151

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UNIVERSITÉ DE MONTRÉAL □ MCGILL UNIVERSITY

INFORMATION SOCIETY PROJECT PAPER NO. I-8

PHASE II.

TELE-INFORMATICS, PRODUCTIVITY AND EMPLOYMENT: AN ECONOMIC INTERPRETATION.

Yves Rabeau, Ph.D.*

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McGill University)
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APRIL 1980.

*Yves Rabeau is professeur-titulaire de sciences économiques, Université de Montréal. He holds a Ph.D in economics from Massachusetts.Institute of Technology and is specialized in macro-economic forecasting and policy studies.

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GAMMA INFORMATION SOCIETY PROJECT:

PAPERS AND REPORTS

PAPER I: The Micro-Economics of Information. Structural and Regulatory Aspects. (J.Bernstein). GAMMA: 1979.

PAPER 2: Macro-Economie de la Société Informatisée. (R.J.Bernadat) GAMMA: 1979.

PAPER 3: La Poussée Technologique et les coûts unitaires décroissants en télématique. (J.Louis Houle). GAMMA: 1979.

PAPER 4: Public Policy and the Canadian Information Society. (P.S.Sindell) GAMMA: 1979.

PAPER 5: Social Implications of the Information Economy. (E.I.Fitzpatrick-Martin). GAMMA: 1979.

PAPER 6: Research and Development in the Information Sector of the Canadian Economy. (R.Wills). GAMMA: 1979.

PAPER 7: The Information Society: The Issue and the Choices. (K.Valaskakis). Integrating Report on Phase I. GAMMA: 1979.

PAPER 8: Tele-Informatics, Productivity and Employment: An Economic Interpretation. (Y.Rabeau) GAMMA: April 1980.

PAPER 9: Public Acceptance of the New Information Technologies: The Role of Attitudes. (W.L.Gardiner). GAMMA: April 1980.

PAPER 10: Industrial Strategy and the Information Economy: Toward a Game Plan for Canada. (K.Valaskakis, P.S.Sindell) GAMMA: April 1980.

TABLE OF CONTENTS

PREFACE

Professor Yves Rabeau's paper on "Tele-Informatics, Employment and Productivity" is one of the background studies produced in the context of formulating alternative industrial strategies for Canada in the face of the Information Economy. The GAMMA Information Society Project is now proceeding into its Second Phase.

The First Phase, completed in April, 1979, identified the various factors leading Canada and other economies into the "information age". In particular, three scenarios of an emerging Information Society were depicted as possible in the medium-term. The first emphasized the maximum interconnection of computer and communication technology, (Télématique). The second explored the possibility of a decentralized stand-alone technology leading to 'private informatics' (Privatique). The third postulated a move towards an information age favouring low and intermediate information technologies (The Rejection Scenario).

Phase II of the Information Society Project, now in progress, explores the implications of these scenarios in various fields. Two principal foci orient the research. The first underlines the importance of industrial strategy and of enhancing Canada's competitiveness in the global Information Economy. The second focuses on social costs and benefits and adopts a more normative value-orientated problématique. This study lies within the first focus.

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Professor Rabeau's paper is an attempt at interpreting the technological changes within an economic perspective - a prerequisite to any industrial strategy. As such, the thrust of the work is not primarily empirical - no new series of data have been compiled - but rather integrative and evaluative. Professor Rabeau interprets the available literature by relating it to the dominant growth-patterns of the OECD economies in the post-war period. Two important conclusions can be derived from this analysis which have obvious policy-implications.

(1) Tele-informatics (or telematics for short, which refers to the confluence of computer and telecommunication technologies) generates a new challenge to the conventional Harrod-Domar-Solar model of economic growth. Whereas the expansionist view of the HDS model suggests that economic growth will in the long-run be balanced between capital and labor (i.e. technological change will not cause massive disemployment), telematics suggests that this may not be the case. Although, theoretically, capital deepening is eventually supposed to create jobs this assumes that there are no limits to growth. In fact, limits do exist and may be caused by energy or resource shortages, pollution-constraints, the failure of the demand side of the equation or simply insufficient savings to generate the necessary capital. Since productivity increases, stemming from the telematic revolution tend to be enormous, astronomical capital requirements may be needed to create new jobs.

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(2) The policy-choices in the face of this situation are essentially four in number:

a) Reject the technology and run the risk of losing international competitiveness.

b) Accept the technology with its high wealth-creating dimension and treat the balanced-growth problem as one of distribution rather than production. This may lead to the creation of fictitious jobs, shorter working hours or allied solutions to equitably spread out the quantum of work needed to produce a given GNP.

c) Encourage the creation of an "Informal Economy" to absorb excess labor. This informal economy's productivity will not be measured by conventional means will include all non-market transactions.

d) Encourage the creation of a 'rejection-sector' in the economy which will use low and intermediate technology which is labor-intensive (craftmanship, etc).

The results of Professor Rabeau's paper are integrated with those of other technical briefs in the GAMMA paper I-10 entitled: "Industrial Strategy and the Information Economy: Towards a Game-Plan for Canada".*

K.Valaskakis,
Director.

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* By K.Valaskakis and P.S.Sindell, GAMMA: May 1980.

I. TELEMATICS AS A SOURCE OF TECHNICAL PROGRESS: GENERAL OVERVIEW OF THE DEBATE.

We can summarize as follows the different aspects of the new technology associated with the use of telematics*which are discussed in the literature:

1° A deepening of information capital in the production function could, for a given amount of output, contribute to reduce the use of all inputs. This would result in an overall increase in productivity. However, an increasing use of telematics would not bring a neutral technical progress; instead it is expected that the associated technical progress will primarily be labour saving although information capital appears to be a substitute to all other inputs. Information capital could be a substitute for:

- basic materials: telematics could induce a rationalization of production processes.
- land and infra-structure: a more intensive use of information capital could bring in smaller machinery and equipment.
- energy: rationalization and automation of production processes as well as the use of smaller buildings would result in energy saving.

* Telematics is a contraction of tele-informatics and refers to the growing convergence of the computer and telecommunication fields.

- transportation services: the use of telematics could significantly reduce the need for travelling.
- non-information capital: telematics would bring in a new technology where computerized production processes would replace the current capital stock. The information capital would therefore become complementary to a new type of non-information capital that would replace the existing capital stock. Since in many sectors of the economy, the existing capital stock is complementary with labour in the context of a fixed-proportion technology, the substitution of the current capital stock by a new wave of information and non-information capital implies that information capital could be a substitute for non-information labour. Recent examples of these substitution effects are assembly lines in the manufacturing sector where new equipment and machinery are computerized and where robots replace workers.
- information labour: so far information labour as we shall see below, was considered as complementary to information-capital. However, the degree of complementarity has declined over time and the new generation of information-capital will be a substitute to information-labour. Hence, a deepening of information capital would result in a reduction of the information workforce. For example, new communication systems (bureautics) in the service industry are replacing

existing equipment and bringing a reduction in white collar personnel.

Therefore, introduction of a new wave of information-capital will result in an overall increase of productivity. It is difficult to estimate the input savings that will result from that new technology. However, many authors (Zeman, 1979), agree that the substitution effect will particularly affect the labour input. Increases in wages have outpaced productivity gains over the last decade and any relative decline in the price of capital should, in fact, bring a significant substitution effect against labour. Furthermore, the capital deepening in the production function and the resulting growth in potential output may create a balanced growth problem. In fact, any increase in unemployment resulting from the substitution effect vis-à-vis labour could result in a deficient effective demand and therefore in an excess of supply in the economy.

2° Production costs of the new generation of information-capital are rapidly declining as production grows, whereas the output performance of this new capital has increased significantly over the recent past.

The decline in cost per unit of potential output of telematic systems results from (Houle, 79) an increased productivity of information capital. Micro electronics as the basic source of a new generation of information capital can increase the productivity of information systems. The cost of components has declined and the price of hardware equipment has followed a downward trend. The declining cost of telematic capital also results in more capital intensive software systems. The primary information industry can offer more complex systems at lower cost to the users as production rises. It is expected (Houle, 79) that the cost of telematic capital will decline at an almost exponential rate in the near future.

As the cost of information capital declines, there is an incentive to substitute information capital to the existing capital stock and to labour: this can set into motion a dynamic process of capital accumulation. As the demand for information capital rises, its production cost further declines; subsequently the change in relative prices of inputs induces a further substitution effect in favour of information capital. Given the rigidity or, more exactly, the upward trend in wages, the decline in capital cost will clearly favour a substitution of capital for labour. Essentially, competition among producers in all sectors of the economy will set the pace of this dynamic process. The possibility of drastically reducing production costs and increasing profit margins and market shares will incite entrepreneurs tu buy the new information capital. Competition could eventually drive out of the markets producers that will not adopt the new technology.

The combination of declining prices for the new capital goods and competition could trigger a very rapid diffusion of the new generation of capital. Consequently, many authors believe that because of the very rapid diffusion rate, of the new technology, the substitution effect in favour of capital may result in rising unemployment.

3° The new information technology can bring not only a new wave of capital goods but also new or improved consumption goods and services.

This proposition has several implications. First, by using micro-electronic devices producers can substantially change the composition of final goods without altering their quality or the nature of the services they provide. The change in the technical structure of a final good can lead to substantial modifications in the <u>production function</u>. The use of micro electronic components in the production of TV sets can reduce labour cost by a very significant proportion. Japanese producers have succeeded in cutting by 70% their labour cost in the production of TV sets. Therefore, micro-electronics can bring an interaction between existing final products and the production function. By changing the technical composition of consumer products, producers can save in the use of various inputs and reduce their production costs. The net effect again can be labour saving and this sort of technical change may amplify the unemployment created by a direct substitution of telematic capital for labour in the production function.

However, one must notice that labour saving technology can reduce the price of final goods for consumers and depending upon the price elasticity of demand, it can result in an increased volume of output. This price effect would contribute to decrease the technical reduction of labour input in the production function.

Moreover, the use of micro-electronic devices can lead to the development of new consumer products and services. In some cases, what would be called "New Products" could be an adaptation for consumers of already existing industrial or commercial equipments.

For example, a new generation of small computers will be offered on the consumer market and could fall into the category of new products. In addition, several applications of mini-computers will be offered to consumers. Domestic robots could be another example of a product already used at the industrial level which will be offered on a large scale in the consumer market.

The development of new products and services will bring an expansion of existing industries or the growth of a new generation of industries. Again, the economic growth associated with this industrial expansion will alleviate the problem of absorbing workers displaced by the new generation of capital goods.

However, a crucial factor in the argument is that the expansion of these industries will differ among countries. Depending upon comparative advantages, some countries could be able to take a large share of the international market for the new products. The impact on employment of the new technology will then differ among countries.

II. CAPITAL FORMATION, GROWTH AND EMPLOYMENT.

2.1. *The Current Situation.*

Most of the OECD economies have experienced a productivity slowdown in the 70's. It has resulted in slower economic growth and constant pressures on costs and prices.

Economic growth has been largely attributable to employment growth rather than to increase in output per man hour. The productivity slowdown has been explained by several factors (Denison, 1979):

- exhaustion of economies of scale within the current technology;
- increasing difficulties of access to natural resources;
- regulation in general and particularly in the case of pollution control; an increasing portion of total capital formation is used to reduce pollution and therefore is not available to improve technology.
- insufficient R and D expenditures;
- growing resistance of labour unions to various improvements in the production processes;
- increasing share of the service sector in the economy where measured productivity growth is significantly lower than in the other sectors of the economy.

Other factors are also mentioned. More recently, increasing energy prices have raised the user's cost of capital since the latter and energy are generally complementary factors in the production function. This has provoked a short run adjustment in the form, a less intensive use of capital in production, and it has contributed to a further reduction of productivity growth.

The slowdown in productivity growth is a very complex phenomenon and it is almost impossible to specify the contribution of each factor. On the other hand, wages have increased steadily over time over the last decade outpacing productivity growth in the economy. As unit labor cost rose over time, prices were on the upward trend in order to restore profit margins. Since both nominal wages and prices rose, the growth in real income was in general modest, and in line with productivity growth, which is the source of economic growth.

In this context of slow growth, capital formation was insufficient to absorb all the new coming workers in the labour market and the unemployment rate in most economies rose in the last decade. The average unemployment rate in the OECD countries has in fact doubled during that period.

2.2. *Telematics and economic growth*

The so-called telematic revolution can entirely change the current trends of productivity slowdown and inflation. The current situation can be reversed if the price of information capital relative to the existing stock of capital and labour falls significantly. The recent trend suggests that this relative price will fall in the near future. This change in relative prices will result in a substitution of information capital for existing capital and labour. Since it is expected that the net effect will be labour saving, (i.e., the economy could produce the current amount of goods and services with less employment), this potential substitution effect raises a familiar growth problem.

This problem of balanced growth between capital accumulation and job creation has been discussed in the technical literature since the 50's.

The structuralists in the 50's believed that labour saving technical progress would result in increasing unemployment in the long run whereas expansionists believed that labour displaced in the short run would find employment in the long run in the context of sustained economic growth (Machlup, 74).

The debate regarding the telematic revolution is basically the same but the order of magnitude of labour substitution may be such (Zeman, 79) that unemployment problems could arise in the short run. Furthermore, in a context of highly open economies, some countries may have real difficulties in absorbing the new wave of technical progress.

In the long run and if we abstract from an unequal distribution of economic growth between say OECD countries, according to the expansion thesis, it is possible that the boom in technical progress will result in a sufficient economic growth to absorb the growing supply of labour. The new technology will shift downward production cost curves and many product and service prices will decline. Since the new technology may result in a saving of all production factors, the decline in prices could be significant for some products. The new technology will allow the circumvention of some of the current impediments to economic growth such as increasing prices of energy and natural resources. If product and service prices decline, there will be an increase in demand and output where price elasticity is greater than one.

The associated productivity growth will raise real income and induce an upward shift in demand when income elasticity is greater than one. New products and services will be developed this process will create new industries, contribute to capital accumulation and job creation.

Growth in real income and the relative decline in prices will contribute to increase the demand side of the economy whereas the supply side will grow with capital accumulation. The telematic revolution could thus bring another era of rapid and sustained economic growth. A growth process of this nature would be limited in the long run by the supply of labour and would not result in rising unemployment.

This scenario is similar to familiar results appearing in long term economic growth models where there is no limit to growth. Given the current trends regarding the limits to growth, the scenario can be seen as fairly optimistic. To what extent telematics will alleviate the current constraint on growth remains an empirical issue. For example, we do not know to what extent the use of a new generation of information capital will result in energy and resource savings. Current trends suggest that energy and scarce resources will continue to put a strain on economic growth. Pollution controls, particularly in the context of a more rapidly growing economy, by diverting a significant part of capital formation to "non productive use" (in the sense that anti-pollution equipment does not contribute to increase, as measured traditionally, output per man-hour) will remain a constraint to growth in the future.

One would have also to evaluate the intersectorial shift in output and employment to evaluate the long term impact on employment. As mentioned before the development of new industries and services will contribute to economic growth. But one would need to know the growth rate perspective of the demand for these sectors as well as their input structure to evaluate their long term potential. For example, the development of new services would not face the same growth constraints as the primary and manufacturing sector. As these services are developed and as the new technology reduces employment in all sectors of the economy, labor employment would shift from the latter sectors to the former. Whether the service industry can absorb the displaced labour will depend on the (price and income) elasticity of demand for services and on the input structure of these new services (more or less labour intensive and more or less user of other scarce resources such as energy). This remains an empirical issue on which we do not have all the relevant data. Overall, it is possible that the constraints imposed on the economic growth of several sectors of the economy combined with the use of labour saving technology could result in different adjustment problems in the labour market. In fact, in a very long term perspective, this would not be an entirely new problem; however, its solution would likely imply a change in our postwar philosophy of balanced growth. We will return to that question in the concluding section.

In the available literature, opinions about the employment impact of telematic revolution vary from country to country. In Europe, the consensus as we indicate below is (Zeman, 79) that the telematic revolution will result in rising unemployment over the next decade. In Japan and in the United States, (A.D. Little, 79 and J.A. Ward, 79) researchers believe that a growing economy will provide enough capital formation to maintain a satisfactory level of employment in the coming years. However, it must be emphasized that most studies underline the fact that in the absence of any empirical experience, it is presently very difficult to appraise the effect of the new generation of capital on the labour market. Furthermore, we must emphasize that the studies look at the medium run perspective and the longer run issues raised by a new wave of technical change are not analyzed.

Beyond the limits to growth, the problem of uneven economic growth among developped countries in the future could be a very important issue. The countries which have invested in R & D connected with information technology and have succeeded to commercialize information equipment will have a tremendous comparative advantage. All countries member of the same commercial block will, under the effect of competition, be forced to adopt the new technology. However, not all countries may be able to participate in the growth of the information industry. Some countries will be exporting their products to the rest of the world; these countries will be exporting to some extent their employment problems to the technology importing countries. In the exporting countries, the rapid growth of the new information industry combined with the development of the service sectors could be sufficient to absorb any displaced workers in other sectors of the economy. In the importing countries, the change in technology will be necessary to maintain their competitive position in world markets.

Countries which will be net importers of information goods (capital and consumer goods) will have to rely more on the development of new service industries to alleviate their employment problem. These countries may experience unemployment problems in the medium run; as the technology is diffused, they could develop import substitutes over a long period of time.

It will be difficult to use tariff barriers in order to avoid the impact of the new technology. In the past, small countries like Canada by maintaining high level of tariffs have incited foreign producers to supply the domestic market by the means of subsidiaries. The current trend set by Gatt negotiations is toward an elimination of these trade barriers. Any attempts to circumvent that trend would result in costly retaliation from trade partners. Furthermore, trade barriers would not be an entirely efficient tool in the case of the telematic revolution since we will be dealing with capital goods as well as consumer goods. The new generation of capital goods will have to be imported in the non producing countries in order to maintain their competitive position in world market. Any attempt to slow the purchase of the capital goods (such as imposing tariffs in order to attract foreign investors) would result in a fatal loss of competitiveness.

2.3. *Short run adjustment problems.*

Several adjustment problem arise in the short run. It is more difficult to forecast the impact on productivity and employment of the telematic revolution in the short run since it involves various rates of adjustment.

As the price of information capital in relation to its output capacity declines, there is an incentive to substitute capital for labour. Subsequently, a rise in the demand for information capital may further reduce the price of capital as production is increased and contribute to accelerate the substitution effect in favour of capital. The time path of this mechanism is not easy to forecast.

Furthermore, competition among firms will also contribute to determine the rate of adjustment. Member firms of powerful oligopolies could set the pace at which they will substitute the new information capital in function of different economic variables. In particular, depreciation of the existing capital stock will be a dimension taken into account in setting the timing of the change in production processes.

This question of the speed of adjustment will have a determining effect on the behavior of the labour market in the short run. The more rapid is the introduction of the new technology, the more likely are the dislocative effects on the labour market. A rapid technical change can result in significant displacement of workers and rising unemployment. But at the same time, shortages of skilled labour associated with the new technology may appear in the market. A number of the displaced workers may be recycled into the new jobs but it takes time to retrain them and disequilibrium in the labour market can last for a certain period.

On the other hand, other factors of adjustment may contribute to dampen the impact on unemployment resulting from the technological change. In the short run, all economic agents will have to adapt themselves to the new technology. This is the familiar "learning by doing" phenomenon where it takes some time before a new technology has its full impact on the productivity of factors of production. Production managers will have to train their labour force and wait for some time to determine the optimum number of workers per unit of capital in the context of the new technology. As the production of goods and services goes on, productivity can rise and the labour saving effect may be distributed over a certain period of time (and in the literature we have examples where the learning process can take years before it gives full productivity effect). Therefore, the expected labour saving effect may not be so radical in the short run because of the learning by doing effect.

If the introduction of the new technology results in the short run in rising unemployment, particularly in the service sector of the economy, the process of economic growth described earlier will have its favorable impact only in the medium or longer run. As a result, there may be a transition period where displaced workers may not find a job since there cannot be a substantial change of the capital stock in the short run. However, displaced workers could in the short run find a job in sectors where the technology allows a <u>substitution</u> between labour and capital. In sectors where sophisticated technology is used (particularly in the primary and manufacturing sector), such a substitution is generally not possible. In other sectors, substitution could be possible if wages were falling relatively to the user's cost of capital. This would generally imply a fall in nominal wages or a decline in real wages in an inflationary context. Institutional arrangements, legislation, the existence of labour unions would most likely prevent the fall in wages necessary for a labour deepening in the economy. Existing social programs like unemployment insurance also contribute to make wages inflexible downward. Sticky wages will be (to a greater extent than in the past technological revolution) an obstacle to any labour deepening in the economy which would ease in the short run any problem of rising unemployment.

As productivity rises, reduction in working hours could be another form of short run adjustment in the economy that could, to some extent, alleviate the unemployment problem. However, reduction of working hours can raise some problems. If workers want to increase their hourly earnings as working hours are reduced in order to maintain their real annual pay, the price of labour will rise in comparison to capital cost. Increasing hourly earnings may induce a further deepening of capital or accelerate the speed at which the new technology is introduced in the economy. Furthermore, if wage pressures appear in these sectors where the new generation of information capital is first introduced, this may induce a spill over effect on other sectors of the economy that will adversely affect employment. Hence, under these circumstances, reduction of working hours could be a "self defeating" adjustment process.

Thus, reduction in working hours could contribute to dampen the displacement effect of workers in the short run, as long as any wage increases remain in line with the rise of labour productivity.

A lack of growth in final demand in the short run could also retard capital formation in sectors which could be producing new products and services. The current inflation period is conducive to slow growth and it may take some time before a more appropriate growth is restored in the OECD countries. An appropriate use of fiscal and monetary policies could contribute to stimulate the growth in demand. However, it must be noted that the policy margin in the current stagflation situation has been significantly reduced for most countries.

Finally, the short run impact of the telematic revolution will again vary considerably among OECD countries. These differences, among countries, will likely be more considerable in the short run rather than in the longer term.

In countries exporting telematic products (either capital goods or consumer products) <u>and</u> services (software packages), sectors producing these goods and services will be growing rapidly and will absorb in part or in total any displaced workers from other sectors. In the short run, some countries will be benefiting from their initial monopolistic power and they will "export" their unemployment problems to other countries. These countries could even be facing shortages of skilled labour and could import workers from other countries.

As the process of "imitation" or diffusion of technology at the international level is under way over time, the initial monopoly power will decline as other producers emerge in other countries. But in the short run, problems of current account surplus and deficits, unequal unemployment rate among trading partners are likely to occur.

In conclusion, the magnitude of the short run effect on the unemployment rate of the introduction of a new technology remains a highly complex empirical issue and we do not have the sample data necessary to quantify the phenomenon. Some authors believe that the effect on unemployment could be substantial for some countries. Hence, governments should already develop strategies to attenuate the effect of the telematic revolution on the labour market. Moreover, an international concertation would be necessary to avoid too large income and employment disparities among industrial trading partners. This question is analyzed in another paper of the study. (See Paper I-10 , Valaskakis, Sindell: Industrial Strategy and the Information Economy).

III. PRODUCTION FUNCTIONS, INFORMATION CAPITAL AND PRODUCTIVITY.

In this section, we examine more technical aspects of the impact of telematics on the economy. In particular, the effects of the new generation of information capital on the production function, productivity and employment are analyzed.

The Porat analysis of the productivity of information worker is not promising for future research. The classification used to disentangle the productivity of factors of production is not compatible with macro-economic concepts and existing data. In particular, there is no measurable output for the so-called information bureaucracy or secondary information sector. We cannot measure productivity of the production factors of Porat's bureaucracy and estimate the trend for the future. The productivity, as measured by Porat of the secondary information sector(in the bureaucracy related to information output), basically reflects the share of information inputs in GNP. It does not measure the productivity of information inputs in the overall production process of the economy.

The conclusion obtained by Porat that the productivity of information workers has declined over time is not valid when we consider the overall production function. As information capital is introduced in the production function, information workers who are complementary to information capital are substituted to non information workers. As a result, the growth of information employment would not necessarily reflect a decline in the productivity of information worker but rather, a substitution of non information workers by information workers. If the information workers have a greater marginal product than non information workers as it is suggested by the relative wage level, then the overall productivity in the economy would rise rather then decline when there is a deepening of information workers in the production function.

Of course, the average and marginal productivity of information workers could be downward sloping and therefore, the average productivity of information workers could have declined over time. But as long as their productivity schedule is above the non information productivity curve, then the average productivity would rise in the economy when information workers are substituted for non information workers.

An approach based on production functions and income of production factors like the one developed by E.Denison, would be more appropriate to derive a trend in the productivity of information and non information production factors. The approach developed by Warskett (79) gives some indication of the relation between information and non information inputs in the production function.

In the latter approach, a macro-economic production function is estimated for the Canadian manufacturing sector under the usual assumptions of constant return to scale and Hicks neutral technical progress. One obtains better statistical results when information and non information inputs are separated in the production function. In that case, with proper statistical information, we could estimate the marginal contribution of each factor to output. It is also found that information and non information workers are substitutes in the production process. When the price of capital falls, the demand for capital input rises as well as the demand for information labour; capital and information workers, the data suggest, are complementary whereas information and non information labour are substitutes. This result is consistent with the hypothesis that information capital is a substitute for non information labour and that information capital is complementary with information labour.

However, estimates of the elasticity of substitution over the period of analysis (1948 to 1973) suggest that the degree of complementarity between information capital and information labour has significantly declined over time. The net positive impact on employment of capital deepening was larger in the 50's than in the 70's. Furthermore, the demand for information capital would be fairly elastic to price changes (more elastic than the demand for conventional capital). Hence, these trends are consistent with the proposition that information capital will, in the coming years, be a <u>substitute</u> for all kinds of labour and that any decline in the price of information capital would induce a significant deepening of information capital in the production function. For a given level of output, a capital deepening would result in a net decline of employment. Consequently, only a sufficient growth in output and final demand would result in a positive growth of employment.

These results for the manufacturing sector seem to confirm the expectation of many authors that the telematic revolution will bring a displacement of workers in many sectors of the economy. But we <u>cannot</u> use the existing sample data to forecast the impact in income growth and employment of a deepening of the new generation of information capital because this capital will bring in non neutral technical progress and will change the past technical relations between inputs and between output and inputs.

Moreover, the introduction of a new generation of capital goods in the production process will likely have a differiantiated impact by sector of the economy and by labor occupation. In the primary and manufacturing sector of the economy, the impact of telematics in terms of capital deepening and labour substitution may be lesser than in the overall economy since the capital/labour ratio in these sectors is already quite high. It is expected that telematics will permit further mechanization of the production process particularly in the case of assembly lines. Some assembly plants for automobile are already entirely computerized and robotized. The robotics will reduce employment of assembly line workers. But the information capital will also induce a saving of all inputs. Process control will allow us to economize natural resources and energy inputs. Information capital as a substitute for traditional capital, would lead to a reduction of the size of buildings. This, in turn, will economize land and energy.

Other aspects of economic activity connected with primary and manufacturing output will be altered. Telematics will result in a better inventory control and a better control of assignment and transportation problems. This will increase overall productivity in these sectors. These examples are given to show that the whole production function will be changed and that we cannot infer, from existing data, the quantitative impact of the introduction of a new generation of capital goods on the productivity of production factors and on the use of specific inputs.

Change in the technical composition of final manufactured products (i.e. products offering the same service but different in their technical composition) will substantially alter the input-output relation in the production function. Some available examples suggest that such changes can be highly labour saving and can result in appreciable rise in productivity. The nature of durable goods,in particular, is liable to be changed by the new technology. Products such as T.V. sets, radios, white goods, cars and so forth, will be changed in the future.

This effect of the new technology will make more acute the existing problem of output measurement; it is very difficult to capture with existing production data these effects of change in the nature of the product.

The change in the production function will imply a substantial modification of the intersectorial input-output relations in the economy. First, the current Leontieff technical coefficients which can be considered a good approximation of the sectoral production function will be significantly altered as production processes are changed. Second, there will be a modification in the flow composition of inputs to each sector. The sectoral demand for some inputs will decline whereas the demand for new inputs will increase. The so-called primary information sector in Porat's terminology will extend and at the same time, change its links with all the other sectors of the economy.

In a country like Canada, existing evidence (Jouandet-Bernadat, 79) suggests that a good deal of telematic products will be imported. Therefore, the import sector of the interindustry table will grow while the flow of inputs coming from domestic sectors will likely be proportionnally reduced in the future. Hence, the use of the current Statistics Canada input-output table to evaluate the impact of the new technology is not very appropriate since the whole configuration of that table will be changing and at a much more rapid pace than what has been experienced in the post-war period.

In the service industry, it is expected that the new technology will change the complementarity relation between information capital and information labour into a relation of substitution. As the new generation of information capital is introduced in the service industry, net employment will decline for a given output. The impact of telematic capital will be felt more heavily on some specific occupations.

For example, a change in computer systems would result in a decline in labour/capital ratio. There will be a decline of employment for analysts and punchers and there will be a change in the composition of labour demand. A new generation of programmers and software specialists may be required as the new technology is introduced in the service industry. A more intensive use of telematics in many sectors will contribute to displace all kinds of white collar workers. The following sectors would be particularly affected by the new technology: banking and finance, insurance, R and D services, postal and telecommunication services, legal and accounting services.

The use of telematic capital will therefore change the production function of the services industry. Bureautics will result in a higher mechanization of many service sectors. But like in the manufacturing sector of the economy, there will be a change in the nature of the supply of services which will bring about change in production process. Banking services are a good example of how a change in the nature of the output will bring a modification of the production function and a substantial rise in productivity. Direct transfer of funds will gradually reduce the use of cheques as a means of payment. Cheque processing functions will therefore progressively disappear in the banking system and most employees related to that function would be displaced. In that case, change in the nature of the service (i.e. use of cheques replaced by electronic transfer of funds) brought by telematics would modify the production function.

As a consequence to the change in the production function of the service industry, the flow of inputs to the service sectors will be altered in the future. Again, we may expect an extension of links between the primary information sector and the service industry. In the case of Canada, the flow of imports to the service sector could rise over time.

Finally, the telematic revolution may also change the organization of the firm. It is not clear if telematics will contribute to a decentralization of operation in large firms or to a centralization. Authors are divided on that issue. Telematics will contribute to reduce the need for transportation and will improve communication within the firm. Communication between geographically distant units in a corporation could be substantially improved. In that case, telematics would be compatible with a decentralization of operation. In a large country like Canada, telematics could contribute to more balanced distribution of employment among regions.

IV EMPIRICAL ANALYSIS.

As emphasized in previous sections, past data on economic growth and technical progress are not very useful to forecast the macro-economic impact of telematics. One can then build scenarios based on different assumptions and derive some implications of the scenarios that could be useful for policy making.

There are three major aspects that a scenario should deal with: the technical implications of the new technology (change in production functions), the long term prospects of the economy regarding growth in demand and supply, and the short run adjustment (speed of adjustment to the new technology in the major sectors of the economy).

Assumptions about the technical aspects of telematics could be based on engineering surveys regarding the capital/labour ratios which could be expected in the future in the various sectors of the economy. For a given level of output, one could, from these assumptions derive the number of displaced workers by sectors brought about by the new technology. Several estimates on this aspect have been suggested by different authors.

Given these technical facts, one could evaluate the growth pattern needed to absorb the displaced workers and the natural growth of the labour supply. Growth patterns would take account of the development of new products and services, the possibilities offered by export markets and import substitution effect and so forth. A few scenarios of balanced growth between demand side and the supply side of the economy could be derived. Then, one could evaluate the policy implications and propose different strategies to favour a balanced growth situation in the economy.

The short term aspects are more difficult to analyse since they imply several dynamic processes. On the demand side, existing time lags of the various demand functions appearing in short run econometric models could be used tc simulate the price and income effects brought in by telematics. On the supply side, various dynamic assumptions would have to be introduced to evaluate the effect over time of the technical change on employment and other production factors. Following this, given some employment targets, one could evaluate different implications for fiscal, monetary and other policies.

The crucial aspects behind these exercises remain difficult to estimate with accuracy. The effect on sectorial production functions and the speed of adjustment are very important aspects in these scenarios and not so easy to quantify since many dimensions of the new technology are not yet fully known. There is always a gap between the known possibilities offered by a technology and what is effectively commercialized. The speed of reaction of economic agents, the time path of the prices of new equipments, the degree to which competition will force producers to adopt new means of production are all difficult factors to evaluate. Hence, at this stage of the process, many scenarios could be considered and it would be difficult to rank them by their probability of occurence.

Different estimates of the impact on employment resulting from the introduction of the new technology have been suggested (see bibliography) - Considering all the limitations of these estimates emphasized in the last paragraph, we must interpret the estimated figures as preliminary.

In some countries, authors forecast a significant rise in unemployment whereas in other countries like Japan and the United States, authors have a more optimistic perception of the growth possibilities particularly because of the good prospects offered by the international market. In Great-Britain, different analysts (Jenkins and Sherman, 1979; Barrow and Curnow, 1979; Lea et al., 1979) are predicting a significant rise of unemployment as a result of the introduction of micro-electronics devices. The level of unemployed workers could rise from the current I.5 million to 5 million in 1990 and the unemployment rate could reach 15%. Other analysts are forecasting a rise in the unemployment rate for other european countries like France (Nora and Minc, 1978) and Germany (Friedrichs, 1979 ;Simmens, 1978). At the sectoral level, the Nora-Minc report forecast a decline of 30% of employment in the finance and banking sector over the next ten years whereas Simmens foresees a decline of 40% of the employment of white collars over the same period.

As indicated before, information workers defined in Porat's broad sense (White collars, informatic workers, etc...) will be particularly affected by the introduction of the new technology. In Canada, these workers accounted for 40% of the labour force in 1971 (Canadian Economic Services, 1977) and this percentage has probably risen over the last decade. The sectoral breakdown showed in Table I (p. 30) indicates that the service industry would be particularly hit by the telematic revolution. If we assume that, for example, 25% of the information workers would be displaced by the new technology over this decade, it would mean that more than one million worker

TABLE I

INFORMATION OCCUPATIONS AS PERCENTAGE OF EMPLOYMENT BY INDUSTRY, CANADA, 1971. (Source: Statistics Canada, 1971 census).

	%
Primary Industries	9.7
Agriculture	1.7
Forestry	18.3
Fishing and Trapping	3.1
Mixing	33.9
Secondary Industries	33.5
Manufacturing	36.2
Construction	25.0
Service Sector	46.4
Transportation, Communications & Utilities	48.4
Wholesale and Retail Trade	45.7
Finance, Insurance, Real Estate	90.9
Community, Business, Personal Services	50.3
Public Administration and Defense	53.0
TOTAL INDUSTRIES	39.9

would have to be absorbed by the growth of the economy. This is about three times the annual average number of jobs created over the last years. This estimate does not include the displacement of assembly line workers and other blue collar workers which will likely take place with a further mechanization of production processes. In that scenario, the economy would have to grow at a much faster pace than in the last two decades to absorb these displaced workers.

The telematic sector itself (as a part of the primary information industry in Porat's terminology) should grow at a very rapid pace over the next decade. But it accounts for only 3.5% of GDP in Canada; only 2% of the work force in 1976 (Jouandet-Bernadat, 1979) was employed in that sector. Furthermore, Canada has been importing a growing proportion of its demand for telematic products over the last decade. This proportion is now estimated at 54% of the demand. Hence, even a considerable growth in that industry, given its small size, would not be sufficient to absorb displacement of workers in other sectors of the economy. An expansion of new activities in the service sector and development of activities oriented toward the export market in the manufacturing industry would be required to maintain a satisfactory level of employment.

V CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH.

LONG RUN PROSPECTS.

We have argued in this paper that the telematic revolution, like other waves of technical progress, creates a typical balanced growth problem. It is a standard theorem that in the very long run market forces in the economy will bring about a balanced growth situation where the rate of growth of labour supply plus the growth rate of productivity generated by technical progress will be equal to the rate of growth of output. This model of growth (often rooted in the mind of policy makers and other economic agents) assumes that technical progress is neutral (it saves equally on all inputs) and that there is no other limit to growth than the labour supply.

In the postwar period, it was feared that (non neutral) labour saving technical progress would make balanced growth an impossible target and result in structural or technological unemployment. This would primarily result from the mechanization of the primary and manufacturing sectors of the economy. On the other hand, the expansionist thesis of the 50's and 60's was that a more rapid capital accumulation would secure a balanced growth in the economy. Development of new products and services in particuliar would generate income and capital formation to an extent sufficient to absorb the growth in the labour force.

Indeed a rapid expansion of the economy, particularly in the service sector has allegedly secured a more or less balanced growth in the 60's and early 70's and no significant rise of technological unemployment was observed in that period. However, it must be remembered that the average hours of work have steadily declined since W.W. II and in fact, over the whole century. An expansionist view of the telematic revolution would then imply that the development of new products and services as described in our paper will bring a sufficient capital formation to absorb the displaced workers and the natural growth of the labour force.

However, it can be argued - without forecasting any spectacular rise in unemployment in the next ten years as some pessimistic studies suggest - that the telematic revolution will represent a new wave of technological progress which will result in a saving of labour input in total production over the long run (say three decades, for example) when the full effects of new technology will be completed. This new wave of technical progress happens at a time where limits to growth will continue to constrain the growth process of the economy.

Information capital will likely be a substitute to all kinds of labour in the next decade. The labour saving technical progress will affect all sectors of the economy, particularly the service sector where displaced employees used to find a job in the last two decades. Even if we expect the development of new products and services and a rise in exports (a factor extremely important for Canada's prosperity in the case of the telematic revolution as indicated in other papers of that study), in order to bolster economic growth, the capital formation needed to absorb displaced workers and the naturally growing labour supply will have to be considerable because of the rising capital/labour ratio produced by the new technology.

The economic system could therefore hit a first constraint set by the supply of saving. Maintaining a balanced growth needed to absorb the workers in the labour market could imply a saving rate well above that which could be realistically sustained in the long run. But even if we suppose that the supply of saving would not become a major impediment to balanced growth, then the current existing limits to growth - which have, in the second half of the last decade, caused a serious slowdown in economic growth - will seriously dampen the growth process. It was argued in our paper that telematic capital would save on the use of all inputs including energy and natural resources and would also contribute to a better control of pollution. However, a rapidly growing capital stock needed to secure balanced growth results in a substantial rise in resource demand and as consequence, shortages will likely limit the growth process. Moreover, as growth proceeds, it is likely that a growing proportion of the capital stock would have to be used to control pollution. Therefore, part of the capital formation - as it is currently the case - would not generate economic activity.

Hence, over the long run saving and resources shortages are likely to make unavoidable a disequilibrium between capital accumulation and the labour supply growth. The net result would then be a growing rate of unemployment, at least in the current keynesian definition.

This possibility implied by the telematic revolution could therefore lead economists and policy-makers to change their Harrod-Domar-Solow philosophy of balanced growth. First, it must be emphasized that capital accumulation set by the telematic revolution and as described in our paper will result in a per capita income growth in the economy. The rise in productivity and the growth in demand will make GNP per capita rising over time. As a result, the whole society in general will be better off and the standard of living should rise at faster pace than in the last decade. The problem that should be studied is how to redistribute the product of economic growth in an unbalanced growth context. It is extremely important to analyse in advance how Canadian Society will deal with the problem of unbalanced growth in the future. The analysis should examine different models of redistribution of economic growth in the context of the new information society. A review of existing models in other societies like Japan would be the starting point of the analysis. A new organization of society could imply among other things:

- a significant reduction in hours of work as a new means of remuneration. As emphasized in the paper, any attempt to increase nominal wages would worsen the unbalanced growth problem. Therefore, reduction in working hours should be seen as a means to increase real income. Consequently, policy measures should be taken to facilitate the organization of leisure in society. The configuration of public expenditures may then have to change over time.

- The creation or development of a fourth sector in the economy (quaternary sector) where we would find "fictitious" jobs defined in a narrow-economic sense. It means that these jobs would have a zero real marginal product as usually defined. In fact, this would mean that the contribution to GNP and economic welfare in general would be quite indirect and difficult to measure with our traditional concept of output per man hour. The fourth sector could be socially useful and desirable and could contribute to the general welfare of society. This is not an entirely new approach to the job creation problem and many federal and provincial job creation programs that have emerged in the last decade are of this nature. These programs create jobs where the contribution of a worker to total output is largely indirect and difficult to measure. The development could be connected with the organization of leisure in the society.

- Development of non-computerized and non mechanized activities such as craftsmanship and the like. Fiscal incentives and other policies could be set to promote the development of a "parallel economy" or a "small economy" within the overall economic system. The "parallel economy" would be basically based on labour intensive economic activities.

We therefore recommend the study of optimum management policies to meet the long-term implications of the telematic revolution. Since changes in the philosophy behind economic policy and in the practical design of the policies are a long term process, we should already start to examine new approaches to economic policy in the context of the coming telematic revolution. Furthermore, the economy will, in the next year, be in a transition period where several existing policies may have to re-appraised.

In the long run, the traditional philosophy of full employment would have to be re-interpreted in the context of unbalanced growth. The current philosophy concerning the redistribution of income may have also to be re-oriented in the context of a growing standard of living accompanied by disequilibrium in the labour market. The impact of these fundamental changes on major social and labour programs should be analyzed. A new approach to stabilization policy could imply the design of policy incentives to develop a "parallel economy" as a solution to disequilibrium in the labour market. The impact of increasing leisure time in society on government policy should also be examined.

Another study should also analyse the implications of a transition period in the course of the next decade. One important dimension of the study would be to examine what appears to be the optimum pace at which we should modify the current economic policies. For example, if unemployment problems are forecasted over the next decade, then the labour programs may have to be modified at a more rapid pace than other areas of economic policy.

SHORT RUN ASPECTS

It will be important for economic policy purposes to build macro and sectoral scenarios to simulate the probable impact of the telematic revolution on the Canadian Economy over the next five or ten years.

As argued in our paper, the supply side of existing econometric models as well as current data on production and employment are not very useful to simulate the impact of a deepening of telematic capital in the labour market. One would need different engineering surveys at the sectoral level to evaluate the input structure in the economy associated with a change in the technology. Given these estimates, as described above, it will be necessary to make different sets of assumptions about the speeds of adjustment involved in the process of changing the production functionsin the economy.

It would be appropriate to derive a few scenarios associated with different speeds of adjustment. (Slow to rapid adjustment scenarios). Different assumptions about the development of the Canadian telematic sector and associated levels of exports and imports of telematic products would have to be embodied in these scenarios. Given the small size of the telematic sector in Canada and the heavy import content of final demand for telematic products, it is quite possible that under a scenario of rapid adjustments, Canada may be a country particularly affected in the short run by the telematic revolution. In that case, it would be crucial to derive appropriate policies to alleviate any major impact on the Canadian Economy.

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