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NEW EVIDENCE ON THE SHIFT TOWARD PROCESS INNOVATION DURING THE LONG WAVE UPSWING

Rod Coombs*
Alfred Kleinknecht**

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* The University of Manchester Institute of Science and Technology (UMIST), Dept. of Management Sciences, P.O. Box 88, Manchester M60 1QD, U.K.

** Free University, Amsterdam, Economics Faculty, P.O. Box 7161, 1007 MC Amsterdam, The Netherlands.

1. INTRODUCTION

Recent research into long waves has produced a great deal of useful theoretical and empirical material which may contribute to a process of synthesis. The general tendency of the research has been to move away from rigid, determinist explanations of long waves, and to incorporate a wide variety of interacting variables into multi-causal models. These variables fall into three very broad headings. First, there are the 'economic' variables such as rates of change of productivity, profit, growth, employment, etc. Analysis of these parameters at both aggregate and disaggregate levels is proving very useful, (Freeman et al., 1982; Van Duijn, 1983). Secondly, there are the 'institutional' variables, such as legal and political stimuli and constraints relating to labour markets and company practive; regional variations in the basic economic processes of the long wave; changes in international currency and trade institutions, etc. (Gordon, Edwards and Reich, 1982). Finally, there are the technological variables, such as number, type, and frequency of innovations, inventions and patents; and diffusion data on particular innovations or groups of innovations, (Freeman et al, 1982; Mensch, 1975; Kleinknecht, 1981).

The assembly of these three groups of variables into a coherent explanation of the long wave phenomenon is still a long way off. So far, the lower turning point of the wave is still proving the most difficult and the most crucial part of the problem, and we do not address this topic in this paper. In general, more progress has been made in explanations of what happens once a long boom has started, and as it progresses to a long depression. However, data to test these explanations is still sparse.

There is then a pressing need for more empirical work on the technical, economic and institutional aspects of long waves in order to test the variety of competing theoretical accounts. Such empirical work must of necessity proceed slowly from one part of the problem to another and so on. In this paper, we make no apology for concentrating only on the technological variables, and in particular on innovation data. Due to the time period of our data, we concentrate on the post war upswing. The analysis does have some implications for the lower turning point however, and these are discussed in the conclusion.

The problems with the analysis of technological variables are both empirical and theoretical. Statistics are hard to obtain and invariably poorly suited to the task at hand. Despite considerable discussion, there is still no consensus on whether to concentrate on innovations or on diffusion processes. These difficulties have been usefully summarised by Freeman, Soete and Townsend (1982). Nevertheless, there is one proposition concerning the role of technical change during the long wave which is now the subject of some agreement, namely that there is a shift in emphasis from product change to process change as the wave progresses. This shift is related to the process of maturation of new industries which grow with the long wave upswing. It is also related to the dynamics of the labour market during the long wave. This possibility is examined by Freeman et al. (1982) who suggest that labour shortages in the upswing may contribute to the pressures to mechanise. It is also consistent with the diffusion data and arguments concerning automation (see Mandel, 1975, and Coombs, 1983).

Empirical evidence on a shift from product to process innovation has been reported for the case of a single industry several times. Freeman et al. (1963) reported this for the chemical industry, and Abernathy and Utterback (1975) have incorporated the idea into their model of industrial development. More recently, Mensch (1976) has spoken of a shift from 'expansionary' to 'rationalising' innovations as the long wave progresses. Freeman, Soete and Townsend (1982) believe that their own data, and that of Kleinknecht (1981) show the shift even more clearly.

In this paper, we use a new set of data (see below for description of sources) to test this proposition more rigorously for the period 1953 to 1973. There are three major differences between the analysis in this paper and that in the previous attempts to test this hypothesis.

1. As Freeman, Soete and Townsend have noted, the classification of innovations as product or process presents many difficulties. A new method of classification is described in section 3.

2. Previous tests have been at a high level of aggregation, which may have obscured some information. In this paper we conduct the analysis first for the entire sample, which covers the whole of industry, and then for a sub-group of the most innovative and most rapidly growing industries. The results are quite different.

3. There must be some doubt about the statistical significance of the shifts reported in previous work. For example in the paper by Freeman et al (1982) the shift in the share of process innovation of around 7% between the 50s and the 60s is based on a total sample for the two decades of only 85. The sample used in this paper is 500 for a similar period. It is therefore possible to assign the innovations to individual years and analyse the significance of any shift by simple regression.

The paper is organised as follows. Section 2 describes the data and their origin. Section 3 describes the classification scheme used. Section 4 presents the results of the classifications and the regressions. Section 5 discusses the implications of the results.

2. The Data

The data are taken from a report prepared for the United States National Science Foundation by the Gellman Research Associates (1976). The aim of this work was to collect a sample of 500 product and process innovations that embody significant technological change. The sample was restricted to innovations that were successfully introduced into the market during the period 1953 to 1973 (inclusive) in 6 Western countries*. It was the intention of the authors to cover innovations from a broad spectrum of the economy. The sampling process started with compilation of a preliminary list of 1160 innovations obtained by a survey of trade literature published from 1953 to 1973.

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*The six countries are: the USA (63% of the sample cases), the United Kingdom (17%), the Federal Republic of Germany (7%), Japan (7%), France (4%), and Canada (2%).

The selection of innovations to be included within the final sample of 500 cases was performed by an international panel of 7 experts. These panelists were encouraged to suggest any innovations for possible later inclusion which were not on the original list of 1160 innovations. The panelists suggested some 150 additional innovations. The resulting list of 1310 innovations was submitted to each of the panelists for ranking by importance. Those 500 innovations that received the highest ranks were then subject to further investigation to ascertain dates, origins etc.

The reconstruction of historical innovation data is a task with many difficulites and ambiguities. For instance, it is very hard to say how far the selection of innovation data from a literature survey imparts any bias, and it is not possible to judge the reliability of the decisions made by the panel of experts.

A sample of 500 innovations over a 21 year period is nevertheless a significant improvement on what has previously been available. Its randomness is certainly not worse than other samples and its size is an improvement on existing data.

Therefore, we assume that the 'Gellman sample' is a useful data base for examining major patterns of technological innovation on an international level during the period 1953 to 1973.

3. Classification principles

The objective of a classification scheme is to separate innovations that create new products or services from those that are aimed at producing the existing set of products and services in a more efficient way. However, as has recently been pointed out by Freeman, Townsend and Soete (1982), such a seemingly simple task is infact very difficult. Besides the problem of how to deal with those cases that are somewhere between pure product innovations on the one hand and purely rationalizing innovations on the other hand, the standpoint of the observer is of some importance. From the perspective of an investment good producer a new NC machine is a product innovation that may even increase employment in his firm, whereas for the final user, the NC machine is a labour-saving process innovation. An autombobile is an investment good if used for business purposes and it becomes a consumer good if used for private leisure. It should be clear that for the purpose of long wave analysis it is not very helpful to take the perspective of individual enterprises.

Rather we have to assess the place and function of a certain innovation within the macroeconomic production system; i.e. we have to take a macroeconomic viewpoint.

One approach would be to simply separate innovations introduced by investment goods producers and innovations introduced by consumer goods industries. As a third and fourth category we would have to leave out innovations coming from basic materials & extraction industries that produce inputs for both consumer and investment goods industries, and innovations from sectors outside of manufacturing industry (trade, transportation, government institutions, etc) whose role is still obscure in a long wave context. Although such a classification procedure relieves us from judgements about the character of individual innovation cases, it leaves us with several problems. First of all, it is by no means sure that investment goods industries only innovate new investment goods (i.e. process innovations,) or that consumer goods producers only concentrate on innovating new final consumer products. Secondly, separation between investment goods and consumer goods producers is not always that clear; often the same enterprise is engaged in both types of production, and statisticians have to make pragmatic judgements about how to group it.

Nonetheless, this "sector-of-origin" approach might yield some indication of how the relative innovative dynamics of consumer and investment goods industries develop over time. According to the hypothesis as outlined in the introduction, we would expect the investment goods producers to have a rising share over time of innovations in the sample and the consumer goods industries to have an opposite trend.

In order to avoid the potential errors of the "sector of origin" approach we have developed a scheme within which to classify each innovation individually. This contains a number of categories which are shown in Figure 1 and described below, with some examples for each case.

Firstly, there are the non-controversial cases of pure product innovations (P) such as colour TV, and pure process innovations (I) such as continuous casting of steel. Difficulties begin to appear with autombile related innovations (seat belts, power steering, disc brakes or electronic ignition) since autombiles are also used for commercial purposes.

Nonetheless, we decided to classify them as product innovations arguing that cars are mainly used as private consumer goods. But what about 'computerised real estate marketing' or 'computerized passenger reservations for airplanes'? There is certainly an element of cost-reduction, but at the same time, these systems are likely to offer new or improved services to consumers. The same is true of such cases as the 'world's first commercial jet aircraft', 'weather satellites' or an 'electron bombardment process to sterilize food and drugs'. None of these examples is a final consumer good. Nonetheless their main impact is providing new or improved products or services to final consumers. Since this type of innovation was quite frequently to be found in the sample, we decided to classify them as a separate class: investment goods aimed at providing new or improved products or services (IP).

Another special category was reserved for 'Medical Instruments and Procedures' (MED). In so far as medical apparatus are concerned, this category comes near to the above-named 'IP' category. However, the 'MED' category also covers services and know-how more directly related to the human body (improved heart pacemakers or procedures for transplanting human organs). We also included new pharmaceuticals in MED. On the whole, the MED category comes quite close to product innovations, although most of these innovations are not directly sold to final consumers.

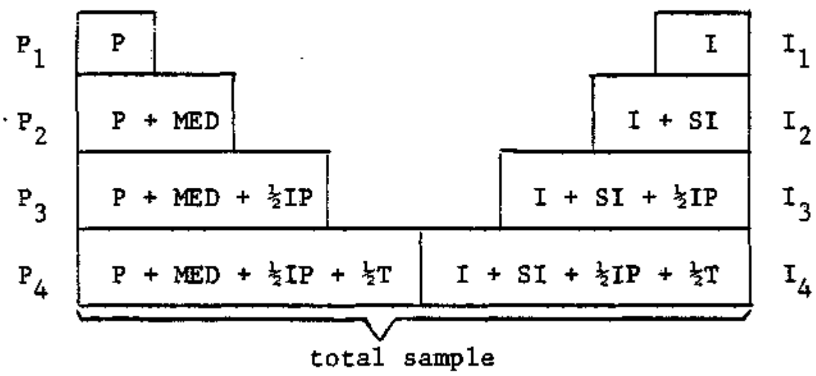
'Scientific Instruments' ('SI') form another category. These innovations are primarily used in research laboratories, but to a certain extent also for industrial quality control. Therefore we conceive the SI category as coming relatively close to process innovations.

The sample contains two other types of innovation that are difficult to group into any of the categories so far mentioned. These are "new technological devices" (TD) and "new technological materials" (TM).

An example of TD is the laser, and an example of TM is epoxy resin. While these clearly are innovations, their function is not limited to one specific area and this potential for multiple application is in general clear at the time of innovation. They therefore constitute new inventive inputs to other sectors outside their sector of immediate origin. These "multi-purpose technologies" have a dual significance; they are innovations for the sector or firm which producers them, but they change the technological possibilities for the whole range of future product and process innovations. It would therefore be inappropriate to classify them as one or the other, since this would be to obliterate an important dimension of their role in the economy.

Having defined these categories of P, MED, IP, I, SI, TM and TD, it is possible to combine them in different ways to represent more or less inclusive definitions of product and process innovation. This is shown in figure 1.

Figure 1



P1 = P =	Narrow definition of product innovations
P2 = P + MED =	Standard " " " "
P3 = P + MED + ½IP =	Wide " " " "
P4 = P + MED + 1IP + ½T =	Extended " " " "

I1 = I =	Narrow definition of process innovations
I2 = I + SI	Standard " " " "
I3 = I + SI + ½IP =	Wide " " " "
I4 = I + SI + ½IP + ½T =	Extended " " " "

(T = TM + TD)

It will be clear from figure 1 that we have decided to divide IP and T between the product and process innovations in the wide and extended definitions. This procedure avoids classifying these innovations wrongly to one side or the other, yet it avoids sacrificing the information contained in the distribution of these cases over time. The IP cases are not controversial in this respect. The inclusion of the T cases can also be argued on the basis that they may contribute to both product and process innovation. In any event this scheme gives us a variety of ways of examining the proposed shift from product to process innovation, as well as the prospect of examining the T innovations separately.

4. Results

4.1 Numbers of innovations by sector of origin

This approach is based on a division of the economy into a service sector and a manufacturing sector.

The manufacturing sector is further sub-divided into 3 main branches:

- basic materials industries
- investment goods industries
- consumer goods industries

This sub-division follows that used by the DIW (German Institute for Economic Research). Grouping of the SIC sectors into these main branches is documented in table A1 of the Appendix.
Table A1 shows the absolute numbers of innovations for the above-named sectors. Since the number of innovations in the total sample exhibits considerable fluctuation over time, it is better to express the innovations of each sector as a percentage of the total. The estimation of simple regressions over time reveals that the percentage shares in the sample of the service sectors and of the basic materials industries show no significant trend.*

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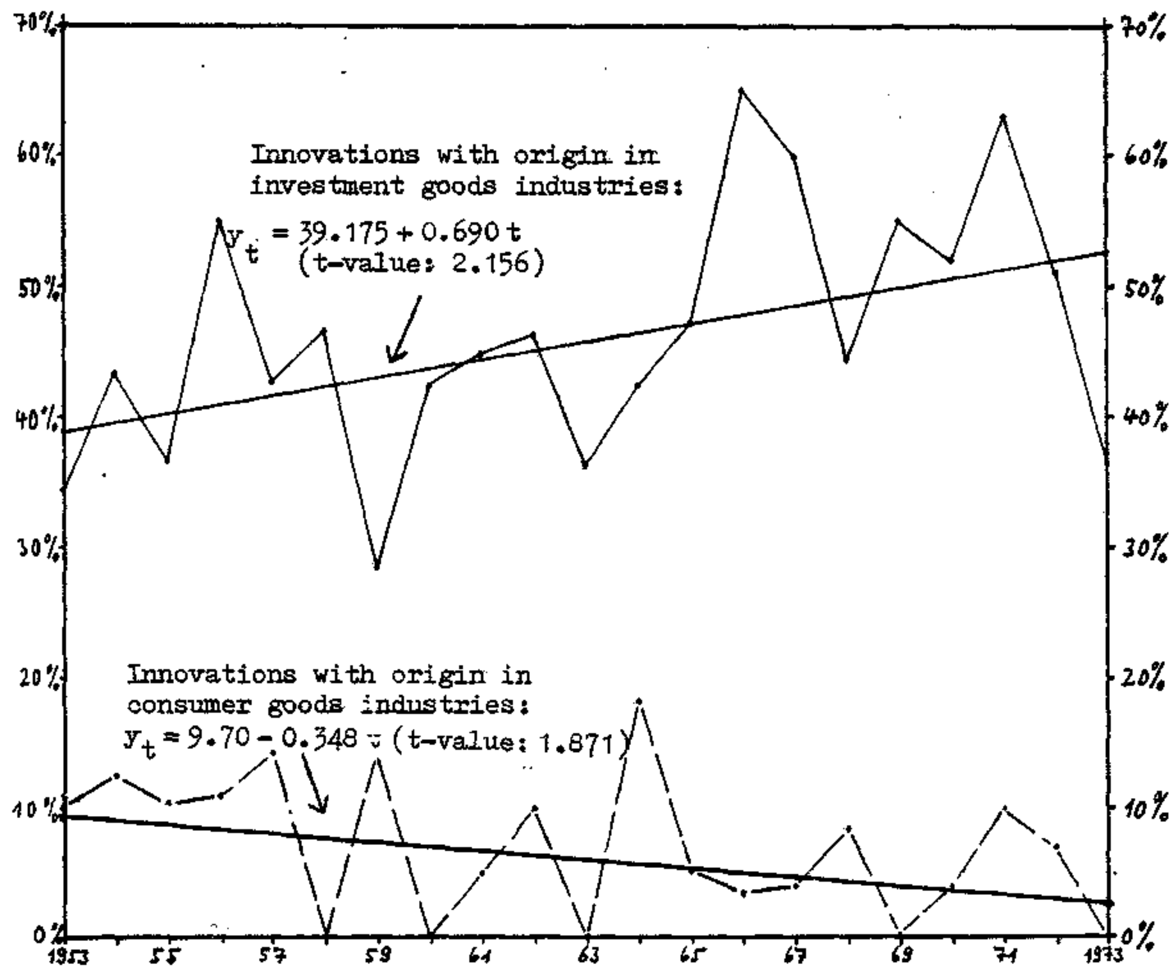
* The regression equations are as follows:
service sectors: y=23.978-0.294t (t-value: 0.697)

basic materials industries: y=27.147-0.048t (t-value: 0.133)

The investment and consumer goods sectors behave according to our hypothesis: Throughout the investigation period, the percentage share of innovations from investment goods producers shows a significantly increasing trend, and the share of consumer goods industries shows a reverse trend (see Graph 1). This can be taken as preliminary confirmation of the hypothesis that in the course of the post-war long wave upswing, emphasis was shifting from product to process related innovations, i.e. the relative importance of the capital goods sector as source of innovation was increasing, whereas the percentage share of innovations from the consumer goods industry was declining.

Graph 1: Annual Percentile Shares of Innovations from Investment Goods and Consumer Goods Industries in Total Sample



4.2 Applying our classification scheme (see Fig. 1)

4.2.1 The Results from the sample as a whole

The results of classifying the entire sample according to the categories discussed in section 3 are shown in table A2 of the Appendix. Here again we estimated linear regressions over time of the percentage shares of product and process innovations according to the various altervative definitions shown in Fig. 1. The results are documented in Table 1.

Table 1 : Regressions over Time of Percentage Shares in Total Sample of Product and Process Innovations (Abbreviations and Definitions: see Figure 1)

Product and Process Innovations according to different definitions:	Regression equations	t-values:
I_1 (narrow definition of process innovations)	$y_t = 51.891 - 0.058\ t$	0.127
I_2 (standard definition of process innovations)	$y_t = 49.561 + 0.699\ t$	1.387
I_3 (wide definition of process innovations)	$y_t = 54.573 + 0.471\ t$	1.013
I_4 (extended definition of process innovations)	$y_t = 67.630 + 0.456\ t$	1.260
P_1 (narrow definition of product innovations)	$y_t = 8.146 - 0.125\ t$	0.579
P_2 (standard definition of product innovations)	$y_t = 14.302 - 0.213\ t$	0.737
P_3 (wide definition of product innovations)	$y_t = 19.313 - 0.441\ t$	1.301
P_4 (extended definifion of product innovations)	$y_t = 32.370 - 0.456\ t$	1.260

Whether the definition used is wide or narrow the slopes of the trends are quite small; i.e. the probability that the increases or decreases might be accidental is relatively high. Therefore the trends have to be interpreted with the utmost care: with the exception of I_1, the direction of the trends is consistent with the shifting hypothesis, but the significance of the slopes is too weak to take the results as a strong confirmation of the hypothesis. However, experience tells us that in innovation theory the most important information is often lost if we restrict our view to large aggregates. In the next section therefore, we have further dis-aggregated the sample.

4.2.2 Dis-aggregation of the sample into modern and traditional sectors

In Kleinknecht (1981) the innovations of the Gellman sample were distributed into 30 sectors of German manufacturing industry. This procedure was guided by the hypothesis that given the strong integration of German industry into the world market, there should be a fairly good correlation between international innovation trends and industry growth patterns - if the "Schumpeterian" approach is relevant. This correlation does indeed exist. The study reveals quite remarkable sectoral differences in the rates of growth of industrial production between sectors and shows that this corresponds with a one-tailed sectoral distribution of innovations. Taking into account differences in the rates of production growth as well as innovative behaviour, the study of Kleinknecht (1981) suggests that it is appropriate to separate manufacturing industry roughly into two parts:

1. "Highly innovative growth industries" which performed a locomotive function in the post-war upswing: Chemicals, Petroleum Refining, Rubber & Asbestos, Cars, Aircraft Construction, Electrical Equipment, Precision Engineering, Plastics Manufacturing.

2. "Traditional industries" with more moderate growth rates and weaker innovation performance: Mining, Building Materials, Iron & Steel, Non-ferrous Metals, Saw-Mill & Timber Processing, Wood-Working/Cellusose & Paperboard, Steel Construction, Machinery Construction, Shipbuilding, Hardware & Metal Goods, Fine Ceramic, Glass, Wood Manufacture, Musical Instruments/ Toys/Jewelry, Paper & Board Manufacture, Printing & Duplicating, Leather Manufacturing, Leather Processing, Shoes, Textiles, Clothing, Food/Tobacco & Beverages.

Graph 2 shows the numbers of innovations originating in these two parts of industry as a percentage share of the total number of innovations in manufacturing industry (total = 413 cases; i.e. 87 out of 500 cases full outside manufacturing industry).

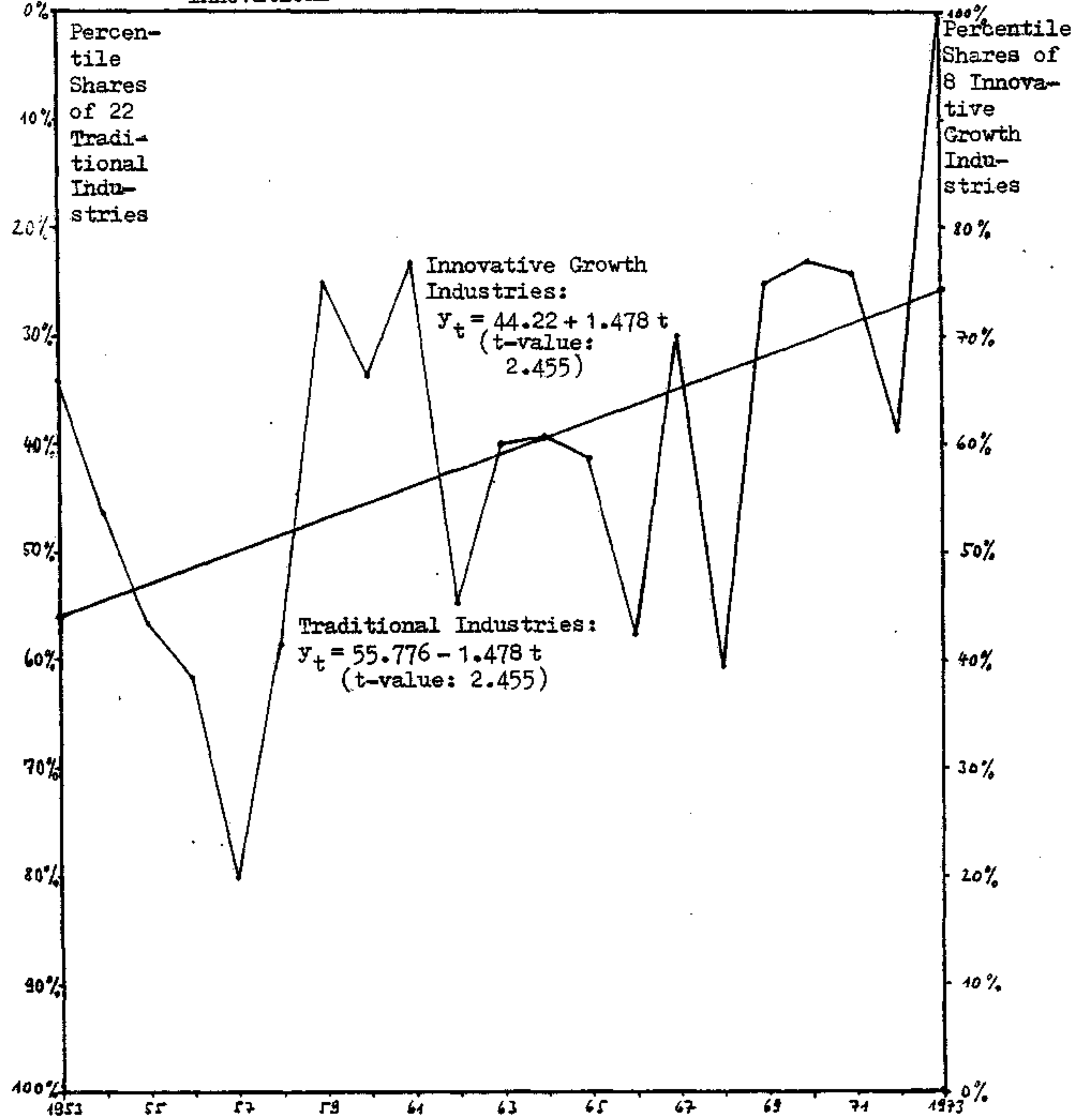
The graph illustrates that during the post-war Kondratieff-upswing there is a rising share in industrial innovation taken by the group of 8 high growth industries, and correspondingly, there is a considerable decline of the relative contribution of the older, traditional sectors. Let us now look at what is happening within these two groups, using the classification scheme presented above (figure 1). A summary of the total period is given in table 2.

Table 2 : Types of Innovations by Modern and Traditional Industries

	I	P	IP	T	MED	SI	D	totals
8 modern growth industries (Chemicals, Petroleum Refining, Rubber & Asbestos, Vehicle Construction, Aircraft Construction, Car Construction, Electrical Equipment, Precision Engineering & Optics, Plastics Manufacturing	73 29.92%	34 13.93%	18 7.38%	70 28.69%	21 8.61%	21 8.61%	7 2.87%	244 100%
22 traditional industries (Mining, Building Materials, Iron & Steel, Non-ferrous Metals, Saw-Mill & Timber Processing, Wood-Working/Cellulose & Paperboard, Steel Construction, Machinery Construction, Shipbuilding, Hardware & Metal Goods, Fine Ceramic, Glass, Wood Manufacture, Musical Instruments/Toys/Jewelry, Paper & Board Manufacture, Printing & Duplicating, Leather Manufacture, Leather Processing, Shoes, Textiles, Clothing, Food/Tobacco & Beverages.	115 68.05%	3 1.78%	13 7.69%	34 20.12%	1 0.59%	2 1.18%	1 0.59%	169 100%
30 sectors of manufacturing together:	188	37	31	104	22	23	8	413
Sectors outside manufacturing industry (trade etc.)	59	1	2	12	5	6	2	87
Total sample:	247	38	33	116	27	29	10	500

The table demonstrates clearly the difference in the ratio between product and process innovations between the two groups: Independently of how we define product innovations (P, P + MED, P + MED + ½IP + ½ T) it can be seen that the 22 traditional industries have only very few of them. This implies that, if there is any shifting from product to process innovations, it can only have taken place within the modern industries; the traditional industries seem to have shifted already long before our observation period. This can also be seen in more detail from table A3 in the Appendix which covers the same data on an annual basis.

Graph 2: Annual Percentile Shares of Innovations from 8 Innovative Growth Industries and from 22 Traditional Industries in Total Manufacturing Innovations



Since there are so few product innovations in the traditional sectors (on any definition) it is not appropriate to pursue further the possibility of a product/process shift in these sectors. In the eight high growth industries, however, it is possible to repeat the regressions on P_1-P_4 and I_1-I_4 to explore the shift within these industries.

The results are summarised in table A4 (Appendix) and in table 3 and graphs 3 and 4 which follow. Table 3 shows that the regressions on the process innovations have significantly positive slopes on all four definitions (I_1-I_4). The slopes of the regressions on P_1-P_3 are not significant; only the slope on P_4 is significant. It should be pointed out that our classification scheme and the nature of the data result in there being many more process innovations than product innovations in the sample (see table A4). This inevitably makes the regressions on the product innovations less reliable. By the same token, however, we can have much more confidence in the regressions on the shares of process innovations in the 8 industries, and the latter are significant even on the most restrictive definition (I_1 , i.e. primarily factor saving investment goods). It does seem then, that 'rationalising' innovations are becoming more important than 'expansionary' innovations in this sample as the upswing develops. Finally, it is important and interesting to note that the T innovations taken alone do not show any significant trend.*

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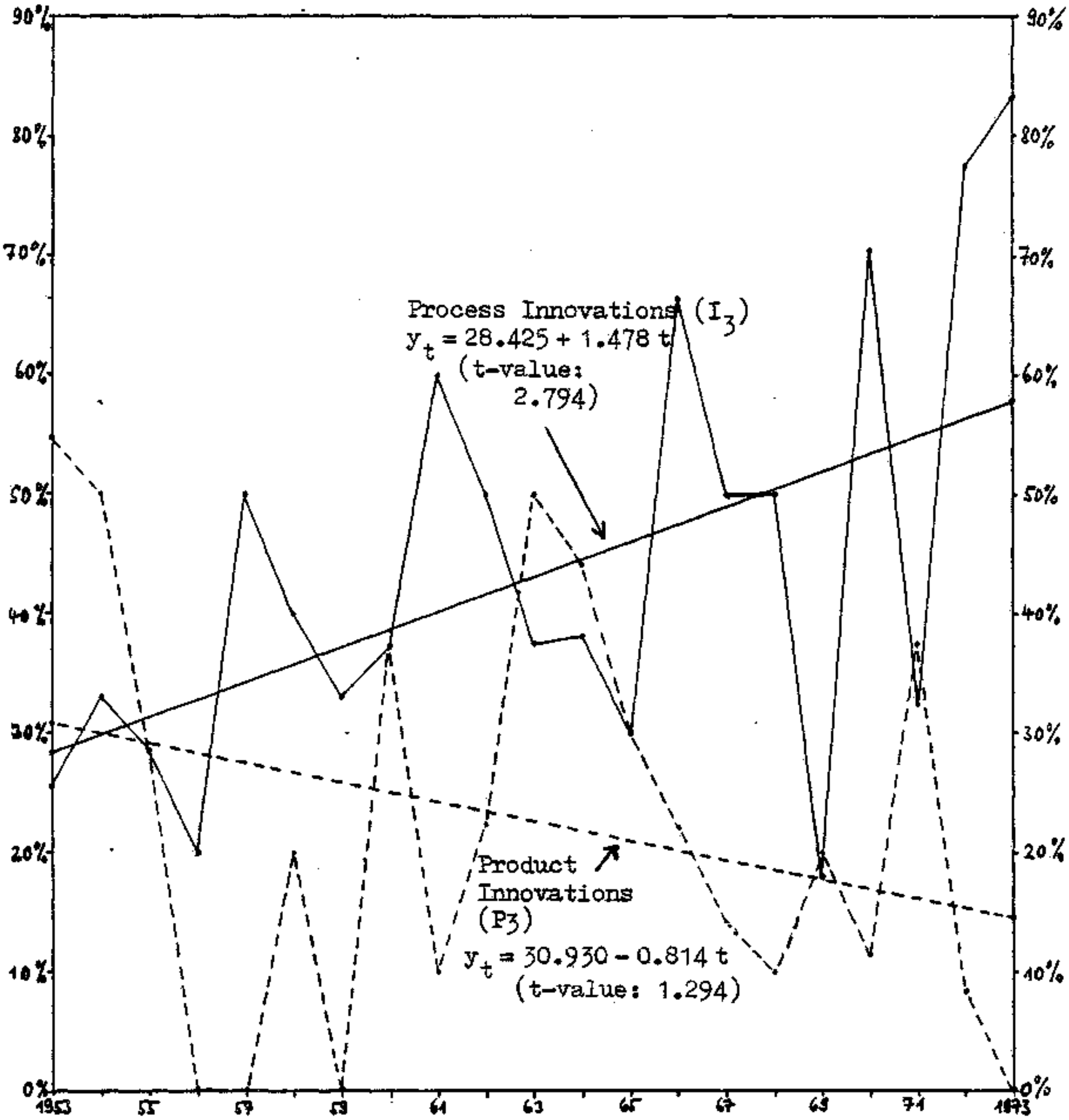
*The regression equation for the percentile share of T innovations in total over time is: $y_t = 40.645 - 0.664t$ (t-value : 1.000).

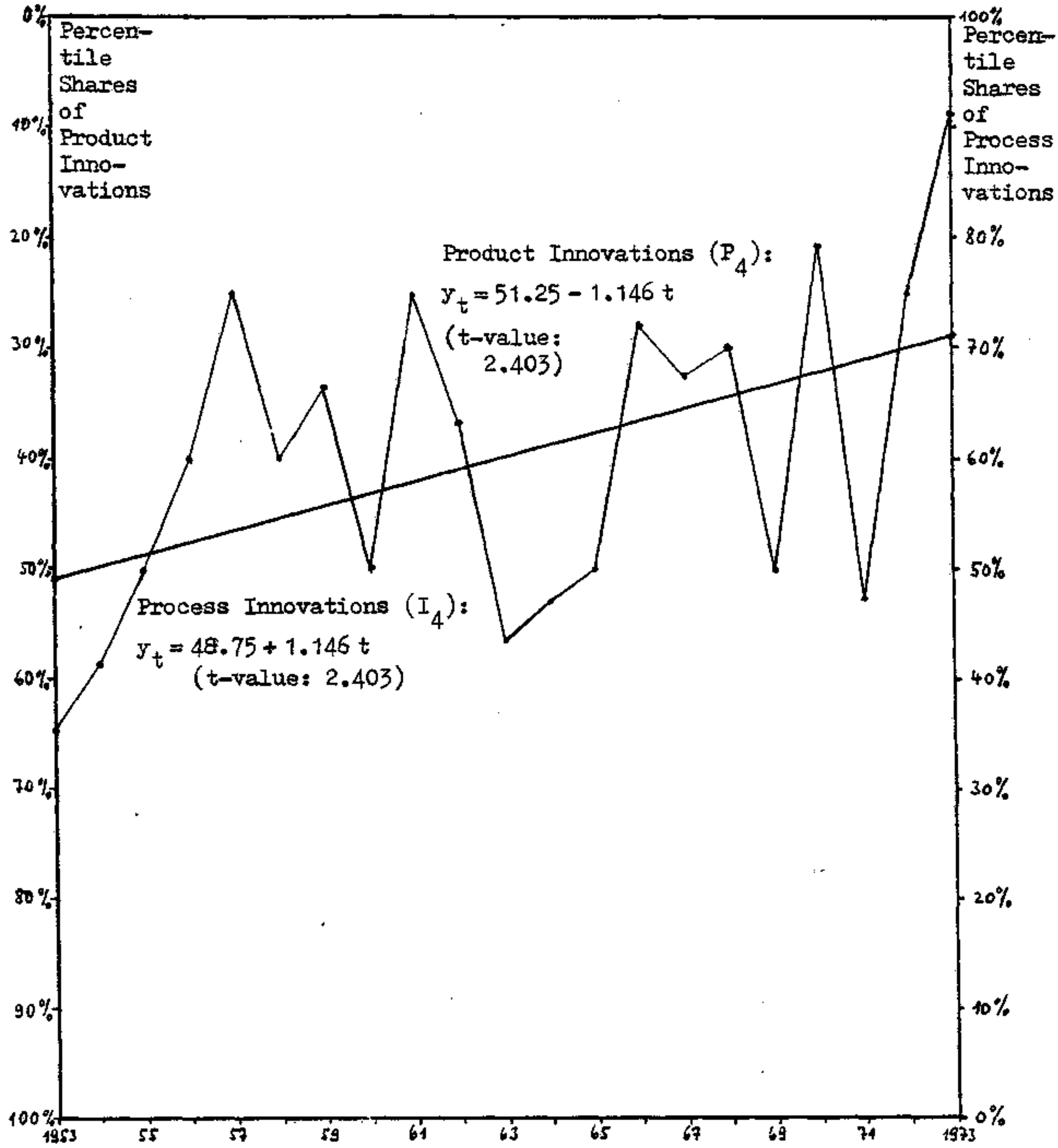
Table 3 : Regressions on Annual Percentile Shares of Product and Process Innovations in Total Number of Innovations within 8 Modern, Highly Innovative Growth Industries (Abbreviations and Definitions: see Figure 1)

Product and Process innovations according to different definitions:	Regression equations	t-values:
I_1 (narrow definition of process innovations)	$y_t = 23.742 + 0.967\ t$	1.818
I_2 (standard definition of process innovations)	$y_t = 24.087 + 1.777\ t$	3.162
I_3 (wide definition of process innovations)	$y_t = 28.425 + 1.478\ t$	2.794
I_4 (extended definition of process innovations)	$y_t = 48.747 + 1.146\ t$	2.403
P_1 (narrow definition of product innovations)	$y_t = 16.894 - 0.322\ t$	0.638
P_2 (standard definition of product innovations)	$y_t = 24.639 - 0.516\ t$	0.949
P_3 (wide definition of product innovations)	$y_t = 30.930 - 0.814\ t$	1.294
P_4 (extended definition of product innovations)	$y_t = 51.253 - 1.146\ t$	2.403

Graph 3: Annual Percentile Shares of Product and Process Innovations (According to "Wide Definition") Within 8 Innovative Industries



Graph 4: Annual Percentile Shares of Product and Process Innovations (According to "Extended Definition") Within 8 Innovative Growth Industries



5. Conclusions

The first conclusion which can be drawn from these results is that the level of aggregation is very important in the study of changes in the character of innovation. The hypothesised shift from product to process innovation was not clearly visible in the aggregate sample except by means of the indirect 'sector of origin' approach. The individual classification of innovations did however, show a strong confirmation of the hypothesised shift in the 8 high growth industries. This is an important confirmation and modification of the hypothesis.

Secondly, it can be concluded that this result gives further support to the models of long waves developed by the authors mentioned in Section 1, since it confirms some of the features of strong industry life cycles which play an important role in these models once the wave is underway. Furthermore, it is consistent with the arguments of Freeman et al. (1982) concerning the ability of the growth industries to continue to generate employment. It seems that as the wave progresses these sectors are likely to move toward 'jobless growth'.

If, in the economy as a whole, and in the growth industries of the upswing in particular, the rate of product innovations has fallen while the total rate of innovation has increased, then it is important to ask what the effect of various policies might be on that situation. Depressed demand will probably accentuate the trend, while expanded demand could not guarantee its reversal. Falling wages might reduce some pressure towards process innovation, but that does not in itself transfer effort to product innovation, especially if the falling wages are within a context of depressed demand. This suggests a role for technology policy, but raises the question of which technologies and products to promote; a familiar problem which will not be pursued further here.

On the difficult question of the nature of technical change at the lower turning point the results are suggestive rather than strongly confirming any hypothesis. The fact that there was a higher level of product innovations at the beginning of the time period than at the end might be consistent with the level also having been high during the latter phase of the long wave depression. On the other hand the peak may have come after the upswing began. The time period of the data (1953-1973) is just outside the period needed to examine this possibility. It is also important however, that the T innovations are effectively random. This is suggestive of the possibility that fundamental technical changes may be less closely coupled to the long wave, as Freeman has suggested. Again however, without more data we cannot be sure that there is not a peak or a trough in T in the downswing of the wave.

In any event these results underline the importance of careful analysis of the nature of technical change in the long wave. It may be too crude to operate only with the categories of inventions and innovations, given the dual significance of the T innovations as multiple-purpose technologies. The tracing of connections between T innovations and their later role as inputs to other innovations would be a useful research strategy, especially if coupled to diffusion data on these and other innovations. In sum, there is a need to move beyond the simple counting of inventions and innovations, despite the suggestive results provided by the method up to date.

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APPENDIX Table A1 : Annual Numbers of Innovations by Main Sectors of Origin

		manufacturing:			
	non-manufacturing sectors	basic materials-industries	investment goods industries	consumer goods industries	total sample
1953	3	24	17	5	49
1954	4	3	7	2	16
1955	3	7	7	2	19
1956	4	2	10	2	18
1957	3	3	6	2	14
1958	4	4	7	0	15
1959	3	1	2	1	7
1960	8	7	11	0	26
1961	7	3	9	1	20
1962	6	7	14	3	30
1963	6	8	8	0	22
1964	6	7	14	6	33
1965	2	7	9	1	19
1966	1	7	17	1	26
1967	5	4	15	1	25
1968	7	10	16	3	36
1969	2	6	10	0	18
1970	3	8	13	1	25
1971	3	5	19	3	30
1972	2	15	21	3	41
1973	5	2	4	0	11
Totals	87	140	237	37	500
Corresponding SIC numbers:	154,161,162,173 374,401,422,431 442,452,461,478 481,483,489,491 494,495,508,602 632,737,739,769 806,891,892,919 951,957,962,966	109,121,131 324,325,327 329,331,339 333-335,281 282-287,289 291,301,242 261	344,351,353- 359,371,373, 372,376,360 362,365-367 369,381-384 386,341,347 349,342	321,243, 249,393 262,307 311,222 228,231 203,206 208,209	

APPENDIX

Table A2 : Annual Numbers of Product and Process Innovations in the Total Sample (Abbreviations and definitions: see figure 1)

	pure I	pure P	I+SI	P+MED	IP	T=TD+TM	I+SI+½IP+½T	P+MED+½IP+½T	totals
1953	16	7	16	15	10	9	25.5	24.5	50
1954	8	2	8	2	2	4	11	5	16
1955	13	2	13	2	0	4	15	4	19
1956	9	0	9	0	1	7	13	4	17
1957	7	1	8	1	0	4	10	3	13
1958	8	0	9	1	1	5	12	4	16
1959	2	0	2	1	1	2	3.5	2.5	6
1960	12	3	13	4	2	6	17	9	26
1961	15	1	16	1	0	3	17.5	2.5	20
1962	17	0	17	3	3	6	21.5	7.5	29
1963	12	4	12	4	0	4	14	6	20
1964	15	3	16	7	4	7	21.5	12.5	34
1965	9	2	10	3	0	6	13	5.5	19
1966	14	2	17	2	1	5	20	5	25
1967	12	1	15	3	2	5	18.5	7.5	25
1968	21	2	22	2	2	7	26.5	4.5	33
1969	5	1	5	2	0	9	9.5	6.5	16
1970	13	1	19	2	0	4	21	4	25
1971	8	6	13	8	1	7	17	12	29
1972	24	0	27	1	3	10	33.5	7.5	41
1973	7	0	9	0	0	2	10	1	11
totals:	247	38	276	65	33	116	350.5	139.5	490

The total sample covers 490 classified cases plus 10 non-classified (difficult) cases.

Appendix, Table A3 : Types of Innovations by Sectors and by Time (Abbreviations and Definitions: see Figure 1)

Years	Industrial Sectors and corresponding SIC numbers (in brackets)					
	Mining (103,121, 131)	Building Materials (324,325, 327,329)	Iron & Steel (331,339)	Non-ferrous Metals (333-335)	Chemicals (281,282-287,289)	Petroleum Refining (291)
1953	I	I	I	I, TM	3 x TM, 6 x MED, P, 4 x IP, I	TM
54			2 x I	I		
1955	I	I	2 x I		P, I	
56	I				TM	
57		TM	I	I		
58	I			TM	I	
59					TM	
1960		2 x I	2 x I		MED, P, I	
61		I			I, TM	
62		I	2 x I		I, MED	I
63			I, 2 x TM		2 x P, D, I	
64		TM	I		MED, 2 x TM, 2 x P	I
1965		2 x I, TM			2 x TM, P	
66			4 x I	2 x TM	TM	
67			I		SI	2 x I
68	TD, I	P	4 x I		TM, I, D	
69		TM		TM, I	TM, I, MED	
1970		TM			3 x I, 3 x TM	I
71		I	TM	I		
72	I	I, SI	I, SI		3 x I, 4 x TM	2 x I
1973					TM	I

Appendix, Table A3 : Types of Innovations by Sectors and by Time (continued)

Years	Industrial Sectors and corresponding SIC numbers (in brackets)							
	Rubber & Asbestos (301)	Saw-Mill & Timber Processing (242)	Wood-Working, Cellulose, Paper-board (261)	Steel Construction (344)	Cars (371)	Machinery Construction (351,353-359)	Ship-building (373)	Aircraft Construction (372, 376)
1953	2 x TM, P		MED		4 x P, I	2 x I , P	2 x I	2 x IP
54	IP				IP	2 x I		D
1955		TM			P	2 x I		TM
56				TD	TD	2 x I	I	
57						IP, 2 x I		I
58	TD					TM, 2 x I	I	TD
59								
1960					I	IP, I		P
61					I, P	2 x I		I
62	TM					TD, TM, 6 x I		IP
63					P	3 x I		
64				I		IP, TD, 2 x I		
1965						3 x I		TM, I
66					P	4 x I	I	P
67						IP, 4 x I		P
68						2 x IP, 5 x I	2 x I	I
69								D
1970					P, SI	3 x I		I
71	P				P, IP	2 x I		2 x SI, TM
72	IP			IP	2 x I, IP	TD, 4 x I		TD
73					I			

Appendix, Table A3 : Types of Innovations by Sectors and by Time (continued)

	Industrial Sectors and corresponding SIC numbers (in brackets)						
Years	Electrical Equipment (360,362, 365-367, 369)	Precision Engineering & Optics (381-384, 386)	Hardware & Metal Goods (341, 342, 347, 349)	Fine Ceramic & Glass (321)	Wood Manufacture (243,249)	Musical Instruments, Toys, Jewelry, etc. (393)	Paper & Board Manufacture & Printing (262)
1953	2 x I, IP	MED, IP		TM, IP		I	
54	2 x P	TD					I
1955	TM		2 x I				
56	2 x TD	I	TM		TM		
57	TD		I		TM		
58		SI					
59	TD	I		IP			
1960	I, IP, 2 x TD	MED, TD, SI					
61	2 x I, SI, TD						
62	2 x TD, I	I, MED					
63	I, TD	I, P					
64	I, TM, P	2 x MED, I, SI	I, TD	TM			I
1965	P, TD	SI, MED	TM				
66	3 x I, D, SI, D	I, SI	TM, I				
67	2 x TD, 2 x I, SI	2 x TD, MED, I					
68	SI, MED, TD	2 x I, TM	D	TM			
69	5 x TD, D	I, P	TM				
1970	3 x I, SI	MED, 2 x SI					
71	I, 2 x P, TD	2 x P, 3 x SI, TD, MED	I				
72	3 x I, 2 x TM	2 x I, TM, SI, MED	I	TD			I
73	I	I, SI					

Appendix, Table A3 : Types of Innovations by Sectors and by Time (continued)

Years	Plastics Manufacturing (307)	Leather & Shoes (311)	Textiles & Clothing (222, 228, 231)	Food, Tobacco & Beverages (203, 206, 208, 209)	Non-manufacturing sectors (services, trade etc.) (154, 161, 162, 173, 374, 401, 422, 432, 442, 452, 461, 481, 483, 489, 491, 494, 495, 508, 632, 731, 739, 769, 806, 891, 892, 919, 957, 962)
	Industrial Sectors and corresponding SIC numbers (in brackets)				
1953			TM	IP	3 x I
54	I				2 x TD, TM, I
1955	TD, I				3 x I
56			IP		4 x I
57			P		I, SI, TD
58					3 x I, TM
59					I, MED, D
1960					4 x I, 2 x TD, P, TM
61	TM				7 x I
62	I			2 x IP	3 x I, MED, D, TM
63					5 x I, TD
64	3 x IP, I				5 x I, MED
1965	I				2 x I
66				TD	SI
67	TM				2 x I, IP, SI, MED
68	P, TM				5 x I, IP, TM
69					2 x I
1970		I			I, 2 x SI
71	3 x TM				2 x I, MED
72			I		2 x I
73					3 x I, SI, TD