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An International Analysis of Differences in Logistics Performance

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AN INTERNATIONAL ANALYSIS OF DIFFERENCES IN LOGISTICS PERFORMANCE

Dr. Pavel Dimitrov
Professor Sten Wandel

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FOREWORD

The Technology, Economy and Society Program focuses on technological evolution, diffusion, and appropriate management strategies. In particular, the objective is to identify those economic and social conditions and circumstances under which new institutions, economic organizations, and technologies can evolve and how such developments affect economic and social structures, such as occupational and employment patterns. Computer Integrated Manufacturing, New Logistics Technologies, Methane Technologies, and Integrated Energy Systems are the main case studies.

The New Logistics Technologies Activity studies trend-breaking technological and organizational innovations in distribution/transportation chains from primary sources through all intermediate steps to final consumption, explores the dynamics of their introduction, and assesses socioeconomic prerequisites and impacts. It contains cross national analyses of logistic structures, performance, and strategies on both macro and micro levels and models to estimate the consequences of future scenarios. The research is carried out in collaboration with an international network of research teams in some 18 countries. Many of these teams are preparing national reports on logistic structures, strategies and prospects.

This paper presents preliminary results from one activity within the New Logistics Technologies Activity at IIASA. The aim of the paper is to reveal the differences in logistics performance among nations, sectors and over time as well as endeavour to explain those differences using public statistics.

F. Schmidt-Bleek
Leader
Technology, Economy & Society Program

SUMMARY

The ratio Value Added to Inventory Value is used as a proxy for logistic performance. Large differences – up to 8 times – have been observed among the 14 nations in the study. The rank among the nations has been rather stable for the last 20 years but the ratio has improved considerably in most countries since 1980.

Several hypotheses concerning the factors which explain the differences in inventory levels are formulated based on theories and case studies in the areas of production, trade, transport, communication, geography and social-economy. Proxies for some of these factors available in international statistics are used as independent variables in multiple regression analyses. The preliminary result indicates that as much as 80% of the differences could be explained by differences in import share, rail share, wholesale structure and telephone intensity. Hence, the hypothesis that differences in national inventory levels are only due to managerial factors or level of economic development could be rejected.

Even if the logistic performance of individual companies can be improved considerably by adopting new management principles – as many case studies show – the total logistic performance of a nation seems to have significantly benefited from investments in transportation, production and communication infrastructures. However, it has still to be shown that these historical correlations are also causal relations that hold true for the future.

ACKNOWLEDGEMENTS

The authors would like to thank our collaborating research teams as well as the Economic Commission for Europe of the United Nations for helping us obtain the information for our data base.

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AN INTERNATIONAL ANALYSIS OF DIFFERENCES IN LOGISTICS PERFORMANCE

Dr. Pavel Dimitrov and Professor Sten Wandel

INTRODUCTION

The aim of the research partially reported in this paper is to explore the differences in logistics performance among nations, sectors and over time and to explain those differences using compatible international statistics.

The focus is on long term developments and not on short term fluctuations during business cycles which has been analyzed [2, 3, 10, 13]. However, the impacts of these short term fluctuations have to be eliminated through, e.g., smoothing out. In addition, the dynamics of business cycles might change due to long term and structural logistic changes. Our hypothesis is that the observed adverse effect of inventories [7, 14] on business cycles will be reduced and the cycles will be shorter if inventories are lowered and the activities along the logistic chains are synchronized. A contradictory hypothesis, originally suggested for the stock market, indicates that faster communication systems causes nervousness and instability.

A literature survey [9] of the many disciplines that might contain theories or empirical data regarding inventory structure and behaviour resulted in a long list of factors that might be influencing inventories. Most previous studies are normative or cases on the firm level. Only a few studies [1, 6, 12, 15] have tried to test which of these micro relations are also true for macro data.

There are several problems of extending the analyses from the firm level to the industry, the national, and the international level, i.e.:

1. Fewer variables are reported. Proxies must therefore be used for many of the variables, e.g., the quality of the telecommunication system is measured as the number of telephones per capita.
2. Variations in definitions, and the way companies, sectors and nations measure. Definitions and standards of the UN Industrial Statistics were used, where appropriate. The remaining variations in definitions and evaluation of inventories and value added are considered to be less than the variations in the observed ratio: Value Added to Inventory Level, the main *logistics* performance indicator in the study.
3. Inhomogeneity of measurements being aggregated, e.g., 1 ton of ore is quite different from 1 ton of integrated circuits in transport statistics and the through put time and thereby work-in-process inventories of shipyards and the automotive industry differs considerably but they are both included in the vehicle industry. It is, therefore, difficult to compare an individual company with the statistical average.

A sample of 14 industrialized countries with differing economic systems and of various sizes were chosen. The sample was limited to those nations for which reasonably harmonized data could be obtained. The lack of comparable transport statistics for individual manufacturing sectors has so far prevented us from studying the transport inventory relations on the 25 sectors we have in our data base.

RESEARCH QUESTIONS, APPROACHES AND HYPOTHESES

This paper only deals with items 1 and 2 below.

Q1: Reveal the differences in logistics[1] performance among countries, sectors and over time.

A1: Compare inventory and transportation statistics using key indicators as productivity, part of total cost, capital intensity, etc. In particular, the ratio: value added to inventory value is used as a measure of inventory productivity. The ratio sales to inventory $\frac{S}{I}=\frac{S}{VA}\cdot\frac{VA}{I}$ is less appropriate since the level of integration $\frac{VA}{S}$ vary considerably. Cluster and time series analyses.

$$\text{Log perf} = f_1 \text{ (Country, Sector, Time)}$$

H1: There are considerable differences in the absolute levels of logistic performance between Japan, the USA, Western Europe and Eastern Europe respectively, and the gaps are getting wider.

Q2: Explain the differences in logistics performance.

A2: Key logistic indicators are taken as dependent variables, and proxies are taken as independent variables for potential explanatory factors, in stepwise multiple regression analyses on cross national and longitudinal data.

$$\text{Log perf} = f_2 \text{ (Log factors)}$$

H2: The long term differences in logistic performance depends on the performance and structure of interrelated systems as follows:

- *Transportation* quality; punctuality, shipment, sizes, frequency, speed, damage, risks, etc. See [16] for an overview. These quality measures are dependent on the mixture of transport modes, the integration via terminals, and the performance of each individual mode. Here the rail share of domestic transport work (ton km) is used as a proxy.
- *Production* processes and products; many variants, complex products, long lead times, inflexible automation, unsophisticated production and inventory control systems, low value added to sales ratios at each plant and many small plants are all contributing to lower value added to inventory levels. Here the number of industrial robots per 10,000 employees in manufacturing is used as a proxy for flexibility. Lack of statistics describing robot density and transportation mode mixtures per sector have so far prevented us from controlling for the variation in sector mix among countries.
- *Foreign trade;* sectors with high foreign trade have higher inventories [1] due to longer, less frequent and less punctual transportation chains and to more complex administration. Hence high import share increases inventories. However, high export share might reduce inventories if the strategy is to locate the warehouses as close to the market as possible, or increase inventories if a central storage and fast transport strategy is chosen. Here we use share of import of GDP as a proxy.

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[1] Logistics is used here in a very general sense to denote all systematic actions aimed at bringing materials from primary sources through all intermediate steps to the consumer. It includes transportation, handling, storage, and related information processes, as well as relocation of the activities in the logistic chain. A logistic chain is a dual network consisting of goods and information flows down- and upstream.

- *Distribution* structure; manufacturing inventories are lower if wholesalers take over part of the stockholding function. Since inventory data on wholesale and retail are missing for many countries we cannot directly include them in our dependent variable. Instead we treat wholesale sales to manufacturing output ratios as an independent variable.
- *Informatic* quality; as with transportation the quality of the information systems along the logistic chains as well as the level of sophistication of the decision support systems contribute to higher inventory productivity and less uncontrolled fluctuations in levels. The amount of informatic cost in the area of logistics could be a measure. However it is not available and we therefore use, here, the number of telephones per 100 inhabitants as a proxy.
- *Geographical* factors; as with foreign trade: long distances, unfavourable terrain or climate, few small producers or consumers spread over a large area; all contribute to higher logistics costs. In this respect the USSR is quite different from Japan.
- *Governmental* interventions; transport, taxation, trade, industry, regional and unemployment policy often have a major influence on logistic performance. The transport deregulation in the US has triggered the development of better logistic services, while central planning with inflexible material supply with long lead times creates excess inventories and shortages simultaneously. However, incentives to invest in new technologies or centralized and highly coordinated distribution systems improves logistics efficiency. Here the rail share variable, can be partially considered as a proxy for restrictions on transport use or a distorted price system.

Q3: How much of the differences in the level of economic development and growth can be explained by the differences in logistic performance?

A3: Direct estimation of logistic costs, input-output modeling, production functions, and trade performance models

$$\text{Econ perf} = f_3\ (\text{Log perf})$$

H3: Studies [1] indicate that the logistics cost of a product, accumulated along the chain from raw material source to final consumption as well as the capital engaged in the storage and transportation activities is 20–60% of the total. Therefore, large gaps in logistic productivity should have had a major impact on the economic growth and market shares. Figure 1 shows the relation between GDP/capita and value added to inventory ratios.

Q4: Sensitivity analyses, "what if" analyses and cost-benefit analyses of the impact of changes in logistic factors on economic performance.

A4:

$$\Delta\ \text{Econ perf} = f_3\ (f_2\ (\Delta\ \text{Log factors}))$$

Q5: Analyze the dynamics of the logistic factors. Driving forces, barriers and regularities.

A5:

$$\text{Log factors} = f_5\ (\text{Forces, Time})$$

H5: Slow changes and regularities in technology shifts.

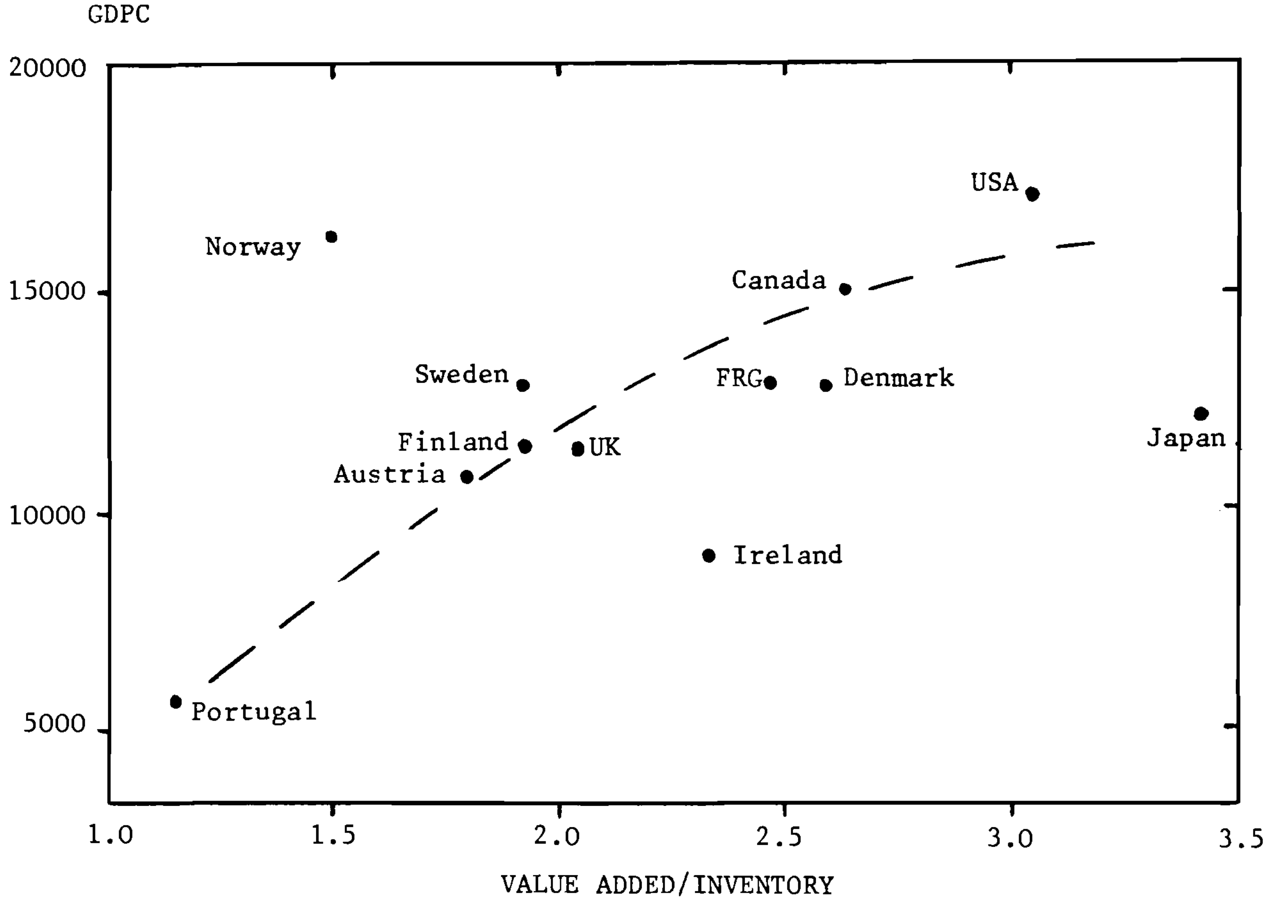

Figure 1: GDP per capita – Value Added/Inventory

Q6: Make alternative scenarios of technical, economic and policy changes that influence the logistic factors and estimate their economic impacts.

A6: After validations on fresh sets of data, the models above can be used together

$$\text{Econ perf} = f_3\,(f_2\,(f_5\,(\text{scenarios})))$$

H6: The economic gaps between Japan, the USA, Western Europe and Eastern Europe will increase if the policy is not drastically changed.

Q7: Find the best logistic strategy(S) considering uncertainties (ξ)

A7: Advanced decision support systems used in policy exercises.

$$\max_{S}\ \mathop{E}_{\xi}\ f_3\,(f_2\,(f_5\,[\text{scenarios}(\xi),\ S]))$$

INVENTORY LEVELS IN MANUFACTURING INDUSTRIES

Our data base of information collected so far contains comparable data for inventories in the manufacturing industry at the three digit level classification of branches of the manufacturing industry for 14 countries; 12 market economies: Austria, Canada, Denmark, Finland, FRG, Japan, Ireland, Norway, Portugal, Sweden, UK, USA and two centrally planned economies: Poland and Hungary. The basic source of information is the UN Industrial Statistics. The data for Poland is provided by a research team working under a contracted study agreement with the New Logistics Technologies Activity.

The main indicator used in the comparative study is VA/I which is considered as a proxy for the logistic performance of inventory productivity of the respective branch.

The following conclusions can be drawn from the analysis regarding cross national comparison carried out so far:

1. Stable differences exist in inventory performance (VA/I ratio) between the different countries. This is true for the whole manufacturing industry as well as the different manufacturing sectors. See Figures 2 and 3. Japan is leading as a rule followed by the USA, Western Europe, Scandinavia and Eastern Europe.

   The difference between Japan and Hungary for the whole manufacturing industry is a factor of four and for the motor vehicle industry a factor of eight. This means that the cost of production would be 30–38% higher in Eastern Europe and 7–9% higher in Europe due to the higher stock levels, if all other factors were equal and assuming that the capital and storage cost is 30% per annum.

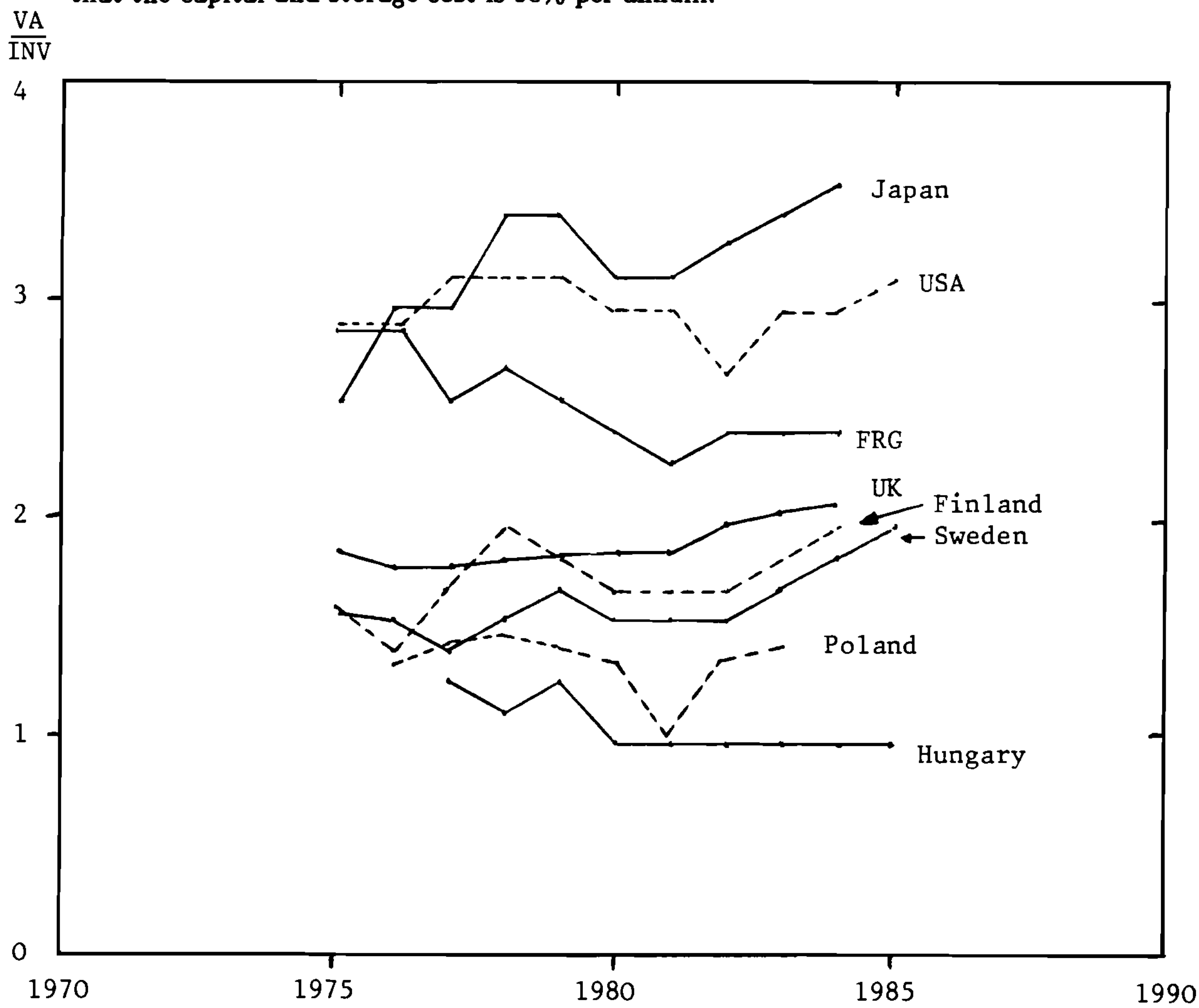

Figure 2: Value Added/Inventory in Manufacturing Industry (ISIC 3)

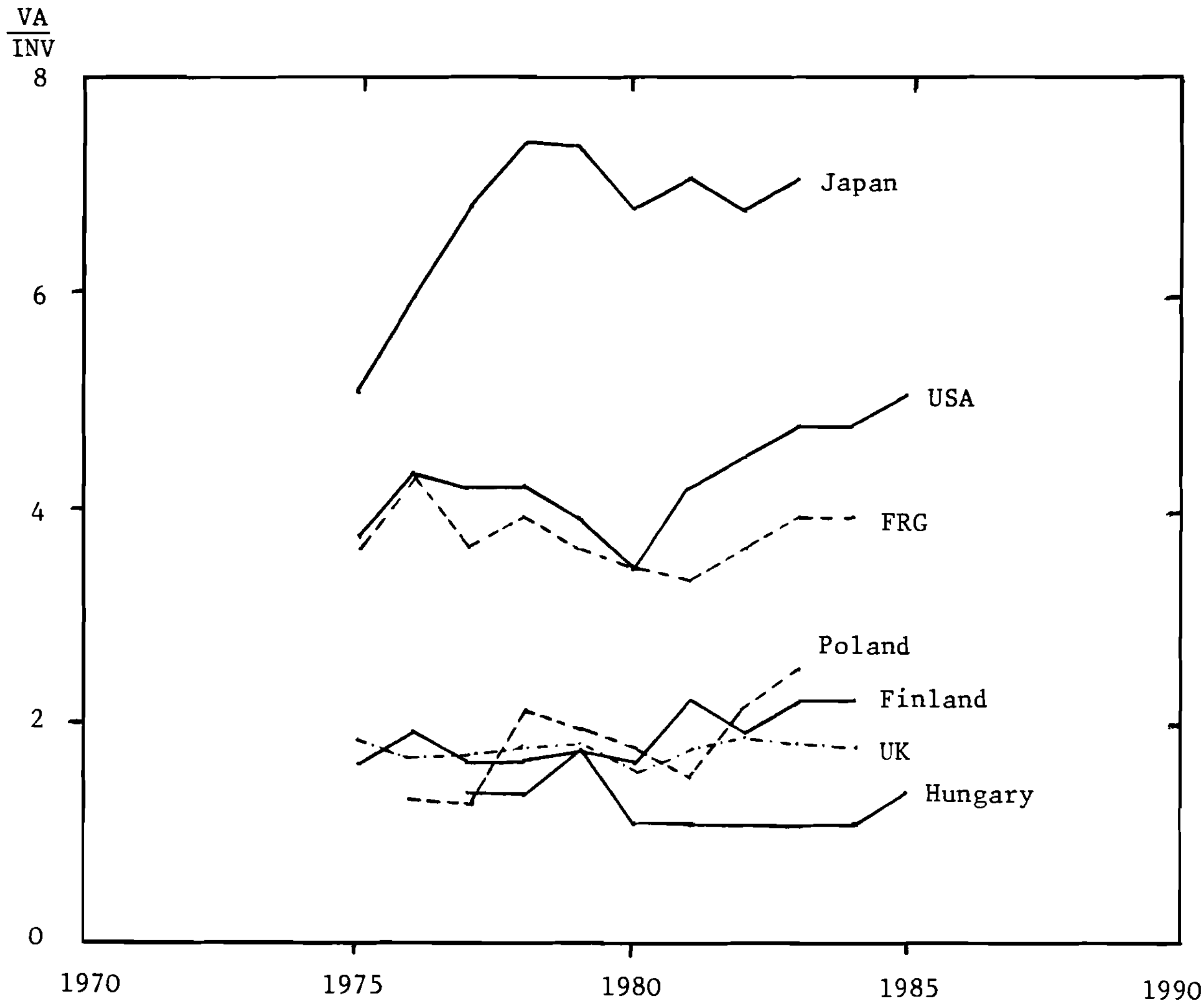

Figure 3: Value Added/Inventory in Motor Vehicles Industry (ISIC 3843)

2. Since 1975 Japan has steadily improved its inventory performance and there is an upward trend for almost all the other countries after 1980. At the same time the gap between Japan and the other countries is widening. This fact requires specific attention. A similar study from Chalmers University [6] aimed at finding the effect of implementating computerized inventory control systems on aggregate inventory levels showed that for the period up to 1980 such an effect did not exist. However the upward VA/I trend in the early eighties might partially be due to that.

3. The VA/I ratio is influenced by the business cycle. If this influence is eliminated the long term shifts can be better seen as indicated in Figure 4.

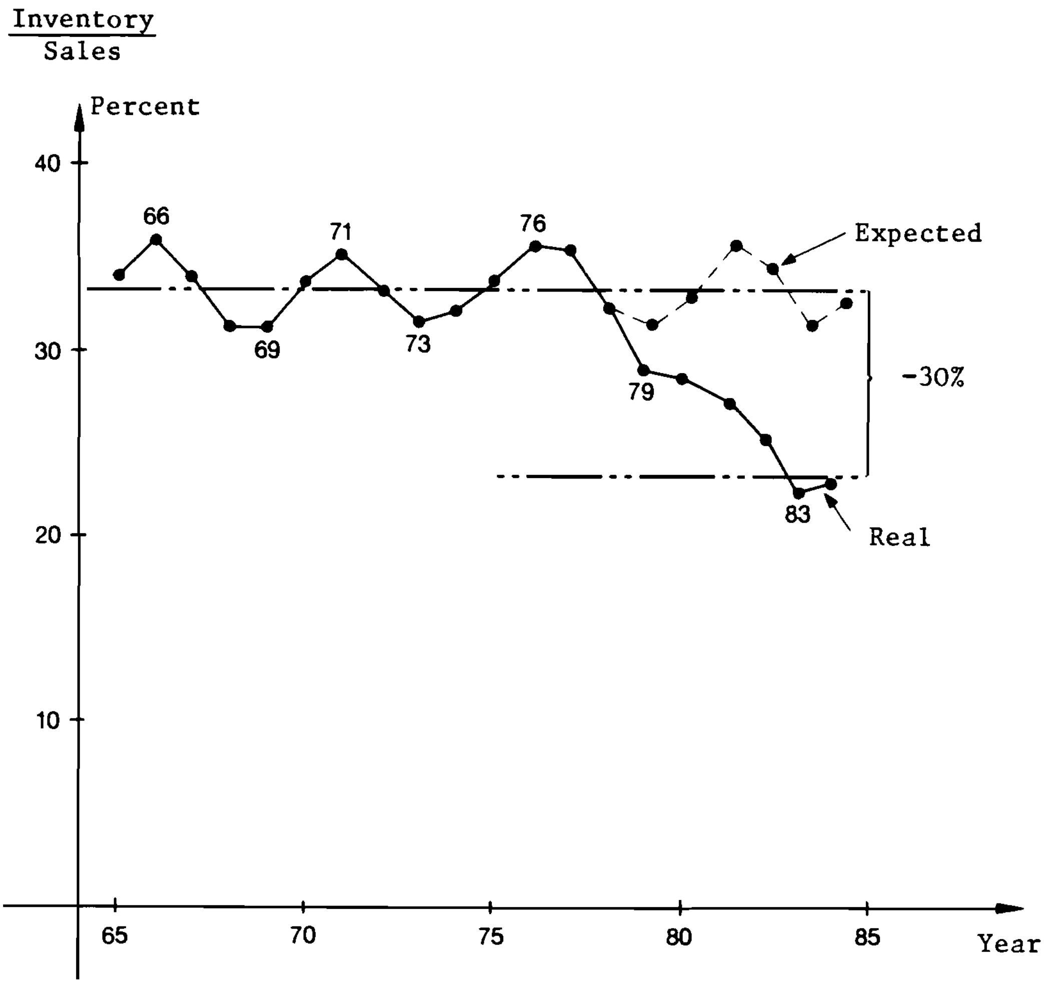

Figure 4: Inventory/Sales Ratios for the 77 Largest Companies on the Swedish Stock Exchange. Source: [11]

EXPLORATIVE ANALYSES OF FACTORS THAT MIGHT INFLUENCE INVENTORY LEVELS

Transport. The surprisingly high correlation between inventory productivity and a proxy for transport quality is shown in Figure 5. Figure 6 depicts the shifts over a 10 year span. Note the large advancements in Japan and the US.

Sweden and Finland succeeded in improving inventory productivity while maintaining a high rail share. This is probably due to three facts:

(a) Rail took over from the slower ship mode, road from rail, and air from road.

(b) Improved rail service quality, particularly the introduction of the mini container.

(c) Penetration of new logistics management concepts.

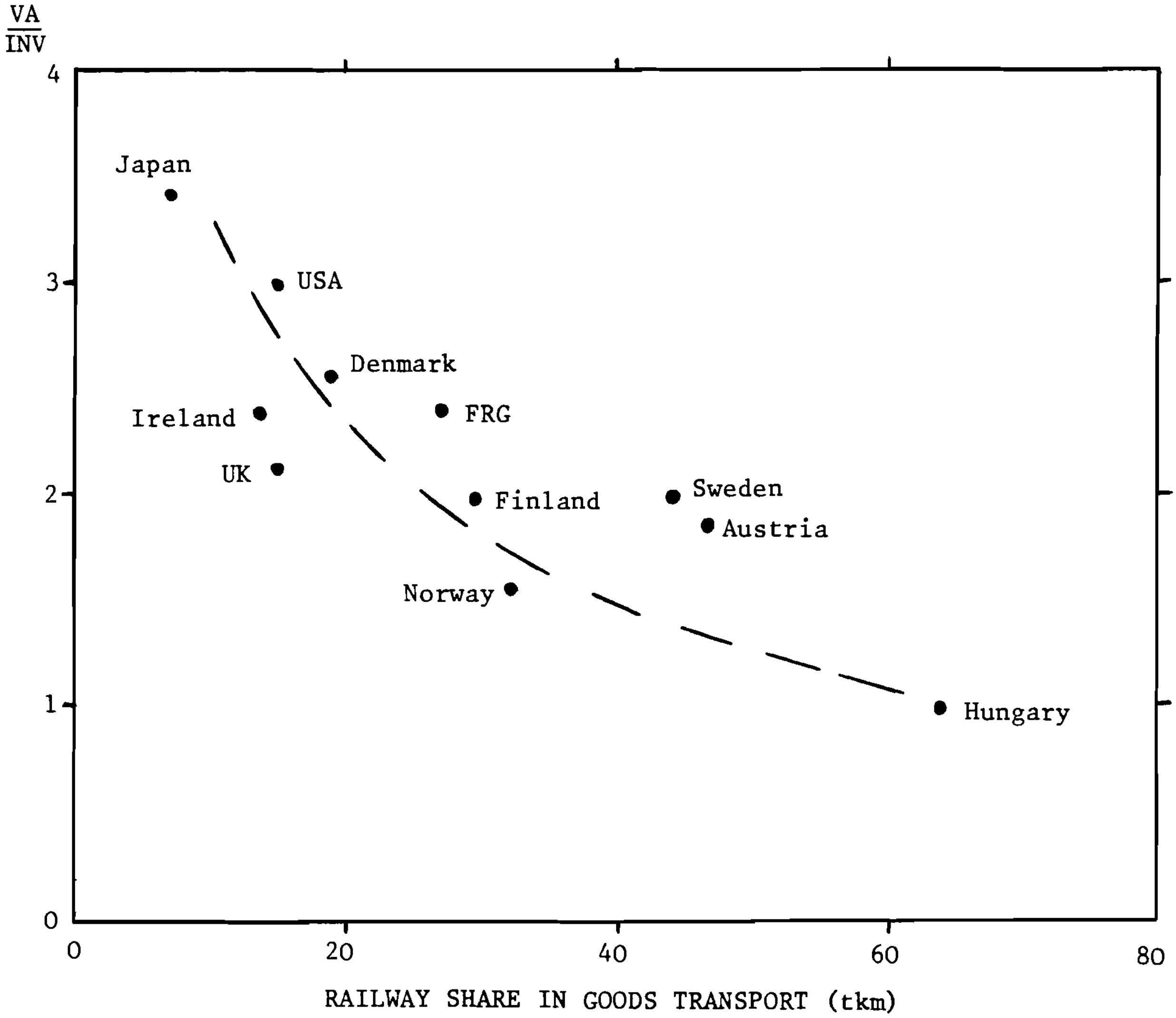

Figure 5: Value Added/Inventory – Rail Share (1984)

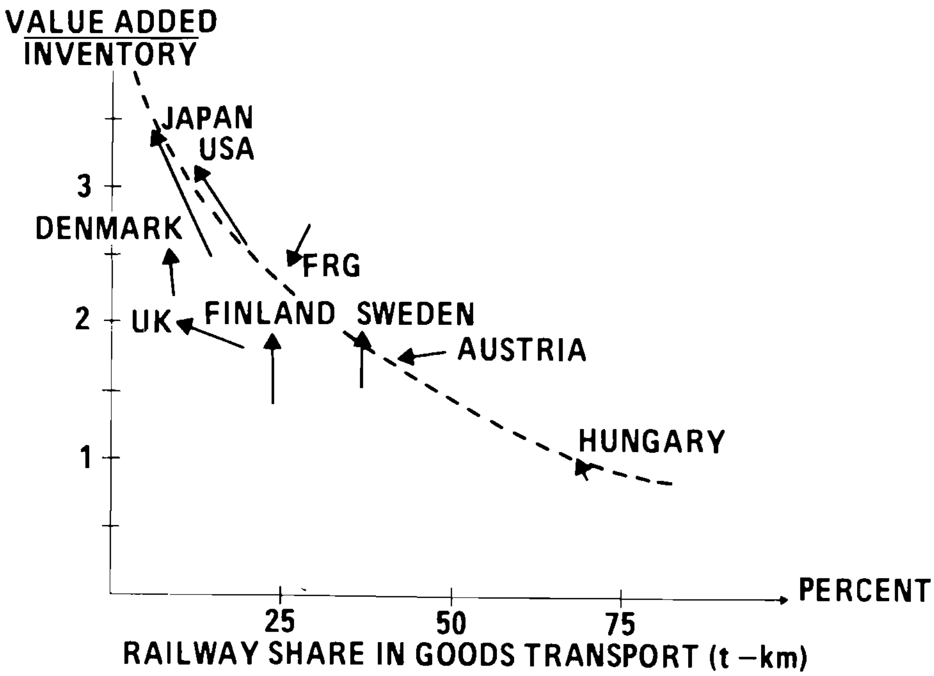

Figure 6: Changes in Turnover and Rail Transport Shares 1975-1985. Source [8]

Production. Figure 7. Inventories do not seem to be well correlated with robot intensity. Probably the share of robots is too small to have any significant impact on the whole manufacturing industry. Better explanatory power is expected on a sector level. According to our analysis, robots have so far mainly been used as stand-alone solutions for simple tasks such as spot welding, painting, handling, as well as for simple assembly tasks. Systems applications as Flexible Manufacturing Systems have started to grow, but have only a minor share of the total robot stock.

Import has a similar impact on inventories as rail share. Figure 8. Ireland is an odd case since the import from Northern Ireland and the UK is expected to cause less logistic problems than imports from remote countries. One possibility could be to weight the import values by distances to origin. The import also includes commodities that are not used in industry. Sector level analyses would eliminate this problem. Another problem is that GDP measures are not completely comparable among countries. For example, planned economies use Net Material Product, which excludes most of the service sectors, instead of GDP. This has been adjusted for, in this study.

Wholesale. Figure 9. The large differences in wholesale intensities deserves a closer analyses. Many layers of wholesalers can be assumed to result in high 'total' inventories, i.e., manufacturing and trade inventories, but lower transport cost due to better consolidation and thereby larger shipment quantities. The complex multilayer distribution structure of Japan in comparison to the USA might explain the lower manufacturing inventories of Japan when the influence of the other logistic factors have been considered. Note that wholesale also includes goods that are neither inputs nor outputs from manufacturing. However, distribution through wholesalers might reduce total inventory levels by central and early-in-the-chain storage concepts.

Telephone density shows high correlation with the number of computer terminals per 1000 employees. However, since we could not obtain the statistics on computer terminals from all the countries in our study we used telephone density. Figure 10.

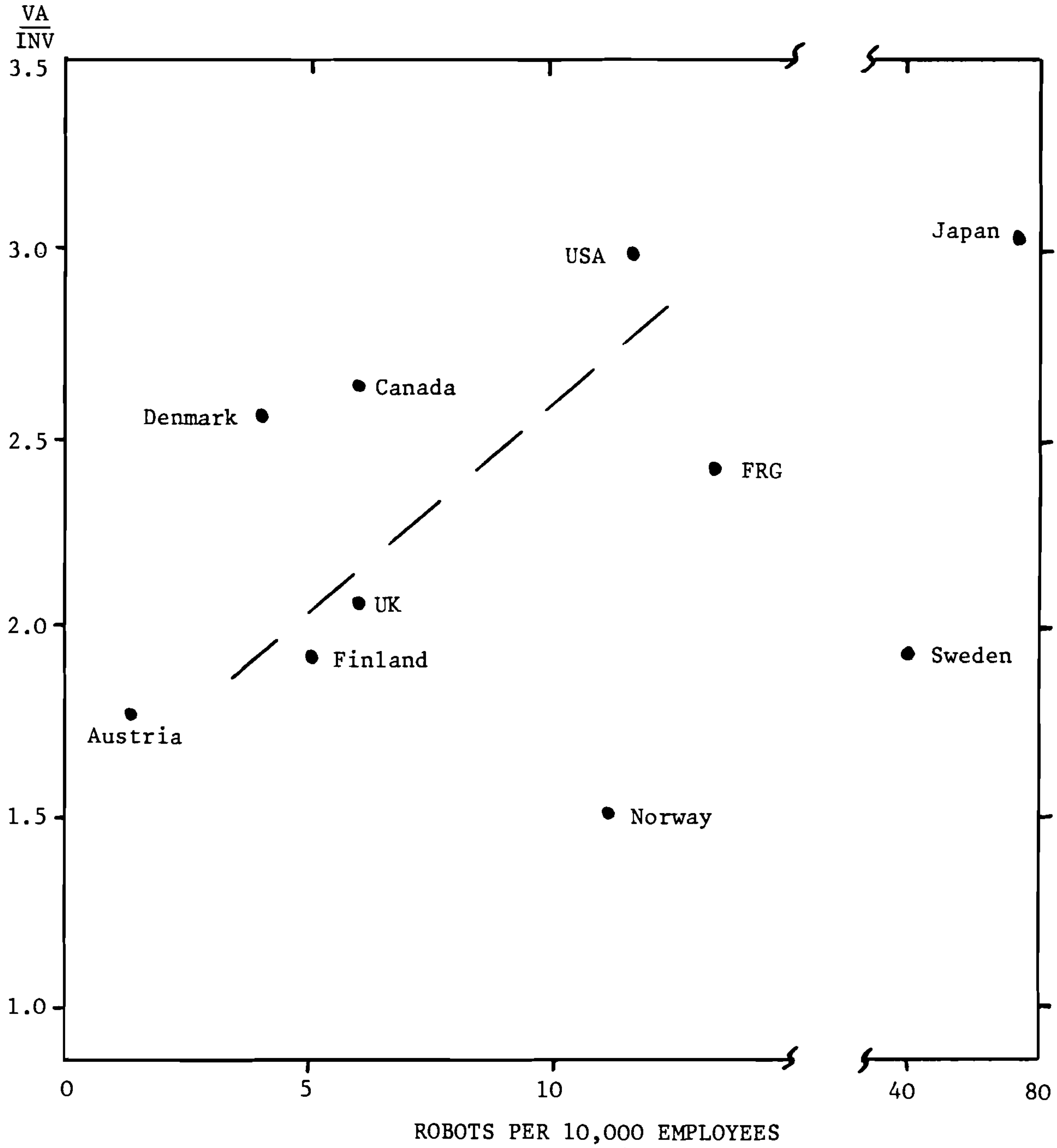

Figure 7: Value Added/Inventory – Robots per 10,000 Employees

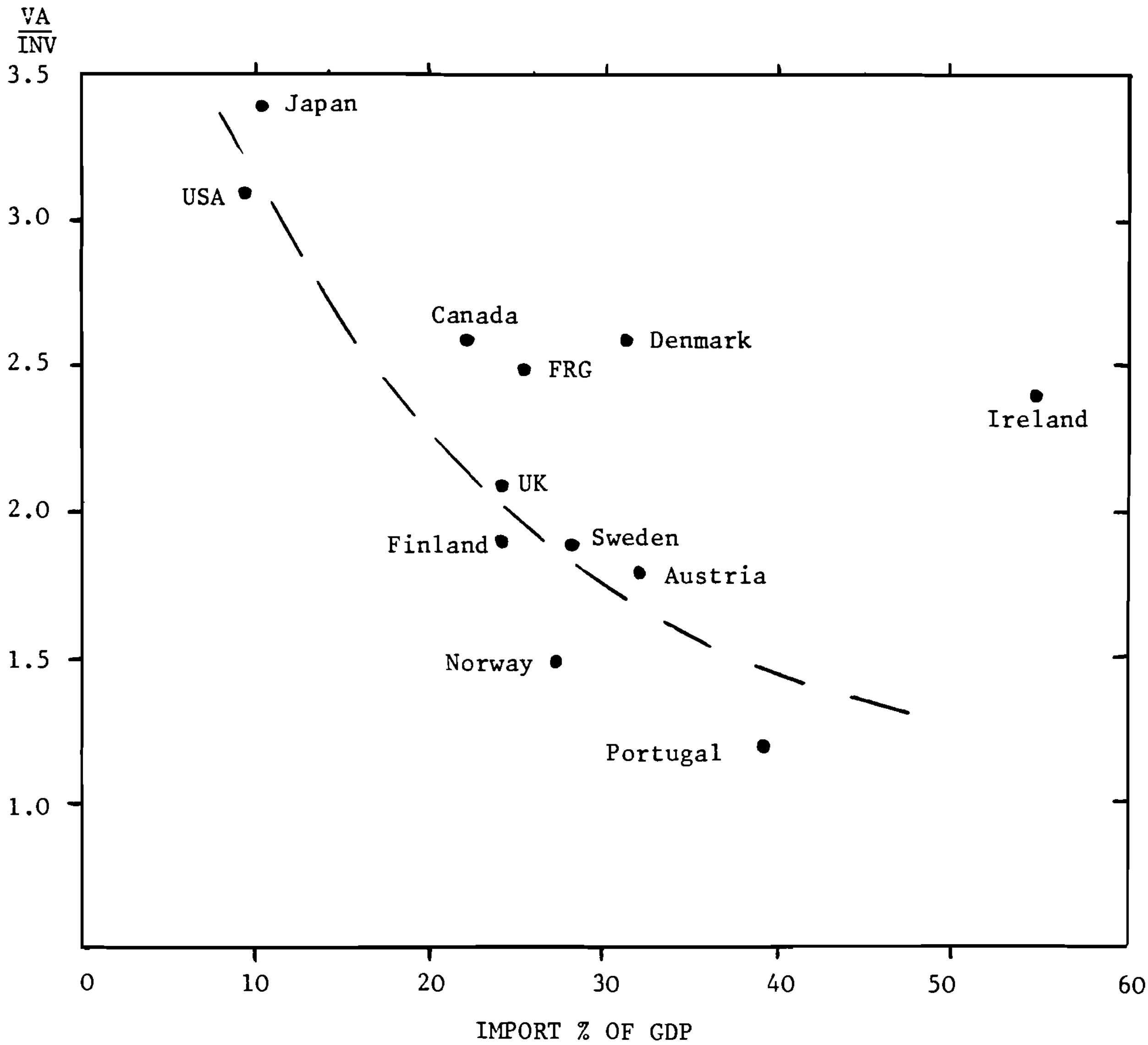

Figure 8: Value Added/Inventory – Import % of GDP (1984)

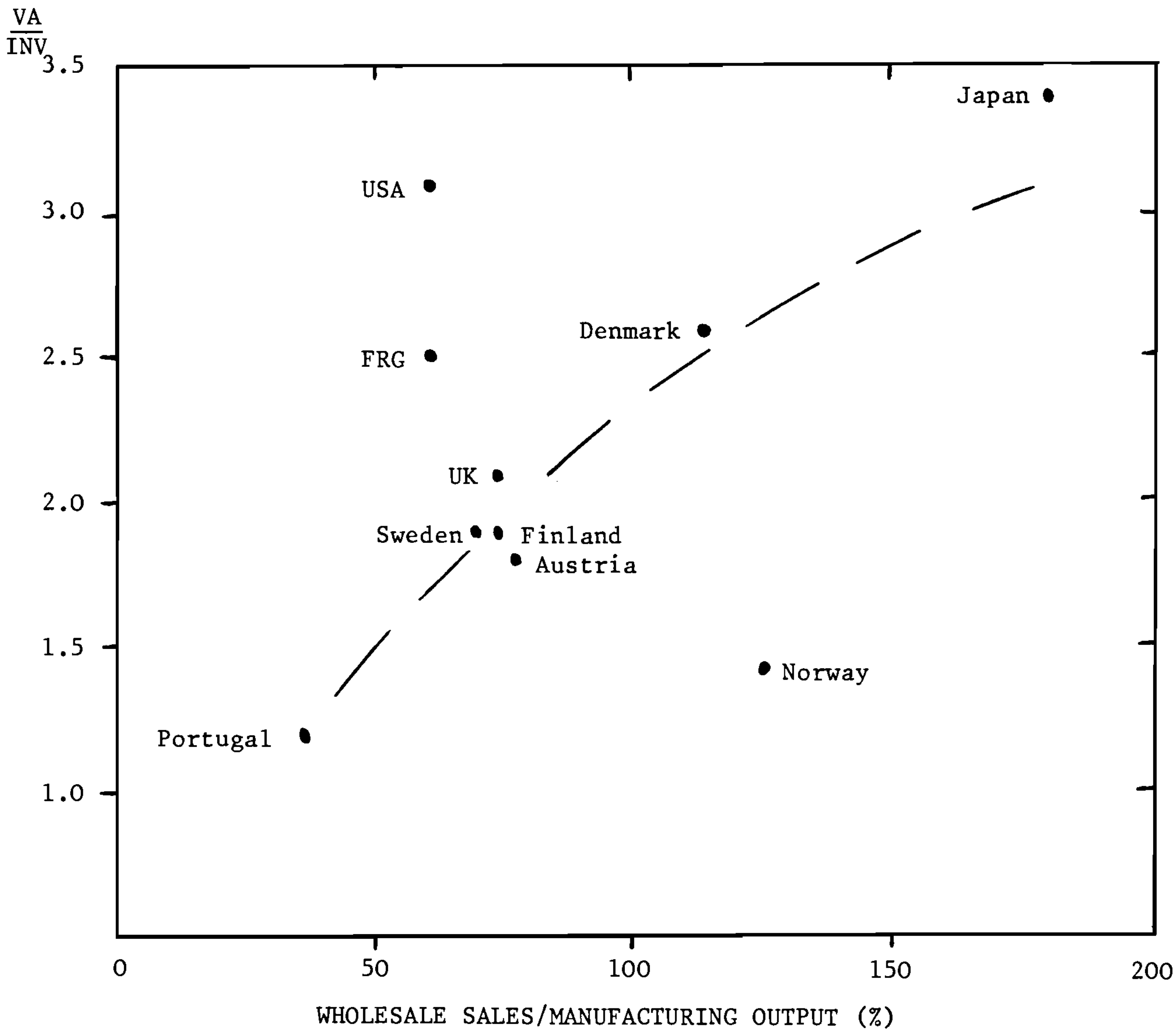

Figure 9: Value Added/Inventory – Wholesale Sales/Manufacturing Output (1984)

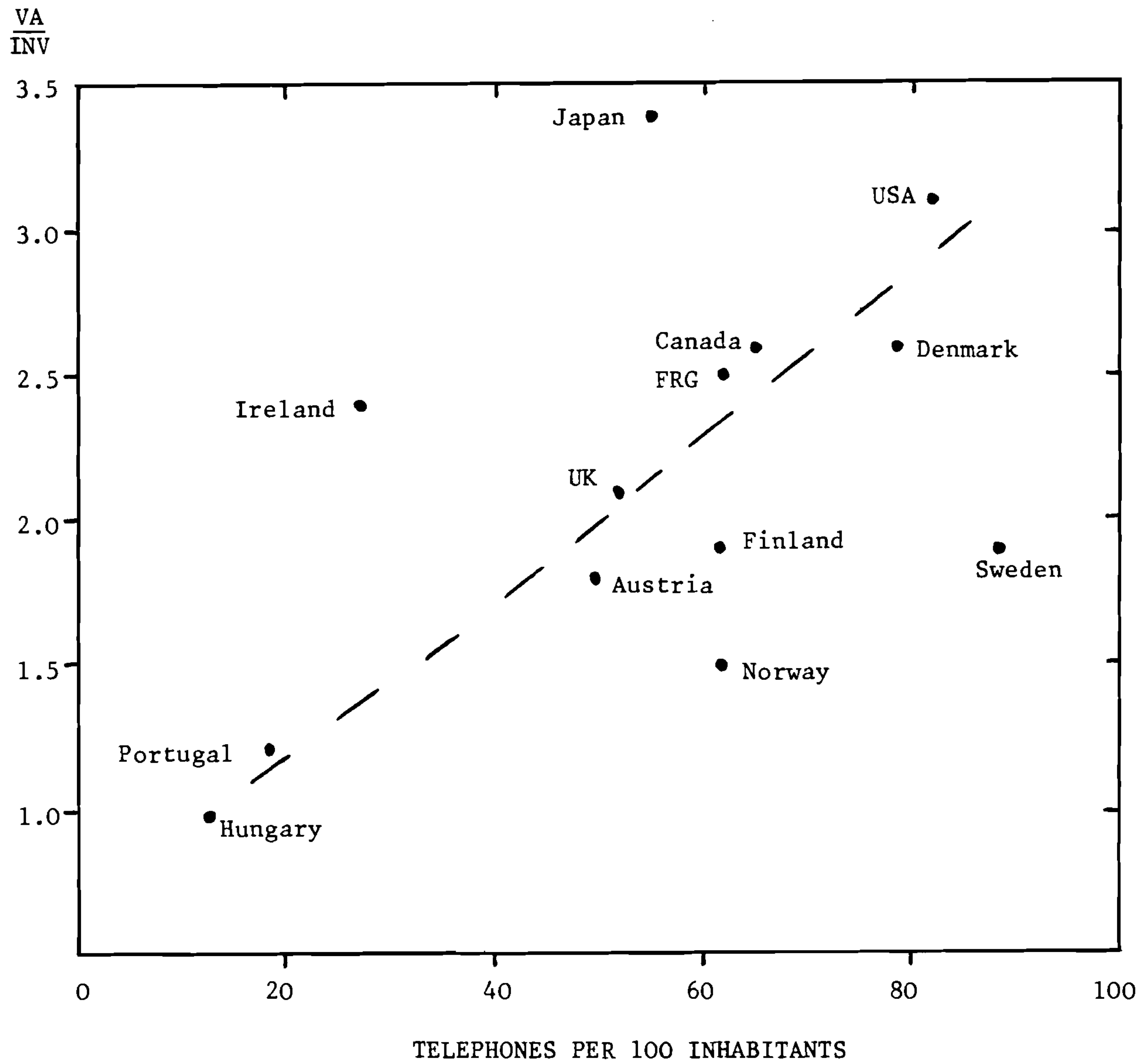

Figure 10: Value Added/Inventories – Telephones per 100 Inhabitants (1984)

REGRESSION ANALYSIS

Regression analysis was carried out to see how VA/I ratio relates to the above listed factors. The following hypothesis was tested:

$$\frac{VA}{I} = f\,(RA, IM, WHS, Rob, Tel) + u$$

where:

RA = rail share of the inland goods transport, (%) (a proxy for the quality of transport)

IM = import in percent of GDP, %

WHS = wholesale sales-manufacturing output ratio in % (a proxy for the participation of the wholesale sphere in the flow of goods)

Rob = robots per 1000 employees (a proxy for the sophistication (flexibility) of production)

Tel = telephones for 100 inhabitants (a proxy for the development of the communication system)

u = error term

A pooled data analysis was carried out on the basis of data for eight countries: Austria, Denmark, Finland, FRG, Japan, Sweden, UK, USA for 1980–84. The data for each country, for each year, over the five year period is considered as an observation. The estimations were performed through stepwise regression. The following equation was obtained:

$$\underset{}{VAI =} \underset{(7.87)}{2.635} - \underset{(-5.42)}{0.032IM} - \underset{(-3.09)}{0.013RA} + \underset{(5.02)}{0.006WHS} + \underset{(1.32)}{0.003Tel}$$

ADJ $R^2 = 0.848$ F = 55.6

(t - statistics in parenthesis)

The results obtained indicate that 80% of the variations of inventories among the investigated countries could be explained by factors related to transport, communication and trade. The regression coefficients are significant on a 1% level or higher except for Tel which is significant only on a 20% level.

The fact that Rob did not exercise significant influence could be explained from one side by the still low penetration rates of industrial robots and especially their concentration in a few manufacturing industries (i.e., motor vehicle) and from the other side that most robots are, so far, used for stand-alone applicatiaons with no impact on systems flexibility. This means that a better proxy should be sought for the flexibility of production. Tests for time effect using both a dummy variables model and an error component model showed no significant bias due to time effect. The regression equation shows that these variables play important roles. However, it is not intended to be used to forecast the impact on inventories of changes in the independent variables.

The analysis of the standardized regression coefficients show that the factors rank in the following sequence: import, transport, wholesale, communication. These results contradict with earlier studies [6, 12], which suggest that differences in inventory levels mainly depends on differences in economic policies and management styles.

FURTHER STUDIES

In order to make firm conclusions these analyses should be extended in the following aspects:

(1) Increasing the number of countries. The data for several East countries is in preparation.

(2) Increasing the period of analysis. Here a problem arises with controlling for I variations due to the business cycle.

(3) Analyses on sector levels. We have some 25 sectors per country in our data base. Unfortunately the transportation data is not generally classified to sectors of origin or destination. The interaction between sending and receiving inventories needs special attention.

(4) Introduce new independent variables describing industry structure, governmental policies, geographical circumstances.

(5) Disaggregate inventories into material, work-in-progress and finished goods and repeat the analysis.

(6) Introduce better proxies for the factors under investigation.

(7) Make better specification of the regression equation. Most probably the relation between the independent variables and VA/I is not linear, as can be seen from Figures 3–10.

(8) Use other methods of analysis, e.g., cluster analyses, production functions and input-output models.

CONCLUSIONS AND RELATION TO OTHER RESEARCH

The preliminary results indicate that most of the cross national differences in inventory levels as well as the improvements made between 1980–84 can be explained by differences in the performance of transportation, production and communication processes as well as the structure of foreign and domestic trade flows. If further analyses verifies that these historical correlations are also causal relations that hold true for future, several far-reaching recommendations for policy consideration and research strategies could be made.

Even if the logistic performance of an individual company can be improved considerably only by adopting new management principles – as many case studies and surveys indicate – large investments in hard-, soft- and orgware are needed to achieve long term improvements for a whole industry or region. The logistic infrastructure sets the limits for logistic productivity improvements and infrastructure improvements gives long term logistic benefits to industry and can also act as a change agent for accelerated developments.

The impact of improvements in transportation on economic growth has previously mainly been analyzed for developing nations. However, the current trend to internalize transportation and synchronize the material flow between the actors along the logistic chains has led to a newborn interest in using improvements in external transportation as a mean for economic growth as demonstrated in some recent studies concerning infrastructure investments [17, 18] and the technical and organizational development of transport process [19, 20]. IIASA has focused on analyses of the long term dynamics of transportation infrastructure [21, 22] and transport informatics [23].

Most research regarding the consequences of automated and flexible production have focused on employment. However, as one study [24] indicates the average cost for wages was 18% of total cost, and only a fraction could be saved, while the average cost for stocks and work-in-process was as high as 37%, of which up to 75% was saved.

At IIASA we have specially analyzed how external and internal transport can better be coordinated [25]. We now continue to survey the logistic prerequisites and consequences of FMS installments using both secondary information and our own international questionnaire survey. Preliminary results indicate an average inventory reduction of 3.5 times [26].

Many researchers, e.g., [27, 28] claim that interfirm and international computer integrated logistics will be the dominant change agent for the future. Hence, the bottleneck for improvement might be in communication standardization, lack of capacity and antique regulation that prevents innovative service developments.

The negative impacts of complicated trade procedures and transport regulations on the logistic performance of Western Europe have been revealed and policy measures have been taken to create an inner market for the European Common Market. IIASA has developed a methodology to analyze the impact of changes in international transport on logistic chains and tested it in Finnish cases [29]. The Economic Commission for Europe at the United Nations is also using the concepts of transport and logistic chains to analyze the impacts of transport policies on international freight transport corridors.

It is well known that the logistic component of total product cost is large, average about 33%, and growing [1]. However, much less is known of the impact of changes in the structure and performance of logistic activities within and between sectors and countries. Therefore, the input-output modeling technique has been extended to explicitly include logistic activities. It has successfully been tested on the Dutch economy [30].

The relations between inventories, trade, transportation, communication and production technology found in this study will now be used in the multinational IIASA INFORUM input-output model. Thereby, enabling us to evaluate growth, structural and trade consequences of alternative scenarios describing the future evolution of logistics and production technologies.

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