ECONOMIC ANALYSIS OF INFORMATION ACTIVITIES AND THE ROLE OF ELECTRONICS, TELECOMMUNICATIONS AND RELATED TECHNOLOGIES

Economic Theory and the Information Economy

Directorate for Science,

Technology and Industry

Working Party on Information,

Computers and Communications

Policy

Working paper prepared
by the
Telecommunications Economics Branch
Department of Communications
Government of Canada
1804-300 Slater Street
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1. Introduction

The phenomenon of growing information related activities in the economy has given rise to policy concerns and strong impetus to its study. Important preparation for the evolution of an information technology policy will come from related economic research at both the theoretical and empirical levels. The most notable contributions to the empirical study of the information economy are by Machlup and by Porat. Through these achievements it is convincingly made evident that a set of information accounts is a practical goal. At least for Canada, this position is corroborated by the reply to the OECD sponsored questionnaire on information accounts. Unfortunately, our understanding of the information phenomenon does not equal our ability to measure it and it is not clear that such measurements would aid policy making or even be meaningful.

So far most of the discussion of the information economy has focused on macro issues. However from the considerations arising in this paper, it has become more and more apparent that greater attention has to be given to the microeconomics of information activities, because only at the microeconomic level can we begin to understand the role of information in the economic process, and to gain a view of its contribution to output. One of the chief concerns as we see it ultimately relates to the problem of the efficient allocation of information in the economy and the apparent incapacity of the price system to manage this allocation. The other very vital concern rests with the uneven distribution in power and income brought about by different degrees of access to information and knowledge by different individuals, but unfortunately this

problem has to be put aside for another day.

This paper consists of four main parts; a brief review of the place of information in economic theory, a discussion of of information accounts, the microeconomic aspects of information demand,and a research proposal. The proposed research focuses on the role of information in the production process and will represent our major input into the Synthesis Report of the Expert Group on Economic Analysis of Information Activities and the Role of Electronics and Telecommunications Technologies.

2. Information and Economic Theory: A Review

Information did not until recently receive much attention by the architects of general equilibrium theory. The intellectual tradition behind neoclassical economics has been largely dominated by the question of the consistency of actions by independent economic agents - the competitive economy not only avoids chaos but enjoys equilibrium in which all markets clear and, under given endowments, optimality in the Pareto sense prevails. In fact pure competition is informationally very efficient. (1)

The production and consumption of physical goods and services in the competitive model reflect the decisions of economic agents who take commodity prices as outside their influence. A unique price prevails on each market, is assumed to be known with certainty, and is perceived as not being under the control of any agent. In addition producers have knowledge of their technology and hence cost curves. Consumers' knowledge of quality is perfect, as is buyers' knowledge for factor services. Thus knowledge of demand elasticities is totally redundant, since price tells everything that remains to be known. Since the information needs of the paradigm is so minimal, the question of market information scarcely arose.

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(1) To quote K.J. Arrow (2.) "The apparent modesty of the information needed is one of the most appealing aspects of the neoclassical model".

Nonetheless, economists have come to recognise the importance of market information in the efficient running of the economy. With the rise of socialist and centrally planned economies, economists were presented with a rich variety of alternative economic organizations. The central position of information then became a key consideration in the theoretical and practical choice among the different organizations. This aspect was dramatised by the debate over the feasibility of a socialist planned economy, starting with Barone (3) and coming to a head with Hayek (13) and Lange (17). Lange, demonstrating the feasibility of economic planning, adopted the essential features of competition to conserve on costly resources that the planners would have had otherwise to allocate away from production to information activities, and so preserve optimality. In fact, the planning solution well highlighted the enormous strain the competitive system places on its primitive information system when trying to recover equilibrium following a shock that puts markets out of balance.

The usual model is that prices move in a direction dictated by the sign of excess demand, while at the same time all prices remain parametric. But if prices are parameters given to buyers and sellers how do changes also take place? What motivates the price adjustment? The only convincing institutional replica of the famous Walrasian auctioneer is indeed the Lange and Taylor model, where the state planning board uses a system of trial and error to arrive at the competitive solution. But a real decentralized economy has no such recourse and will demand more than price information and a mechanical feedback mechanism to maintain a semblence of stability about its equilibrium position (see Rothchield (22), Fisher (12), and Diamond (9)).

In reality, of course, the economy for the most part manages to stumble its way roughly towards equilibrium, despite our not knowing in detail how the process takes place. The adjustment is neither swift nor perfect, as is testified by the economy's short run inability to absorb large injections of new participants into the labour markets, to correct imbalances in international payments, to neutralize external and internal inflationary shocks, and so on. But somehow economic agents in the real world more or less read correctly the market signals which tell them of the gains to be had by trade and, on average, the outcome provides a new set of price and quantity signals which validates the actions taken. However, this happy result does not always materialize, producing a breakdown in information flows with disasterous consequence, as occured during the Great Depression. The danger of a depression arises when a shock causes a fall in purchasing power which, before a recovery can be made by a slowly adjusting economy, initiates a decline in sales. This in turn produces layoffs and a further fall in income, initiating a full blown downward spiral in economic activity. These events could have been avoided if the pessimistic information produced by the market signals were ignored and other sources of information were read, as was urged by J.M. Keynes and is now followed by modern governments.

The information flows to the economic agents, when the economy is out of equilibrium, thus having a crucial bearing on stability. We know very little of the economy's adjustment process, of how information is translated into producer's and consumer's expectation, of how these in turn gets translated into actions which create future expectations and so on.

The small demand for information thus appears to be a flaw rather than a virtue of the competive equilibrium model, for so much depends upon information being costless, on there being no uncertainty, and on all the rest.

But equally important is that any savings on informational costs possible in the decentralized competitive economy has to be balanced by other costs.

In a decentralized economy as, indeed, in any economy, the relationship between individuals and property has to be coded and enforced. Buyers and sellers trade by entering into contracts, these being backed by the enforcement powers of society which thereby helps to reduce incidents of cheating or default, and consequently diminishes the risk attached to the contracted trade. Property is registered under an individual's name and is protected to a degree from theft or damage. Some of these are inherently information type administrative activities. In fact, the whole equilibrium structure is held together by a massive institutional superstructure through which the terms of such contracts are policed and their fulfillment enforced. By having to define and maintain property rights, society elects to keep institutions which it did not come by without great costs and, whatever the economic system, these costs of administrating and storing information are unavoidable even if they can be minimized.

Once the competitive conditions no longer hold, a unique market price cannot be expected to rule any more than can a price array. Any multiplicity of prices on a market for a homogeneous good can be perceived as a reflection of incomplete information available to the economic agents. It is in this vein that Stigler (23) initiated the modern literature on the "Economics of Information", where it is shown informational costs can explain such diverse phenomenon as frictional unemployment (19), product quality diversity (1), "thin" markets, (24), and even market structure (15).

Information costs, like transaction costs, are an impediment to trade. Because knowledge about the variety of product quality, price and availability has to be acquired either through search

or by hiring the services of some appropriate search agency, full information on market conditions will in fact not be sought. Market participants can live with imperfect knowledge since it would not be optimal to allocate more than a certain limited amount of resources to information gathering. It is better to operate under conditions of uncertainty and tolerate the risks involved. But if such risks become too great, markets will collapse or be non-existent, unless some risk shifting arrangement can be constructed, such as the stock market or insurance institutions. Even so, very large uncertainties may still deter the emergence of risk shifting institutions which would otherwise have allowed markets (especially futures markets) to form or , for example, socially desirable research and development projects to proceed. The expected returns to risk adverse investors would simply be too low, in these instances, to make risk bearing arrangements profitable. We will return to this theme later.

Another aspect worth mentioning is the tendency for over-investment in a form of information termed market signaling, for example education as proof of productivity, leading to improper allocation of resources (M. Spence (24)). This phenomenon is analogous to the over-investment which occurs in advertising when it is used as a medium of competition between oligopolies.

Information flows not only figure largely in the modern industrial economy but even go a long way to shaping the economic structure. The availability or unavailability of the requisite information determines the existences or non-appearance of

markets, and the need for market information gives a strong spur to the growth of search and non-speculative brokerage industries. The rise of risk management industries, including the insurance, finance and speculative brokers industries, makes increasingly possible the shifting of risk and thus the opening of wider economic opportunities. In the dynamic development of the economy, information, as embodied in educational attainment and in new technologies produced by R and D, is all-important. As well as increasing society's stock of knowledge, part of the tremendous educational expenditure goes into simply replemishing the continually depreciating stock which would otherwise die out in the succeeding generation. Major industries in the economy today are the telecommunications and computer industries. This variegated demand for information shows up in the national accounts as output devoted towards the production, processing, and distribution of information and, indeed, information activities are now taking the lion's share of GNP.

This is an important fact little noticed by economists apart from the notable exception of F. Machlup. While much detailed analytical work on the economic role of information has appeared in the economic journals, a comprehensive view of the consequences flowing from the transformation to an information-based economy was left to the enquiries of sociologists, futurologist and other intellectuals who have expressed serious concern over the social dislocations which may result in the near future.

3. The Rise of the Information Economy

The dominance of research and development in the modern industralized economies, the rapid rise of telecommunications and computer industries, has given emphasis to the importance of information-related activities to productivity and thus economic growth. Bell (6), Drucker (11), and Parker (20) maintained that the development of new technology in the information sector was causing a fundamental change in our social structure - the coming of a post-industrial society. The dimensions on which this change can be measured are the future orientation of an economy based on knowledge, implying an attempt to forecast and manage technology in order to control the social results of innovation, and a new intellectual technology of decision-making to facilitate the broad scale management of choices among alternative futures.

Parker (20) advances two main related themes. The first is that potentially unlimited economic growth can be sustained in the face of limited resources.

> In the approaching information age, the characteristic machine is one that processes information, augmenting not human physical energy but human information processing. The difference is a significant one. Since energy is used to manipulate symbols rather than physical objects, the consumption of energy and materials can be made arbitrarily small by using smaller and smaller physical representations of symbols in information machines. This means that in an information age unlimited economic growth is theoretically possible even though a steady zero-growth state is reached with respect to energy and materials.

His second theme is that increased expenditure on information activities leads to economic productivity gains in the rest of the economy. He states that research and development, and education have both led to more efficient production and more of the same will continue to foster growth. Drucker (11) also argues that increases in knowledge are the most important factor behind economic growth.

The theorists had no concise empirical framework which could be used to measure or test the concepts. For example, Bell was forced to use a wide spectrum of indicators such as the number of scientific periodicals published and the number of books in Yale's library. Although these data are often interesting, the wide variety of data can be confusing and even contradictory. For this reason, Machlup (18) pioneered the use of the national accounts as a basic framework for analysis. After defining and securing markets for education, research and development, communications media and information services, he eventually concluded that information industries accounted for 29 per cent of United States' GNP and employed 31 per cent of the work force. Machlup is currently updating his work to 1975.

M. Porat refined Machlup's work, developing more complex and detailed calculations. He also used the wider concepts of information suggested by Bell and others. He concludes that the information sector comprises about 46 percent of the United States GNP and accounts for about 50 percent of the civilian labour force. Porat's thesis, The Information Economy (21) is the most current and detailed empirical study presently available.

With the increasing dominance of information activities in the economy, it is conjectured that the economic-social institution will have to undergo extensive transformations. The market allocation system especially will be under siege owing to the public-good aspect of information. Thus greater public provision of goods and services is foreseen by Bell.

The forecasts provided by Parker and by Bell warn of the approaching information age and its consequences for the socio-economic institutions, employment, inflation and economic growth. The various issues presented by this transition can be summarized as follows.

-Less share of GNP in physical output, more share for non-material "information".

-Rapidly falling costs in computer and communication developments has profound implications for production, the organization of business and society generally

-Production processes can be further automated and controlled with the use of less staff. Fabrication as well as assembly work can be turned over to robots. Significantly, these developments are becoming economical for shorter production runs leading to wider application.

-The labour-intensive administrative and information processing activities are becoming increasingly subject to capital-using technological change. Lower level white collar employment is threatened by such developments as electronic funds transfers, electronic mail and the use of smart machines in the retail trades.

-Information output is difficult through private provision, giving natural cause for the growth of the public sector. The assumption is that the latter is less efficience and produces a drag on economic growth.

-With the phenomenonal rise in the price of energy and materials, information activities and developments may save on these expensive and scarce inputs. The telecommunications infrastructure can substitute for physical transportation, storage of information in computer memory can replace paper filing, etc.

-Large problems of regulation will present themselves as information networks grow and become more unified. Already we are faced with the progressive integration of computer and telecommunications industries, equipment and services.

- As national wealth becomes increasingly dependent on information activities, so the gap between rich and poor countries will widen or narrow according to international information policy. The potential for the development of poor nations is greater through the growth of the information sector, since scarce resources can then be saved. Such an outcome will depend on the international flow of information expertise and machines, and on a similar internal development by the LDC.

As the list of issues above tend to show, the problems associated with the predominance of information activities in the economy are often paradoxical. The potential productivity gains from further growth in information output may well be nullified by the particular organization of information production that emerges. Greater investment in information - intensive machines is clearly on the horizon but fear for the displaced workers, whether well-founded or not, dims the hopes based on these developing technologies.

No doubt the economy will experience great strains through the transition phase to the information stage of development. But it is unlikely that the economics of the situation will dictate a unique outcome to the process. For instance, the non-market provision of information is not as inevitable as has been made out, and the predicted inefficiencies can thereby be largely avoided. For an open economy such as Canada there is the additional dimension presented by international trade. This fact weakens our confidence in any forecasts of the direction our domestic economy will take, for naturally Canada will have to depend to a large degree on specialization in trade. What form this specialization will take is particularly unclear to date. In short, there are many economic considerations that have to be heeded if we are to gain a more accurate picture of near future developments.Thorough economic analysis will be required before policy prescriptions can be drawn up. A first step in this direction would be to answer in more detail the question, what is it that exactly constitutes the information economy. We shall turn to this question in the next section.

4. Defining and Measuring the Information Sector

The concept of the information economy gives emphasis to the fact that a large proportion of the GNP of advanced industrial societies results from producing, processing and transmitting messages and symbols, rather than from the production and distribution of physical goods and services. Information networks and facilities unify the economy as did the infrastructure of roads and railway in a previous age. The telecommunication and computer industries contribute significantly to GNP, as do government information services, including education. The formation of telecommunications capital establishes an information infrastructure which widens the scope of economic management and control, and permits a better coordination of production from the early stage of contracts for raw material inputs to the final stage of distributing the produced output. The processing of information at high speed by computers and their associated software has incalculable implications for production and economic productivity.

These developments show up through the National accounts but not directly as statistics organized about the concept of information. The nearest current measure of information activities is given by the service sector; indeed information growth may partly explain the tremendous growth in this sector. But the service nomenclature is inappropriate and it would be more revealing to begin with information as a basic concept for the development of an accounting framework. This consideration can thus be seen as the basic impetus for information accounting.

National information accounts provide both a description and a systematic approach to the measurement of the information phenomenon, although one can effectively argue that the information concept is both vague and too broad. The question of definition, the code by which information activities are distinguished from non-information economic activities remains, to be settled.

The fundamental conceptual issue in developing a detailed framework of accounting is to clearly specify the central role played by information in the economic system. The difficulty of this task is compounded by the broad definitions of information such as the definition of Porat:

> Throughout this thesis, "information" is defined as the bundle of activities that produce, process and distribute symbols as opposed to things.

Adopting this kind of definition leads to extreme heterogeneity in the activities of the information sector and it is this heterogeneity which leads to doubts about the centrality of the economic activities which are placed in the information sector of the accounts. Many activities of the data processing industries and the telecommunications industries fit easily into most perceptions of information activities and their centrality to the economic and social system would not be generally disputed. However, the information accounts treat such obvious industries on an equal footing with the motion picture industry, the photographic supplies industry and the comic book industry. It can reasonably be argued that these industries are also communicating information, however, their centrality to the economy can be called into question. They clearly do not provide the economy with its essential inputs and outputs.

These observations, indicating a fundamental uncertainty over the relative importance to be assigned to information outputs, is only one of many confusions that shows a general failure to fully clarify the purpose of the accounts. If all the accounts achieve is to record the progression over time of a phenomenon whose existence is scarcely more than statistical in content, there is little cause to expend effort on their production. The problem lies chiefly in the fact that not sufficient effort has been expended on identifying the problems which the accounts are to address. A better case could possibly be developed for information accounts by first specifying actual policy or theoretical issues that require attention and then demonstrate the superiority of an analysis rooted in the new accounts over other empirical approaches. The collection of such problems may then give rise to sufficient concern as to warrant the expense of keeping detailed accounts. We shall return to this question in section 6 below.

If we consider only the specific problem of extracting information accounts from the national income account we can readily see that, as always in developing new accounts, inaccuracies and errors are unavoidable. Due to its special economic nature however, much information activities occur outside the market system, leading to a significant compounding of these statistical errors. A multitude of assumptions will have to be made, for example, in order to record in statistics the value of information output produced in the "secondary" or non-market sector, such as by the private and public bureaucracies.

Separate information accounts for the U.S. have been produced by F. Machlup and M. Porat, using greatly different methods. Machlup based his work on the final demand components of the national income accounts,

and also did not always adhere to the concepts and definitions of the national accounts. Because final demand is classified according to who pays for it, the household, business or government, care has to be taken in deriving the information outputs. For example, programmes produced by commercial radio and TV stations sponsored by advertisers will not appear as such in final demand but only as a business expense accounted under the production costs of the sponsoring corporation or firm. Also, for this exercise it would be more helpful to start from the sources rather than the final sales of economic output. Table 1, taken from Porat, conveys a rough impression of Machlup's approach.

Table I

From The Information Economy

TABLE 4.1: COMPARISON OF MACHLUP APPROACH WITH THE PRIMARY INFORMATION SECTOR FINAL DEMAND
(USING NATIONAL ACCOUNTS CONCEPTS & DEFINITIONS)

INDUSTRY	MACHLUP[1]	NIA[2]
EDUCATION	60,194	21,232
Education in the home	4,432	0
Training on the job	3,054	0
Education in the church	2,467	0
Education in armed forces	3,410	0
Elementary & secondary		
Monetary expenditures	16,054	16,054
Implicit costs	17,285	0
Colleges & universities		
Monetary expenditures	4,443	4,443
Implicit costs	8,314	0
Commercial, vocational	253	253
Federal programs, nec	342	342
Public libraries	140	140
RESEARCH AND DEVELOPMENT	10,990	7,330
Basic research	1,016	741
Applied research	9,974	6,589
MEDIA OF COMMUNICATION	37,563	18,994
Printing & publishing		
Books and pamphlets	1,595	1,552
Periodicals	1,811	780
Newspapers	3,956	1,453
Stationary & office supplies	1,852	952
Commercial printing	2,879	592
Photography	1,600	1,600
Phonography	1,035	1,035
Stage, podium & screen		
Theatre and concerts	313	0
Spectator sports	255	0
Motion pictures	1,172	1,172
Radio and television		
Radio station revenue	523	0
Television station revenue	1,030	0
Radio & TV set repairs	1,982	1,982
Radio & TV investments	0	0
Telecommunications media		
Telephone	7,642	3,300
Telegraph	318	137
Postal Service	3,000	900
Other advertising	5,000	3,539
Conventions	1,600	0
INFORMATION MACHINES	8,922	8,732
Printing trades machinery	350	350
Musical instruments	190	0
Motion picture equipment	147	147
Telephone & telegraph equipment	1,200	1,200
Signaling devices	200	200
Measuring & controlling instruments	4,968	4,968
Typewriters	272	272
Electronic computers	332	332
Other office machines	937	937
Office machine parts	326	326
INFORMATION SERVICES	15,542	15,567
Professional services		
Legal	3,025	1,507
Engineering & architectural	1,978	0
Accounting & auditing	1,138	0
Medical (excluding surgical)	2,083	2,083
Joint with financial services		
Check deposit banking	n/a	n/a
Securities brokers	647	575
Insurance agents	2,173	2,173
Real estate agents	n/a	n/a
Wholesale agents	1,229	1,229
Miscellaneous business services	1,714	0
Government services		
Federal	1,555	8,000[a]
State and local		---[c]
TOTAL KNOWLEDGE PRODUCTION	$133,211[b]	$ 71,855
% OF GNP	29%	16%

[1] Machlup's "Knowledge industries, total value", 1958

[2] National Income Accounts Concept of primary information sector final demand.

[a] The Federal, state and local governments are final demand sectors. Their purchases include goods, services and wages. The $ 8 billion represents only wages of those information workers engaged in primary industries within government, e.g., printing, legal services.

[b] Machlup adjusts GNP to include imputations. The 1958 GNP was actually $448,400. Figure used in the Machlup book was $442,200 before adjustments, and $475,600 after adjustments.

[c] State and local education has been accounted in "Education."

Source: Machlup, ibid., Table IX-1, pp. 354-357 and conceptual definitions in the text.

On coming to the scene later and being able to take advantage of greatly enhanced computer facilities, Porat was able to set up accounts based on the measure of value added. This approach starts from a more detailed breakdown of economic activity, especially in terms of industry output, yielding directly a more precise and detailed identification of the source of economic activity, in terms of output and employment. Table 2 shows in the last column the contribution of the U.S. information value added in 1967 by industry at a highly aggregative level. Porat has also produced an input-output table of inter-industry transactions in information and non-information goods and services.

Table 2

From The Information Economy

TABLE 4.11: COMPONENTS OF VALUE ADDED AT THE 2-DIGIT SIC LEVEL

($ Millions, 1967)

	EMPLOYEE COMPENSATION	NET INTEREST	CAPITAL CONSUMPTION ALLOWANCES	INDIRECT BUSINESS TAXES	PROFIT-TYPE INCOME	TOTAL INFORMATION VALUE ADDED
Total Primary Information Industries	136,488.0	- 3,031.0	12,151.0	11,555.0	42,862.0	200,025.0
Total Private Sector	94,895,0	- 3,031.0	12,151.0	11,503.0	43,808.0	159,326.0
Total Public Sector	41,593.0	0	0	52.0	- 946.0	40,699.0
CONTRACT CONSTRUCTION	6,972.0	29.0	225.0	100.0	1,201.0	8,527.0
MANUFACTURING	24,449.0	268.4	1,941.6	410.6	5,621.8	32,691.4
Nondurable goods	8,872.3	53.8	799.8	176.3	1,860.0	11,762.2
Paper & allied products	1,146.1	34.7	246.6	41.3	70.0	1,538.7
Printing & publishing	7,726.2	19.1	553.2	135.0	1,790.0	10,223.5
Durable goods	15,576.7	214.6	1,141.8	234.3	3,761.8	20,929.2
Furniture	403.3	2.5	23.4	9.5	88.9	527.6
Machinery, exc electrical	1,885.9	37.0	176.1	33.9	1,065.4	3,198.3
Electrical Machinery	9,717.7	139.0	604.6	136.4	1,525.4	12,123.7
Misc manufacturing	636.9	4.0	28.2	8.4	93.7	771.2
Instruments	2,932.9	32.1	309.5	46.1	988.4	4,309.0
COMMUNICATION	7,703.0	691.0	2,462.0	2,361.0	4,391.9	17,609.0
Telephone & telegraph	6,641.0	645.0	2,279.0	2,330.0	4,134.0	16,029.0
Radio & TV	1,062.0	46.0	183.0	31.0	257.9	1,579.9
TRADE	8,765.4	142.9	880.4	3,032.5	3,231.9	16,053.1
Wholesale trade	4,533.4	78.8	469.3	1,979.5	1,523.3	8,584.3
Retail trade	4,232.0	64.1	411.1	1,053.0	1,708.6	7,468.8
FINANCE, INSURANCE, REAL ESTATE	20,197.2	-4,319.3	4,721.4	5,021.7	15,803.9	41,424.9
Banking	5,875.0	-1,268.0	589.0	373.6	6,160.9	11,703.5
Credit agencies	2,581.0	-5,565.2	359.1	73.2	1,762.2	-789.7
Security & commodity brokers	1,540.6	- 146.3	31.3	340.9	1,012.9	2,779.4
Insurance carriers	7,237.8	- 872.8	329.0	1,108.6	1,023.6	8,826.2
Insurance agents	1,729.0	- 48.0	115.0	21.4	1,667.1	3,484.5
Real estate	1,233.8	3,581.0	3,298.0	3,104.0	4,177.2	15,394.0
SERVICES	26,809.0	157.2	1,920.5	577.2	13,557.0	43,021.0
TOTAL GOVERNMENT	41,593.0	0	0	52.0	- 946.0	40,699.0
Primary wages - Federal	10,231.9	0	0	0	0	10,232.0
Education wages - State & local	26,928.0	0	0	0	0	26,928.0
Postal services	4,433.4	0	0	51.6	- 946.0	3,439.0

A preliminary estimate of the size of the Canadian work force in the information sector, as defined by Porat, has been made from the census data for 1961 and 1971. The results show a rough similarity between Canada and the U.S. as regard the proportion of total employment in the information sector (tables 3 and 4).

In the course of classifying occupations as information or non-information a large degree of arbitrariness could not be avoided. The present occupational classification system of course is not coded with prime regard to information type activities and this naturally leaves plenty of room open for many distinct possible estimates to be made of the information sector. Moreover, there would also be no basis of choice between any two estimates.

We have briefly reviewed the accounting of information activity as a way of illustrating the difficulties and imprecisions involved. A more serious issue than that of the ambiguities inherent in information accounts arises, however, since one cannot help but ask to what degree does it matter whether the measure shows the heterogeneous information sector to be 34% or 50% of the total economy. Can these numbers tell academics and policy makers anything useful, and in what sense do they signify qualitatively different economic situations? The truth of the matter is that the accounts do not tell us much concerning what is so special about information activities. As mentioned earlier, there are reasons to be uneasy regarding the advent of the information age, but at this stage much more needs to be known about the economic role of information. The aggregative macro approach of Machlup and Porat remains decidedly under-utilized without a more complete microeconomic study of the subject. It seems we need to arrive at a closer view not only of the causes giving rise to the demand for information but also of the intrinsic difficulties inherent in the optimal provision of such goods and services. Below we consider this closer look, giving particular attention to the viewpoint of business demand, while paying scant regard to consumer demand for information.

TABLE 3

SUMMARY
INFORMATION SECTOR: EMPLOYMENT AND PAYROLL
CANADA AND UNITED STATES
PORAT DEFINITIONS

Type of Information worker	Canada, 1971			United States, 1967	
	Number of Employees	Payroll		Payroll	
		Amount	% Distribution	Amount	% Distribution
	('000)	($ millions)	(per cent)	($ millions)	(per cent)
KNOWLEDGE PRODUCERS	432.77	3,661.9	8.0	46,964	10.3
Scientific and technical workers	155.56	1,405.1	3.0	18,777	4.1
Private information services	277.21	2,256.8	5.0	28,187	6.2
KNOWLEDGE DISTRIBUTORS	489.43	3,077.8	6.7	28,265	6.2
Educators	394.37	2,635.1	5.7	23,680	5.2
Public information disseminators	50.91	186.0	.4	1,264	.3
Communication workers	44.15	256.7	.6	3,321	.7
MARKET SEARCH AND COORDINATION SPECIALISTS	763.59	5,425.1	11.9	93,370	20.0
Information gatherers	50.06	221.4	.5	6,132	1.3
Search and coordination specialists	185.27	974.6	2.1	28,252	6.2
Planning and control workers	528.26	4,229.1	9.3	58,986	12.5

TABLE 4

SUMMARY

Type of Information worker	Canada, 1971			United States, 1967	
	Number of Employees	Payroll		Payroll	
		Amount	% Distribution	Amount	% Distribution
	('000)	($ millions)	(per cent)	($ millions)	(per cent)
INFORMATION PROCESSORS	1,515.50	4,838.3	10.6	61,340	13.5
Non-electronic based	641.66	2,469.6	5.4	34,317	7.5
Electronic based	873.84	2,368.7	5.2	27,023	6.0
INFORMATION MACHINE WORKERS	175.82	842.9	1.9	13,167	2.9
Non-electronic machine operators	64.61	305.4	.7	4,219	.9
Electronic machine operators	41.21	179.1	.4	3,660	.8
Telecommunication workers	70.00	358.4	.8	5,288	1.2
Total Information	3,377.11	17,846.0		243,106	
Total Work Force	8,510.53	45,569.0		454,259	
Information as % of Total	39.7	39.2		53.5	

5. Microeconomic Approach: Information as a Market Commodity and Its Provision

Information goods and services are produced in the economy to meet the demand by business as intermediate inputs, by households for final consumption and increased earning power, and by government for planning purposes. However, markets for information present the price system with several difficulties, and more care than usual has to be taken to ensure that allocative efficiency is maintained.

A major difficulty with market provision arises from information having all the attributes of a pure public good where consumption by an additional individual does not diminish the consumption of others. In addition to this feature, the non-paying consumer cannot easily be charged for the service provided, and private incentive for the provison of information is correspondingly weakened. Finally, much of the technology of information production is characterised by rapidly increasing returns to scale so that competitive markets have a slim chance to make an appearance. Indeed there may be no markets for some information goods and services and unless some institutional or other arrangements are made to allow the private investor profitable returns from sales, public provision will become necessary. On this account, the standard information scenarios contains projections of further growth in the public sector of the economy.

In spite of these theoretical considerations, there exists considerable tradeoff between public and private provisions. Public goods can be made available in the private sector and private goods can be provided by the public sector. Telephones in one country are owned by the government, in another by private corporations under regulation, and yet in another country private and public telephone corporations co-exist.

The television signal, normally accessible to all within station range, can be shorn of its public attribute and be "privatized" through the help of technology, as with Pay TV. Sale of advertising time and space forms the principal revenue of private radio and TV stations and most of the revenue of the paper media. It is not the final consumer who is charged for the communication service but business, which employs the service as an intermediate commodity towards the sale of final goods and services. The nonappropriability problem is thus avoided and in general one can expect some other similar arrangement to take place whereby goods with the non-exclusion and indivisibility attributes of public goods are provided for within the market system of allocation. The one major issue here of course is the efficiency of this allocation when some third private party and not the final consumer is acting as purchaser, or when the product is consumed jointly with another, as in the case of advertising. Clearly, inefficient or not, a market may fail to materialize simply because no arrangement can be found to overcome the nonappropriability problem. Property rights will be difficult to define whenever exclusion is costly or impossible. Yet a multitude of alternatives are in fact available to see to the market provision of information, these largely involving the assignment of property rights (patents and copyrights, for example) structured so as to overcome inherent investment disincentives.

Although private or public provision can be made, whenever marginal cost pricing and its associated allocative efficiency are absent, it is difficult to find the proper signals which will give warning of over-or under-investment in information activity. This is a market failure conundrum which will be certain to present real difficulties for policy. The cost of public provision is measurable but the benefit is not, excepting

in a theoretical sense of the dollar amount of consumer surplus prevented from becoming a deadweight loss. The cost of adapting private property rights are known to exist but are no more amenable to measurement. Through the patent system a temporary monopoly over new knowledge is legally recognized, as a way to ensure the recovery of costs. Yet, in spite of the patent system, not all the benefits of the new knowledge are appropriated by the producer and the private sector may fail to invest in socially worthwhile research as the return is not high enough. On the other hand, it can be argued that propriety over information as safeguarded by patents is a prime reason for the thinness of competition and the rise of those monopolies. This is a dilemma which is deeply rooted in the system of property rights ruling commercial activity in a decentralized economy, and the dilemma will prove hard to dislodge. None of the alternatives available to society for the supply of public goods is without its institutional costs, so that in making the decision net optimality has to be considered, based on the level of social satisfaction attained after these costs are netted out. Society may then judge that collective provision is superior in spite of the highly visible cost of a public bureaucracy giving a partial explanation for the different treatments accorded public goods in different countries.

The new pervasiveness of information in the economy is reflected in developments which even now present further practical difficulties for policy. These problems issue from the fact that the separate technologies and services of communications and computers are rapidly converging. The telephone switching system uses computers and physically separate computer facilities. This close meshing of the two industries will render present regulatory policy - where telephone carriers are regulated but not the suppliers of computer service - less capable of carrying out its intended function.

In addition to that development is the gradual replacement of the paper media by the electronic media. Here the computer is gaining dominance through the reorganization of information storage and retrieval systems. The full economic potential of this innovation can only be realized if a single generalized network or network interconnection system is formulated. This fact will not necessarily mean a reorientation of our policy thinking under the behest of information growth. In fact, formulae have already been put forward to meet the challenge to market provision presented by this intermeshing of computers, media and telecommunications:

> Since there is likely to be continued technological change in the area of commercial communication, a more modular approach to multiple interconnected networks with common interconnection standards and a payments clearinghouse mechanism may be preferable to a monolithic single network, which would have a tendency to stifle technical innovation. "Social Implications of Computer/Telecommunications Systems". (Telecommunications Policy Research...Report on the 1975 Conference Proceedings (ed. Bruce Owens), p. 82 Aspen Institute Programme on Communications).

One aspect of this type of policy approach is that it provides a specific example of the flexibility society has to pursue efficiency within the framework of the price system of allocation. Whether a payment clearing house is a socially optimal solution is not so much the issue as is the apparent ready availability of a workable solution rooted in our own experience, such as the Trans Canada Telephone System. The problem is, however, in safeguarding the public interest. An elaborate bureaucratic system may arise so as to monitor the allocation and price system which is put into operation. The increment this policy adds to the already large bureaucracy has its own social costs and other institutional solutions may present themselves as a less costly alternative.

Much stress was laid on the theoretical problems associated with providing information through market organizations. This was because the presence of such problems go some way to explain the growth in bureaucracies both public and private, as well as indicate the causes behind the practical adoption of existing market arrangements. We now turn to the question of business demand for information, giving in more detail the factors behind the internal production of information versus buying on the market.

From the standpoint of production, information as an input to current output of other commodities is used to several purposes. The most notable business expenses on information are made in the anticipation of reducing market uncertainty, through market research, and the reduction of production costs through R&D. Expenditures are also devoted to product quality improvement, quality and financial control, advertising, management cordination and control, legal advice, hiring and screening of new employees, and resource exploration. Separate from these functions, information is substituted for energy and resources, as the price of the former drops and the price of the others rise.

The private bureaucracy of the firm produces internally many of these information services. However, we first note that the integration of information production into the firm is not inevitable, as is testified by the sizeable consulting services industry. Few passenger transportation firms include an internal travel agency, but mostly all buy such services from the market. In fact, the decision to produce or buy information largely depends on advantages of scale, transaction costs, and in the extreme, the collapse or nonexistence of certain markets. The latter possibility will be caused by disincentives restricting the range of contracts that can be drawn up between agents, disincentives themselves brought about by too little information regarding product quality.

The brief recapulation of business information demand allows us to conceptualize a formal model of information derived demand in terms of a production function. In such terms information can be hypothesized as being employed by the firm (a) as a primary factor input substitutable for other primary inputs, labour and capital; (b) for improving the average quality of both labour and capital and (c) for reducing the uncertainty involved in the firms' marketing decisions over its planning horizon. All of the above uses of information would lead to the internal production of information by the private bureaucracy.

The productivity of private bureaucracies will depend on the importance to the firm of these uses which, empirically, will be hard to distinguish. For this and other reasons productivity will be difficult to measure, but not impossible where parallel markets exist. In principle, given the value of inputs and the value of the information output to the production of final goods and services the profitability of the internal information "quasi-firm" can be established. The pricing of the quasi-firm's output will be much easier for those outputs for which markets exist. The situation should be distinguished from the case of the public bureaucracy where no output valuation is attempted or possible.

An empirical programme for the investigation of information productivity at the level of the industry is discussed in the following section.

6. Topics for Research

The incentive for setting up an information accounting system, as was noted earlier, springs from the belief that information activities are central to the economy. But that stand of itself is unsufficient cause to initiate the expensive task of producing a fresh accounting system. It is also necessary to show that the reworked numbers can be useful for economic analysis and policy making. For instance, a statistical dichotomy between information and non-information inputs can be useful if one can show that these inputs are utilized differently in production. This applies as well to primary factor inputs such as capital and labour. Can a better understanding of the production process be achieved by distinguishing between information and non-information workers as well as between information and non-information capital? By narrowing our perspective to that of industry users, the issue can be conceptualized most simply in terms of the traditional production function relating value added output to labour service and capital service inputs. We chose to study one aspect of the production activities as it relates to information in the hope of being able to clarify certain outstanding issues. One such issue that has not received attention is the relevance of information accounting for production studies. This point evidently begs the question - is an examination of production activities relevant for learning the details of information's pre-eminent role in the economy? The answer is strongly affirmative as we shall explain.

The growing magnitude of information's economic role raises important issues of possible misallocation of resources and non-optimal levels of information output. However, these problems arise in different sizes and directions at different locations in the information sector. An obvious example is the widespread suspicion than under-investment occurs in R and D output, while too many resources have lately been diverted to the private and public bureaucracies.

The problems of misallocation which cannot be satisfactorily handed by markets require administrative action. This in turn involves evidence or information on the productivity of information related inputs into production. In principle, more detail regarding inputs and outputs will lead to a better basis for administrated allocation decisions; Porat's input/output table can be seen as a step in this direction. Yet it may happen that the informational characteristic of inputs are less rather than more important than their other technical characteristics. If this were true the prospects for determining the economic contribution of the information group or subgroups of inputs will be very small.

While conceptually we can separate information inputs and outputs from non-information goods and services it is not necessarily true that the same separation is made by the technology. This issue is a familiar classification problem where commodities are grouped in such a way that members of the group are close substitutes with respect to either consumption or production. In the information accounts the major grouping will take place according to the information content or activity of each commodity. However, there is no evidence that the regrouped commodities any longer correspond to a partitioning along lines of substitution in production. As inputs the reclassified goods and services may prove to be technologically dissimilar or at best, a high level of inessential detail has been produced by subdividing existing classification groups as information and non-information.

Let us examine this question more specifically in terms of production functions, since it is proposed to estimate such a function and test our hypotheses with it. The traditional neoclassical production function designed to explain industry value added output treats aggregate capital and aggregate labour as the two primary factors which are technically allowed to be substituted

for each other. Materials and energy inputs, the so-called intermediate inputs, are assumed to be "strongly separated" [1] from the primary inputs and their costs are substracted from the value of gross output to yield the value-added figure. In this approach labour is treated as a homogeneous aggregate, despite the manifold roles-managerial, research, supervisory, administrative and production work - fulfilled by employees. Implicit in this adoption of a single index of labour services is the presumption that all occupations are close substitutes. Similarly, the lumping of structures, machines and equipment under the one index of capital is a procedure which treats capital services from stocks of different kind, for example metal presses and the buildings housing them, and of different durability, as essentually alike.

The tradition of fitting production functions using only two primary inputs did not arise because there was universal concensus that two inputs aggregates were satisfactory and no further detail of factor inputs was needed. The sheer lack of data coupled with the inflexibility of functional forms for production function estimation purposes placed a severe restraint on empirical work. While a data breakdown between salaried and wage employees is possible for Canada, and capital of more than one type can likewise be distinguished, the familiar Cobb-Douglas and Constant Elasticity of Substitution (CES) specifications of production functions are inadiquate for a deep empirical study of multi-input production relations. The CES specification imposes the severe restriction that all pair elasticity of substitution be equal, while the Cobb-Douglas restricts further the elasticity of substitution to be unity.

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(1) The concept of strong separability is studied in Berndt and Christensen (1974). A test of the validity of the strong separability assumption, i.e. of the existence of value added production function, has been made for Canadian manufacturing (Denny and May (1977)) and the assumption is rejected.

Only recently have functions with sufficient flexibility of form been specified[1], giving a new spur to empirical production analysis.

At an abstract level some information goods and services may fit the description of intermediate inputs, but information employment and information capital, as defined by the information accounts, are clearly primary inputs. By considering the value added output of an industry, we can concentrate on the role played by information labour and capital in the production of output. This brings us back to the previous question: Does the dichotomic classification of inputs and outputs as information and non- information reflect a significant aspect of the structure of production? In other words, we are asking if we can construct a consistent index for information inputs and one for non-information inputs, and that these indices explain output better than other partitions of inputs into indices. If this is the case, then information accounting is worthwhile. But if on the contrary there is no evidence for the technical distinction between information and non-information labour on the one hand and between information and non-information capital on the other, then as far as production analysis is concerned we can do without the information system of accounts and continue to explain the level of industry value added output in terms of aggregate capital and aggregate labour, or by some other input aggregation system.

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(1) Examples are the trans-log (Christensen Jorgenson and Lau, 1971) and the Generalized Liontief (Diewert (10)). Both examples are functions which are quadratic in the arguments (inputs) and hence represent only a <u>local</u> approximation to some true functional specification that satisfy the neoclassical conditions.

There is in fact some recent evidence for the inappropriateness of a single labour aggregate (Berndt and Christensen 1974), at least for U.S. manufacturing. In that study labour of two types was distinguished, production and non-production workers, and a three factor production function (with capital as the third factor) was fitted. Certain tests on the function's estimated coefficients found that the conditions for a consistent aggregate of labour were violated. The findings show that whereas the two types of labour are highly substitutable, one is substitutable with capital and the other is complementary to capital. If we make the rough correspondance between non-production workers and information workers, and between production workers and non-information workers, these results can be seen as supporting the call to distinguish between information and non-information employment.

In the course of discussing the problem of determining information's contribution to the overall industry productivity, we had observed that the technology must distinguish between information and non-information inputs for such a determination to be possible. This issue concerning the industry technology can be subjected to empirical testing as we will indicate later. However, there are other issues than can bear examination and we discuss these below.

The validation of the hypothesis that information labour and capital are technically distinct or separated from non-information labour and capital implies that we can correctly refer to the production of information internally to the firm as being an output of a "quasi-firm", to use the expression coined by Porat. Firms in the industry can be conceptualized as consisting of two parts, the production side and the firm's internal "bureaucracy" which produces much of the company's multifold demand for information services. Tests may show the extreme case of "strong separability" to rule where the information output and non-information output combine in a Leontief fixed-coefficient manner to produce industry value added. Under such circumstances there is no substitu-

bility between the two types of output and information would not differ technically from other commodities classified as intermediate input factors. The chief advantages of knowing this to be the prevailing technological structure are two-fold. Firstly, the ratio of information to non-information activities is not responsive to relative prices in the sense they would be if substitution took place. Secondly, the conventional productivity measure for information used by Porat, the ratio of real output to information inputs, can validly be applied to each industry and the thesis of Porat that the productivity of information inputs for the economy as a whole is in decline can be supported or opposed.

However, there is a sense in which the industry can be comprised of firms with an internal information quasi-firm but where information activities are substitutable with productive activities. This possibility is a particularly interesting one since information inputs cannot legitimately be treated as an overhead cost as in the previous case. Given that the results of such tests can be explained and accepted then two implications follow. One implication is that the Porat measure of information factor productivity will not have the same impact, since the measure will not be independent of other activities in the industry. The other is that the relative factor price changes will effect the ratio of information and productive activities. A fall in the price of information capital service owing, say, to the decline in computer service price, would not only have an impact on the wage share of information workers, but would also affect the relative importance of information to non-information activities and hence affect the production worker wage share.

To sum up, administrated allocation decisions regarding information require evidence on the technological structure of production with respect to information inputs. Such evidence can give valuable insights for information policy by providing guidence on the issue of productivity measures and the impact of relative price changes on labour income. However, the actual testing procedure remains to be defined and its feasibility established, a consideration to which we now turn.

The feasibility of the study depends on two factors, the availability of annual time series data (the industry under consideration being Canadian total manufacturing) and a suitable methodology for estimating and testing a four input production function. The latter is now becoming established in the literature; see for example Berndt and Wood (1976), Hudson and Jorgensen (1974). The greatest problem will be presented by the type and quality of the available data and its assembly. A preliminary investigation has shown the feasibility of obtaining time series on price and quantity indices for Canadian total manufacturing on information workers, non-information workers, information capital, non-information capital and on value added output (see appendix). The question of data quality and comparability is one that cannot be answered at this stage, but some difficulty will arise because of the data coming from different sources.

Regarding the methodology, the production function will not be estimated directly, but instead the four factor demand equations will be the object of estimation. Thus the value of cost share for each factor will be regressed against the quantities of the four inputs. The estimated coefficients will be subjected to tests to determine statistically if the conditions for separability hold. Basically this is a test to see if the marginal rate of technical substitution between the productive inputs is independent of the

level of the information inputs and vice versa. Also from the values of the estimated coefficients we can derive the values and sign of the partial elasticity of substitution between pairs of inputs.

In addition, tests can be formulated and applied to the important issue of returns to scale and the technical issue of the convexity of production isoquants.

The input price and quantity variables are jointly determined as far as the industry is concerned and certain predetermined variables have to be specified to purge the inputs of correlation with the disturbance terms. The variables would represent the external influences affecting demand for manufacturing output, the supply of labour and the supply of capital, over the time period considered. Some of the variables used will include national population, working age population, personal income tax rates on labour income, sales tax rates, sales of consumption goods and durables to government and for export, and tangible capital stock at the end of the previous year.

7. Conclusion

The concept of the information economy has been articulated chiefly in macroeconomic terms while the allied statistical work has concentrated on the production of national information accounts. The position taken in this paper is that an analysis of the microeconomic foundations of information can contribute significantly to an understanding of the information economy. Certain key questions can only be approached through such an analysis. How deeply rooted in the economy is information and what forces led to its predominance? What economics factors and requirements shape the demand for information and how does it get provided? Exactly what do the national information accounts tell the researcher and policy makers? These and other questions led the discussion in this paper along several, convergent, lines.

First the importance of information flows in the economy was stressed, especially how the information relayed back and forth between economic agents influenced the structure and existence of markets. A second line of the discussion considered the problems of market provision of information and the growth of non-market provision through bureaucracies. The paper then reviewed the sources of the business demand for information. All these discussions clarified and provided a basis for examining, in empirical terms, a preliminary microeconomic study of information demand. Because of its importance, a proposal is made for the analysis to involve the production process and the role of information in it.

Section 6 already details what might be expected from the research. It remains only to say that this is only a beginning and that other vital economic functions of information deserve to be examined, as, for example, the contribution of information related activities to economic growth.

1. economic factors which shape the demand for information

2. sources of business demand for information

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Appendix:

This section reviews the data sources and procedures employed in constructing the data series to be used in the proposed study. The data series are for Canadian manufacturing 1948-1977. The variables involved are price and quantity indices of information capital, non-information capital, information workers, non-information workers. Included also is the index of total manufacturing value output. Instrumental variables are also discussed.

Labour Data

Occupations at the level of detail practical are to be classified as information or non-information. Time series are needed on: Information workers' hours of work, non-information workers' hours of work, employment by occupation and wage by occupation. A Divisia index with baseyear 1961 of the information wage can be constructed from the information occupations wage data. Similarly an employment index of information employment can be constructed, as well as one for hours of work. The product of this employment index with the average hours worked by information workers yields man-hours of information labour services. The calculation of average hours for both categories of workers is a feature to be settled. The same task above is to be done for non-information workers.

The simple approach discussed above ignores certain very important considerations. For one thing, this approach neglects the improvement in labour quality which characterized the historical period being considered. In fact the employment series should be adjusted for the rising average level of educational attainment of labour. Adjustments should also be made to reflect the different occupational and sex composition of labour when calculating the average hours of labour services. Secondly, the statistics should include the labour component of non-incorporated business income as

well as supplementary labour income, which have varied considerably over the historical period.

Capital Data

Capital stocks are to be divided between information capital and non-information capital. Information capital consists of structures, equipment and machines used by information workers. A suitable index of information capital stock can be constructed from the value of inter-industry purchases of capital goods under the assumption that capital services are proportional to the stock. The value of information capital divided by the price index will provide an index proportional to the capital services. Both the value and price data can be obtained from the input-output table for the Canadian economy. A similar procedure will yield the non-information capital stock and service price series.

Capital service prices are a function of the opportunity cost of capital, the rate of depreciation, the rate of change of the asset price, and the tax structure. The presence of tax policies affects both the opportunity cost of capital and the depreciation components of the service price. The tax rates on property and income reduce the after-tax rate of return, while investment tax credits and accelerated depreciation allowances reduce the present price of capital assets. Ideally these factors should enter the analysis through an equation which determines capital service price.