-effective-solution. In reality the size of market envisaged by each country, as well as the values of α and λ varies from country to country. But the model readily suggests that only those countries which are relatively efficient in their R and D (large α) and have high capabilities to learn from others (large λ) are likely to accept themselves into a collusive agreement.

Technologically less advanced countries, which may have a strong will to learn from others but from which others find little to learn, may find it difficult to have themselves accepted as Club members. It would be more realistic to allow for positive externalities associated with intra-Club trade expansion. It would require a more sophisticated model to treat explicitly the trade-off relation envisaged in the choice of Club members as between the the income gains arising from acceptance of a technologically poorer partner and the loss in R and D efficiency resulting from it.

It is difficult to imagin the Pacific Community to function as a

technology club as well as a trade club. But if an effort is to be made towards some form of progressive technological cooperation, the initiatives ought to come on the part of technologically less advanced nations. The OPTAD scheme which stresses the leading role to be taken by the five industrially developed countries, as often suggested by Prof. K. Kojima, could hardly include a technology club type arrangement with developing nations. To make it still worse, any collusive arrangement among the initial leading members , should it ever come into being, will make them consider unattractive to get the membership reopened to technologically less advanced nations.

IV. Pricing of technology under oligopolistic competition: - another case in favor of keeping the OPTAD as an Open City rather than a closed Community

The present rules of the game of international competition and cooperation are such that the advanced countries wish to maintain a system of conflict resolution via competitive markets at least in the long run, while making some efforts of mutual collaboration and partial coalescence in attacking technological frontiers of world-wide interest. It is highly unlikely that these rules should be modified to any radical extent with or without an OPTAD.

Lacking in all of Kissinger's Three Securities (energy, grains and weapons), Japan is pledging in favor of the Krugman (1979)-type game where technological comparative advantage is to offer a key instrument for her Economic Security. Some contend that Japan's survival rests on how she utilizes her technology as a bargaining power in order to warrant a stable share in the world market for herself. Such a statement, probably inspired by the balance-of-power game of old days, can be awfully misleading.

As Arnold Wolfer (1962) once put it, "security" is a frequently invoked word but the concept is more ambiguous than it first sounds. It would be rather anachronistic, let us hope, to associate security with the absence of the possibility of a "threat to survival". With Krause and Nye (1975), we should be satisfied by redefining "security" as what constitutes a "value" in itself, instead of an instrument of power: - a value along with other clusters of values which national security policies are intended to protect (such as economic welfare, political independence and prestige). Then, economic security implies essentially the absence of threats to the minimum acceptable level of national economic welfare. This is in fact consistent with the convention in economic analysis whereby our expected future streams of income are discounted by uncertainty.

Even though technological leaders in some (and not all) sectors are to play in an imperfect market, the situation may be more realistically simulated by oligopolistic competition than by oligopolistic coalescence. The Economic Security strategy drawing on technological comparative advantages may thus assume charaster-

istics similar to an oligopolist pricing strategy under threats of emulators. An application of control theory à la Gaskins (1971) and Magee (1977) in this context can provide some useful insight.

(1) Objective function to be maximized (Present value of the earnings from technology sales):

$$W = \int_0^{\infty} [\ p(t) - c\ ]\ q[p(t),\ t]\ e^{-rt}\ dt$$

(2) Amount of technology to be transferred through product trade and/or licensing:

$$q[p(t),\ t] = f[p(t)]e^{gt} - x(t)$$

(3) Speed of response of emulators. ($dx/dt = \dot{x}$):

$$\dot{x}(t) = k[p(t) - \bar{p}]$$

If one likes, $k = k_o e^{\alpha gt}$ and $w(t) = x(t)e^{-\alpha gt}$.

where p: Terms (price) of technology transfer;
$\bar{p}$: Limit price below which trade would be uneconomical;
c: Cost per unit of technology or its product; (1)
f(p): Future world demand for the particular technology as envisaged at given point of time;
x: Amount of the same technology or its substitutable to be sold by emulators;
r: Discount rate;
g: Growth rate of world demand ($g < r$);
k: Response coefficient.

The solution of this pricing policy model is the one that maximizes Equation (1) under constraints (2) and (3). It is given as a path lying somewhere above the locus that warrants no emulator's entry, $p(t) = \bar{p}$ where $\dot{w} = 0$, and below the short-run profit maximizing price (locus $\dot{p} = 0$). The higher the current price is set, the faster the response of emulators. The long-run equilibrium is envisaged at a point where $\dot{x} = \dot{w} = 0$ (no more new entry) and at the same time $\dot{p} = 0$ (no more price decline), and at this point the innovator's expected share in world market ($\hat{s}$) is equal to $1 - \hat{w}/f(\hat{p})$, and $\hat{w}$, long-run share of emulators, is given by:

$$\hat{w} = \left\{ \frac{r}{g+r}\ [f(\hat{p}) + f'(\hat{p})(\hat{p}-c) - \frac{ko(\bar{p}-c)}{\alpha g+r} \right\} \Big/ f(\hat{p}).$$

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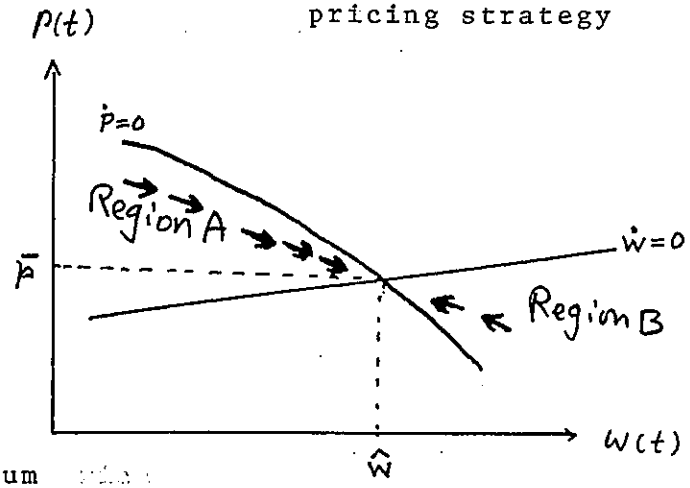
(1) It is reasonable to introduce here explicitly factors affecting c (unit cost) such as the country's own R and D, world stock of knowledge from which she can learn, relative price of production factor, e.g. wage rate, in such a way that a similar form of cost function may be applied to both innovation leaders and followers. This possibility is neglected here, however, since our primary concern is to see how an innovator in leading position at given point of time makes his decision for the pricing of his technology.

Fig. 1 An oligopolist's pricing strategy



The higher is the discount rate, the smaller $\hat{s}$. That is, the innovator will put less weight on the long-run market share, and adopts the "Make-hay-while-the-sun-shines" type policy. The higher the innovator's cost advantage, the lower the price charged now and he anticipates a larger market share in the long run.

Also it is interesting to note that the long-run equilibrium price, $\hat{p}$, will be lower in world stagnation ($g < 0$) than in prosperity.

At a later stage as the particular technology has been well absorbed into the importers' own production lines, the cost advantage may shift in favor of the latter - a phenomenon often called the "boomerang" effects in Japan. When this occurs, the catching-up late comers are to find themselves in Region B in Figure I and move from there towards point ($\hat{p}$, $\hat{w}$), cutting into the previously established market share of the countries from which they used to import.

Particularly important in the context of this paper is the finding that an institutional set-up which keeps the basic response parameter (ko) at a reasonably high level will make the leading innovator choose the strategy to sell larger quantities at lower prices at any point of time. That is, a reasonable degree of competition among technologically advanced countries implies a greater benefit for the importing developing countries. On the other hand, should the importing countries insist too prematurely upon diversification of their import sources, the innovator would rather raise the price and sell less of his technology in favor of short-run profit earnings.

The developing importers, too, join sooner or later the position of emulators. They have their own k's that determine the speed of catching up. A lower p(t) may well have the effect of delaying their effort of hatching k in their own industry.

In regard to the relatioships between technology sellers and importers, one may stress the following implications of the above reflection:

(a) The existence of technological gaps is not per se a cause of the persisting inequalities between the advanced and the less advanced; it only suggests the importance of technological capacitation for the latter to participate in the dynamics of international division of labor;

(b) A collusion of the countries located in Region A would not only result in reduced accessibility to new technology for developing countries but also would delay the emergence of new followers in Region B;

(c) An operationally useful theory of international trade will have to take into account more explicitly the time dimensions of the structural adaptation process underlying the development of late comers' technological capabilities.

V. Sequences of technological development: - a retrospection in the historical experience of Japan

First, a model for a priori theorizing, and then a retrospective analysis of a historical course of events.

Consider a particular sector of technology or of industry. The logistic curve fitted on the learning process has a saturation level, which stands for a target of planning for technological capacitation. Beneath the logistic curve lies a model of capacity build-up behavior similar to those often used in the economics of expectation formation, such as:

$$\frac{S_t}{S_{t-1}} = \left(\frac{S^*_t}{S_{t-1}}\right)^{\beta}$$

where S* indicates the desired level of stock and β a response parameter ($0<\beta<1$). This can be shown to be equivalent to, e.g., a Gompertz-type logistic:

$$S_t = S^* a^{b^t},$$

in which $S_t = aS^*$ when t=0 (the so-called half-time) and $\beta = -\log b$.

Target S* should be formed realistically, taking into account the experiences gained through production, engineering, development and adaptive research in the past, and also with an informed outlook over the programs for institutional and structural diversification required to reach the target.

Thus, S* is a function of planned imports of new foreign technology, domestic R & D and engineering organization, industrial training programs, as well as various incentives policies designed for promotion of import substitution.

But the planning of such policy inputs cannot usually be continuous, if modifiable occasionally on a "rolling" basis. And, with or

without those policy interventions, the social and institutional changes that underlie innovation processes are historically known to be at best "step-wise". Shifts from one step to the next are accompanied by policy adjustments which are sometimes expansionist and sometimes reformist in nature. Thus, in reality, the learning curve shifts up intermittently from one planning period to the next. And in all likelihood occasional economic changes and policy modifications will inflict further discontinuities upon an otherwise smoother development path.

This is illustrated in Figure 2 below. It is not at all surprising if a time series study on historical paths of capacitation encounters certain kinds of cyclical fluctuations that the logic of a single logistic learning curve cannot comfortably strangle off.

Thomas Vietoricz (1972) once studied the electrical machinery industry in Mexico and attempted to put into relief the concept of developmental sequences in technological capacitation and thresholds for successful participation in international competition for a number of specific product lines.

The various curves shown in Figure 3 plot the technological level of the most sophisticated product (measured in terms of KVA capacity) as it first appeared in domestic (commercial) product lines. In the case of power transformer and electric motor it can be seen clearly that the technology level of the Mexican industry rose rapidly in the early years, but the rate of increase diminishing in subsequent periods. The second jump seen after 1969 in electric motors reflects the addition of new larger-capacity motors. Particularly noteworthy is the fact that the modernization of electric motor production facilities for export purposes started more than a decade after the initial production for domestic market, and that it began with much smaller models than those being currently produced for domestic uses.

It is regrettable that the Vietoricz study covers only the development paths up to late 1960s, and probably fails to see through the entire process of catching up.

By way of a supplemental evidence, a retrospective analysis of the experience in Japan, recently conducted by the author, will be reviewed below. Here again, heavy electrical machinery, especially items for power generation, are chosen. This industry enjoyed a consistently rising trend of electricity demand since late 1880s - a factor convenient for us to concentrate on the dynamics of supply capability relatively undisturbed by any fatal irregularities on the demand side.

Water wheels, boilers and steam turbines are selected for illustration purposes. Table 1 summarizes in capsule form the developmental

Fig. 2 Shifting learning curves with structural adjustments

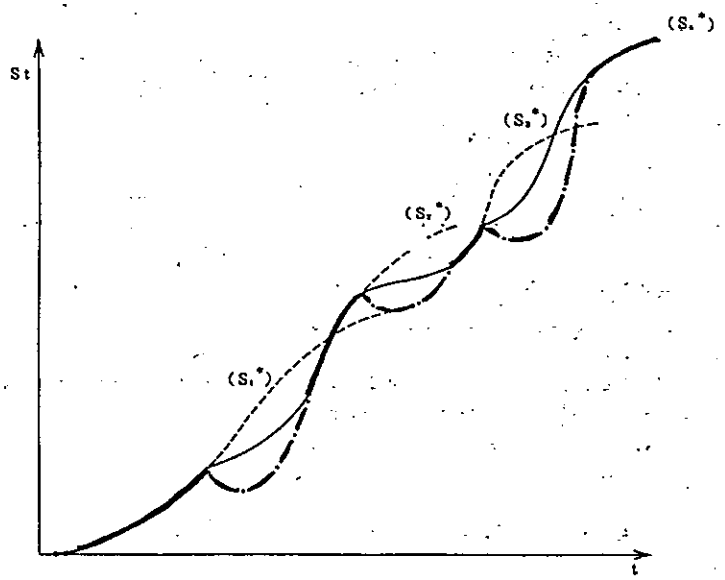
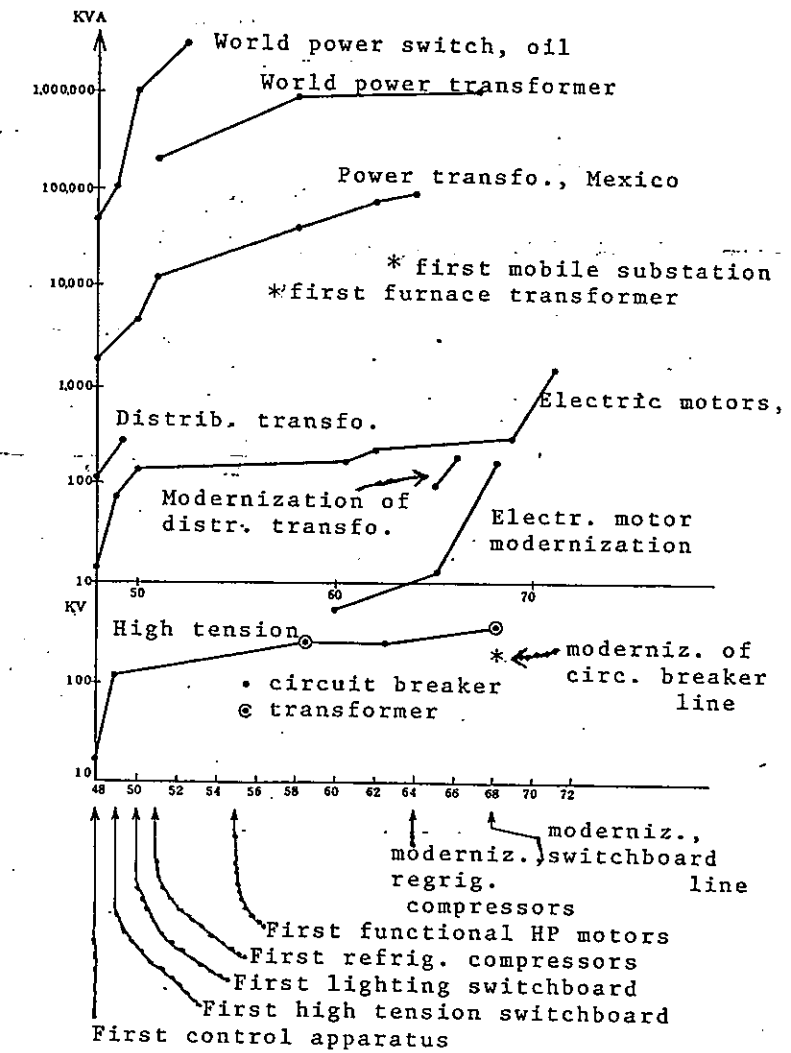


Fig. 3 Development sequences in heavy electrical equipment manufacturing in Mexico



Source: T. Vietoricz (1972)

sequences in those three productlines through the period about to enter World War II.

A more generalized pattern of developmental sequences that is more or less commonly applicable to all the three subsectors may be represented by the following four Stages:

Stage I : Increasing imports of power equipment and trial production of various domestic models; gradual progress in the environmental conditions favorable for import substitution , including public procurement systems for electrification, diffusion of related technologies; [first gestation period]

Stage II : Sudden increases in effective demand for domestic products, caused by the cessation of imports during the World War I period; a big push by the Government towards "technological autonomy"; [first stimulus for the "widening" of infant industries]

Stage III: First ordeal of international competition (even in public procurements) and renewed efforts of absorption and assimilation of foreign technologies; some progress in the diversification of domestic product models and adaptive improvements on imported models; [first serious internal adjustments and the second gestation period for international competition]

Stage IV : Near completion of catching up in these particular industries, with cost advantage emerging in large-capacity products; emergence of mutually competing firms within each subsector; relative narrowing of the KW capacity variation in the product-mix of each subsector; [catching up with international level of technology].

"Turbines" alone are examined in Figures 4, 5 and 6 which reveal some more interesting features of the sequential development processes. (1) Here are some of the findings from these Figures and related information.

(i) Initial gestation period:
Two factors should be noted in this connection: Firstly, progress in technological substitution on the demand side, and secondly, active demand policies, as the utilization of related technologies (especially for power distribution) took root.

In the case of wheels, the first factor needed nearly 30 years

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(1) A more detailed presentation is available in Japanese (M. Usui, 1979)

to evolve (see Period 1 in Table 1) and the second factor became visible only subsequently (Period 2). For boilers, both factors presented themselves rather simultaneously in their Period 1 as well as Period 2. Both factors emerged simultaneously within Period 1 of turbines. Apparently turbines benefited by the experience accumulated with the two predecessors and thus could complete their Stage I in no more than a decade.

(ii) Import substitution drive:
World War I which stopped most imports from abroad pushed the Government to adopt an active import substitution strategy, including "technological autonomy". The latter meant above all R and D activities undertaken by Japanese researchers themselves with the help of foreign experts and the establishment of a gradually increasing number of public technological research and diffusion centers. But it was the import stoppage that actually stimulated the widening of domestic infant industries, including the introduction of large sophisticated models in domestic production.(1)

This phase was only short-lived, however. With the end of the War, the infant industries, particularly for relatively large capacity products, quickly retreated in face of international competition, and were compelled into another decade of gestation which accompanied a resurge of foreign technology imports.

The Government seems to have had then little control over the course of events and been institutionally incapable, if it wished, of barricading its technological autonomy policy against the inflow of imports. It is difficult to say, however, whether a prolonged protection at this particular point of time, had it been ever possible, would have positively contributed to the efficiency of the subsequent efforts of technological capacitation.

(iii) Movement along the shifting cost curves:
Figure 5 shows a relationship between the development of domestic technological capabilities during Stages III and IV and the cost of production of equipment per kw of its capacity. It should be noted that the capacity level plotted on the horizontal axis represents that of the currently largest model when it first appeared in domestic production. (Note that this cost per kw has little to do with the price of electricity actually charged.)

It seems that the industry struggled at (at least) four successive

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(1) The boiler industry, which had been overwhelmed by foreign enterprises even during Period 2, left little room for domestic enterprises . It thus failed to take advantage of this opportunity for domestic production of larger models. Instead, some indigenous innovations (e.g., Takuma Boiler) took place in small capacity categories, which saw wide use as industrial boilers.

thresholds or steps for modernisation during the last two Stages: 2o MW, 30 MW, 55 MW and then 75 MW. Each threshold was overcome as the industry came to challenge a higher level of capacity . In fact, Stage III was a period during which the first 20 MW level problem was conquered to face in turn the second 30 MW-level problem. It was at Stage IV when the industry, after having passed the second threshold, and the third one, finally came to challenge a higher barrier above 75 MW level.

It should be noted therefore that our Stage can be comprised of two or more steps for progress. It is open to question whether some of these steps could have been skipped with the help of a more careful planning so as to shorten the time period required for learning by doing.

(iv) Product differenciation and industrial organization:
Important features of Stage III were not only the advancement of KW ratings of new products, but also that a degree of product differenciation took place even for higher-capacity models. However, only a few firms were active yet to produce them.

There was only one kind of turbine for electricity generation and another for ships during Stage II. The number of high-capacity turbine models increased to five for electricity generation and six for ship engines. Diversification reflected to a large extent that of the sources of technology imports from abroad.

Catching up at a further increasing level of technological complexity seemed to be facilitated by a reasonable degree of competition in the supply market. Thus Stage IV witnessed an increasing number of competing domestic firms producing similar products. This may be interpreted as an indication of the diffusion of "design technology" - an important step for deepening of technological capacity.

VI. Some policy implications

Even though the analysis along the above line is yet far from being complete, it would be worthwhile to explore its implications for the issue of policy efficiency in technological catching up as well as the requirements of positive adjustment to changing patterns of international division of labor.

As for the first issue, there seems to be a merit in distinguishing the "effectiveness" criterion from the "efficiency" criterion in appraisals of industrial and technological policies. "Efficiency" here refers as usual to the notion of economic efficiency in the overall allocation of resources and thus stresses the efficiency

Fig. 4 Steam turbines: highest-capacity products imported and domestically produced in various years

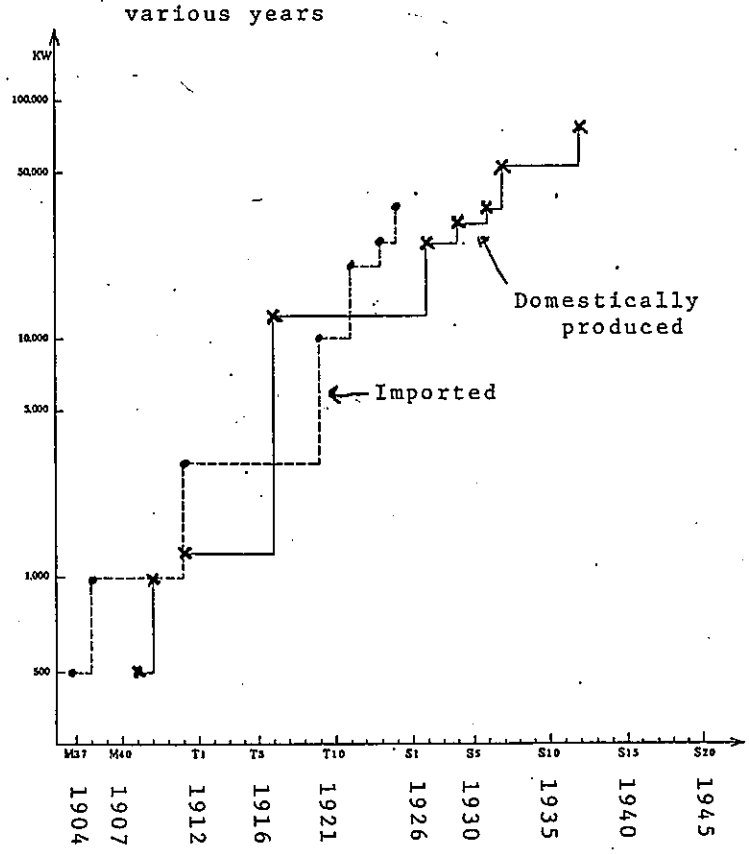
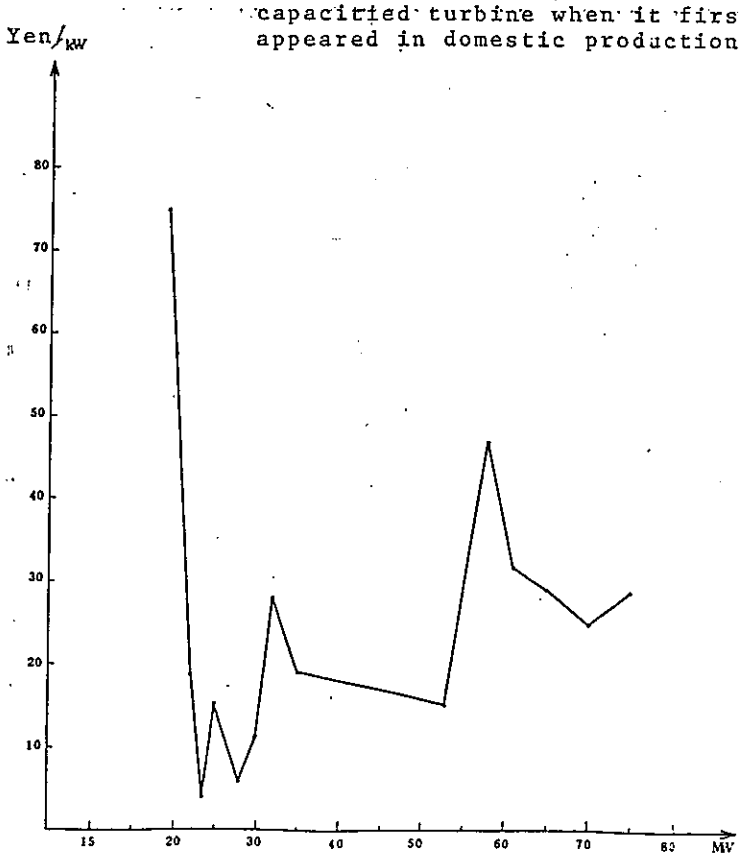
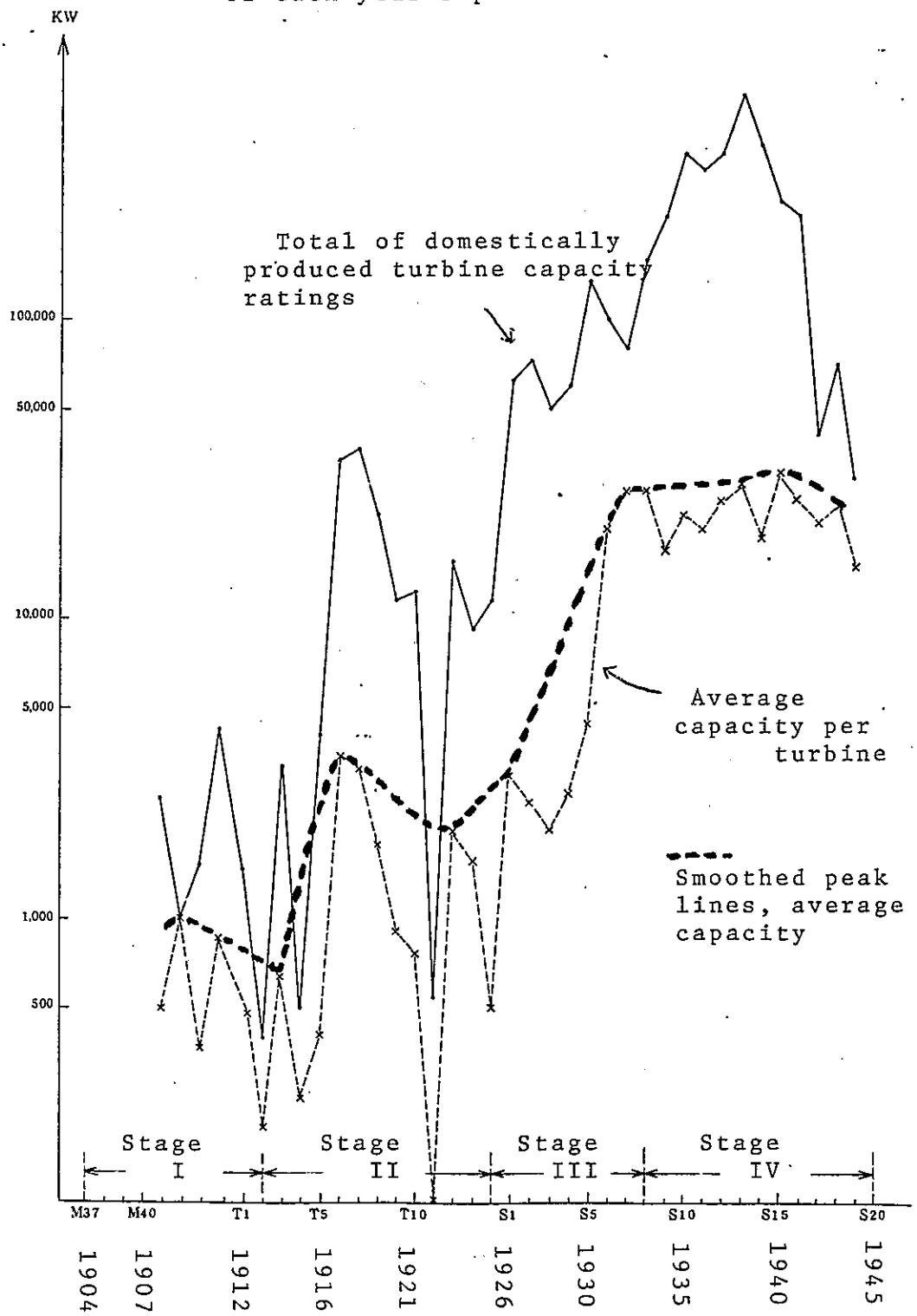


Fig. 5 Cost per KW capacity of the largest capacitied turbine when it first appeared in domestic production



(Capacity rating of new products)

Fig. 6 Total sum of generation capacities of domestically manufactured steam turbines and the average capacity per turbine of each year's product mix



in terms of capacity utilization.

One is impressed by the strong parallelism revealed in Figure 6 as between the total sum of KW capacities of domestically produced turbines and the average KW capacity per turbine implied in the product mix each year. When the demand for domestically produced turbines declined (in favor of imports), a greater proportion of it went for lower-priced, well-accepted, less sophisticated domestic products the production technology for which had been perfected at the preceding stage.

In Figure 6, connecting the peaks of the fluctuating path of average capacity-per-turbine would give a smoother, though still fluctuating, curve. In a way this smoother curve may be taken as representing the performances of the economically efficient core of domestic technology.

The gaps between this curve and the original fluctuations may be considered as revealing the year-to-year capacity utilization rate. The underutilization may have been caused among others by short-run demand instabilities. But according to the efficiency criterion one can say that the extent of supply-demand gaps which current economic and industrial policies failed to cope with is indicative of the inefficiencies of the policy inputs, including certainly technology policies.

Had the import substitution policy been pursued with firmness and consistency in accordance with proper medium- and long-term plans, at least part of the supply-demand gaps could have been avoided. It is likely that current investment and trade policies were not very closely tied up with the management of technology policies, the latter being usually geared to longer-run objectives.

Now, "effectiveness" of technology policy refers to its effect of promoting domestic technological capacitation processes. One may well attribute the fairly distinct palpitations shown by the smoothed dotted curve in Fig. 6 to ineffectiveness of technology policies primarily.

Of course, critcs themselves may not be too sure of the precise extent to which the technology policy authority ought to be blamed. The alteration of an expansionist-widening phase and a reformist-deepening phase, if not an outcome of intended policy, seems to underlie the basic notion of cycle in our life pattern. Not all the palpitations could be dispensed with since some form of cycle stems from the social and institutional adaptation process in which relatively slowly changing factors (culture, attitude, accepted rules of game for resolution of conflicting interests, etc.) interact with more quickly responding factors (economic and monetary affairs). And it may not always be a steady demand management that proves truly effective for stimulation of innovations.

Indeed, our system fluctuates between two types of environments as each is the cause of the other. For example, to quote the words of Peter Bernstein, financial analyst of the Federal Reserve Bank of New York (1979), "the easy attitude toward risk in the euphoric stage is what brings the good times to en end. Risk aversion and caution eliminate the excesses and lay the groundwork for richer rewards ahead. ... Indeed, one reason why the timing is so tricky is that people take so long to recognize change and to recall that it is inevitable. ... Solutions create problems. By this I mean that we may be successful in devising solutions to today's problems but those solutions are destined to become in turn the problems we will have to solve tomorrow."

This quotation is not meant for promoting fatalism nor for justifying all kinds of defects of the so-called science and technology policy being almost ubiquitously experienced in both developed and developing countries. But it should be taken as a real challenge to our arts of policy design for development.

There is still another important policy implication that should not be overlooked in taking up the above challenge.

The existence of asymmetry in the distribution of older and newer items in an expanding product assortment is often noted. That is, relatively common and cheaper items take up a disproportionately larger proportion of the total volume of production, with newer, more sophisticated items constituting less and less.

Reverting to the turbine history in Japan, the maximum capacity product in production was of 1,000 KW towards the end of Stage I, and the actual production showed, at least at peaks, an average per-turbine capacity that was not too inferior to that. However, in Stage II the peak-time average size did not exceed 3,500 KW despite the availability of technologies for models over 12,000 KW. The peak-time average remained even lower. Stage IV regained a comfortable ratio of 25,000 KW (average production) to 75,000 KW (maximum), but no higher than that.

The user's resistance in acceptance of new innovations has long attracted the attention of histographic researchers on technology diffusion, such as Nathan Rosenberg (1976).

The tendency of simpler, low-cost products surviving in the market longer than expected, can threat the perspective for international trade adjustment. Lagged response of consumers, labor unions, old aged and women workers, conservative welfare policy of governments, etc. all combine to spare room for the producers lingering on older product lines than available technology would justify. The pattern of international division of labor thus changes perhaps at a much slower pace than the narrowing of technology gaps between the advanced and the developing countries.

This suggests that there is an important question yet to be resolved if we really hope for the best of an OPTAD as a forum for mutual policy coordination. That is how to establish an acceptable frame of reference or norms according to which we can make the solutions to our today's problems consistent with ones to be anticipated for tomorrow's problems. Indeed, the timing is the most sensitive factor for forward-looking policy to be really effective.

Certainly an improved framework of mutual exchange of information would be essential. But one could hardly expect effective policy prescription from hodgepodge of anecdotal evidences and contentions. And if a fair judgement for tomorrow depends on an improved ability to learn from the past, there is still scope for improving our understanding the very process of catching up in which so many countries are struggling at various stages. This understanding is just as important for relatively advanced countries in improving the timing of positive adjustment on their part.

Thus, further research aimed at more incisive understanding of the problems of technology assimilation and accumulation being currently envisaged in Latin American countries may be facilitated by further retrospective studies on Japan' experience. Since, as for the latter, there is no ready-made format of universal utility available, a collaborative approach enabling to respond to each particular country's needs would be essential. Cooperation in policy research should precede policy coordination. This is still more the case if we are to move ahead toward some form of OPTAD.

STEAM TURBINES	BOILERS	WATER WHEELS

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