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THE TRANSBORDER DATA FLOW PHENOMENON:
A MULTINATIONAL ENTERPRISE INFORMATION FLOW PERSPECTIVE

par

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ABSTRACT

The recent information explosion, as manifested in the phenomenon of Transborder Data Flows (TBDF), is explained. TBDF is the movement, accross national frontiers, of high speed computer data. (Our study excludes the transactions of data bank operators). Since the multinational enterprise (MNE) is responsible for a substantial proportion of these flows we have chosen to regard TBDF as intrafirm information trade. The virtue of this view is that the problem can then be attacked within the scope of information economics and the behaviour of the firm under conditions of uncertainty. By treating information as an input to the production process we are then able to characterize it by a derived demand function. This is done by solving the profit maximizing problem of a firm facing random demand, operating in imperfectly competitive output markets and able to acquire positive cost information that alters the probability distribution of demand and, consequently, expected profits. The firm, in our model is risk neutral but requires information because of the distinction we impose between uncertainty and risk. The latter describes the unknown characterized by a known probability distribution. Uncertainty, on the other hand, is present to the extent that information revealing the true probability distribution is not free. In its extreme form uncertainty is characterized by states of nature that are all equiprobable. Uncertainty is transformed

into risk through the application of information. In the derived demand functions information turns out to be a function of own price, a risk variable which is positively related to potential losses from not selling at a given profit margin and the possible range of demand fluctuations, the flexibility with which the firm can dispose of excess production, and the relative importance of trade.

Empirical tests are performed over a cross-section of 16 OECD countries for the two periods 1976 and 1981. TBDF, which is the information variable, is approximated by data on leased, voice grade, international telecommunications circuits. It turns out that risk is significant only in 1981. This failure of risk to explain TBDF in 1976 is viewed in terms of new technology diffusion as well as through the phenomenon of «bounded rationality».

Finally, we discuss some important policy implications with a warning to those governments who would indiscriminately regulate TBDF, that information control policies, in some cases, may be equivalent to restrictive trade policies. Indeed, it is shown that even the risk neutral MNE alters its behaviour under conditions of uncertainty when information is introduced as a choice variable. As such, policies that constrain TBDF will impact on trade behaviour.

RESUME

Dans cette thèse, la récente poussée d'information qui se retrouve dans le phénomène de flux de données transfrontières (FDTF), s'explique. Le FDTF est le mouvement de données informatisées à travers les frontières nationales. (Notre étude ne tient pas compte des transactions des banques de données commerciales.) Comme l'entreprise multinationale (EMN) génère une proportion substantielle de ces flux, nous avons choisi de regarder le FDTF en terme de commerce d'information intrafirme. L'avantage de cette optique est que le problème peut donc être envisagé dans le cadre de l'économie d'information et le comportement de la firme sous les conditions d'incertitude. En traitant l'information comme un entrant au processus de production, on peut donc la caractériser par une fonction de demande dérivée. Nous procédons en résolvant le problème de la maximisation des profits d'une entreprise au prise avec une demande aléatoire, opérant dans un marché d'extrant à concurrence imparfaite et en mesure d'acquérir l'information coûteuse qui altère la distribution de la probabilité de la demande et, par conséquent, les profits attendus. L'entreprise dans notre modèle, est neutre au risque mais exige de l'information à cause de la distinction existant entre le <u>risque</u> et <u>l'incertitude</u>. Le risque décrit une situation où il y a plusieurs états de nature possibles, caractérisés par une

distribution de probabilité connue. L'incertitude, par contre, est présente parce que l'information nécessaire pour décrire la vraie distribution de probabilité n'est pas gratuite. Dans sa forme extrême, l'incertitude est caractérisée par les états de natures qui sont tous équiprobables. L'incertitude se métamorphose en risque par le truchement de l'information. Il arrive que dans la fonction de demande dérivée, l'information devienne une fonction de son propre prix, une variable du risque qui est elle-même positivement reliée aux pertes potentielles en n'exploitant pas une marge de profit donnée et les fluctuations de la demande, la flexibilité avec laquelle l'entreprise peut se débarrasser de la production excédentaire, et l'importance relative du commerce international.

Des tests empiriques ont été effectués sur une coupe transversale de 16 pays de l'OCDE pour les deux périodes 1976 et 1981. Le FDTF, qui est la variable d'information, est simulé par les données sur les circuits de télécommunications internationaux loués. Il appert que le risque n'est significatif qu'en 1981. L'incapacité du risque d'expliquer le FDTF en 1976 est due à la diffusion d'une nouvelle technologie et au phénomène du "bounded rationality".

Enfin, nous discutons également de quelques implications importantes pour les politiques en matière de télécommunication avec un avertissement aux gouvernements qui voudraient, sans faire de distinction, réglementer le FDTF, que les politiques de contrôle de flux d'information, dans certains cas, peuvent être équivalentes à des politiques commerciales restrictives. En effet, nous y démontrons que même une entreprise neutre au risque change son comportement dans les conditions d'incertitude quand l'information est introduite comme une variable de choix. Comme telles, les politiques visant à contraindre le FDTF auront un impact sur le comportement du commerce international.

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I) INTRODUCTION

Transborder Data Flows (TBDF) refers to the movement of computer data that crosses at least one national frontier. The transmission channels for the bulk of these flows are circuits leased from the various international telecommunications companies (such as Teleglobe Canada, ITT, Italcable and so on). A very much smaller (but growing) proportion of TBDF (as of 1981, the last year of our empirical study) moves over public data networks (such as Telenet, Tymnet and so on). In view of the increasingly evident desire of governments to exercise some control over the TBDF phenomenon, it has become of considerable importance to find a tractable explanation for these flows.[1] That is, one which will allow the impact of future government regulations to be at least approximately quantifiable. We stress this point only because it underlines the importance of explaining the TBDF phenomenon. While we will comment on the direction of such regulatory impact, it should be understood that this is not our main aim. Our more modest goal is to provide the appropriate perspective from which to view TBDF.

We will argue that the substantial proportion of TBDF must be viewed as the movement (or trade) of risk-mitigating information and should properly be considered the purview of «Information Economics». Given the theoretical predictions of the impact on production (and consequently on income and employment) of risk, the implications of this view should be apparent. We will, however, not be concerned with the impact of different risk preferences on the behaviour of the firm under conditions of uncertainty, confining ourselves, rather, to the single case of risk neutrality. As such, the relevant literature is Mills (1959), Leland (1972) and Turnovsky (1973), who have all shown that under certain circumstances even firms that are perfectly risk neutral, will alter their behaviour under conditions of uncertainty. This is unlike the standard textbook case, attributed to Sandmo (1971), who tells us that the risk averse perfectly competitive firm, under conditions of uncertainty will produce less than that corresponding to the point where expected price equals marginal cost. However the risk neutral firm will produce at that point and if we take the long run view whereby expected price and actual price are coincident, then there is no difference in behaviour under conditions of either uncertainty or certainty when the firm is risk neutral. However, as Leland (1972) and Mills (1959) demonstrate, when the firm's choice variables are either price or price and quantity in a market structure characterized by monopolistic competition, then even the risk neutral firm will alter its behaviour under conditions of uncertainty. But these models do not consider the role of information, alterations in behaviour being the result rather of cost curve influences. Our model will assume risk neutrality, but, unlike these other studies, the firm's behavioural changes will be the result of information that alters the probability distribution of random demand.

To the extent that the principal role of information is as an input to the specification of the myriad probability distributions upon which most activity is based, the economics of information and uncertainty seem best suited to explain the recent explosion of information production. As can be seen from figure I, information flows, in the form of TBDF, has grown by close to 70% between 1976 and 1981. Over that same period, world trade has grown by about 52% while the older form of business information flow, Telex, has only grown by 41%. We will therefore be concentrating our study on TBDF, which involves massive volumes of data movement. Specifically we will be asking:

> «What characteristics, within the framework of information economics, account for the rapid growth of TBDF between 1976 and 1981?

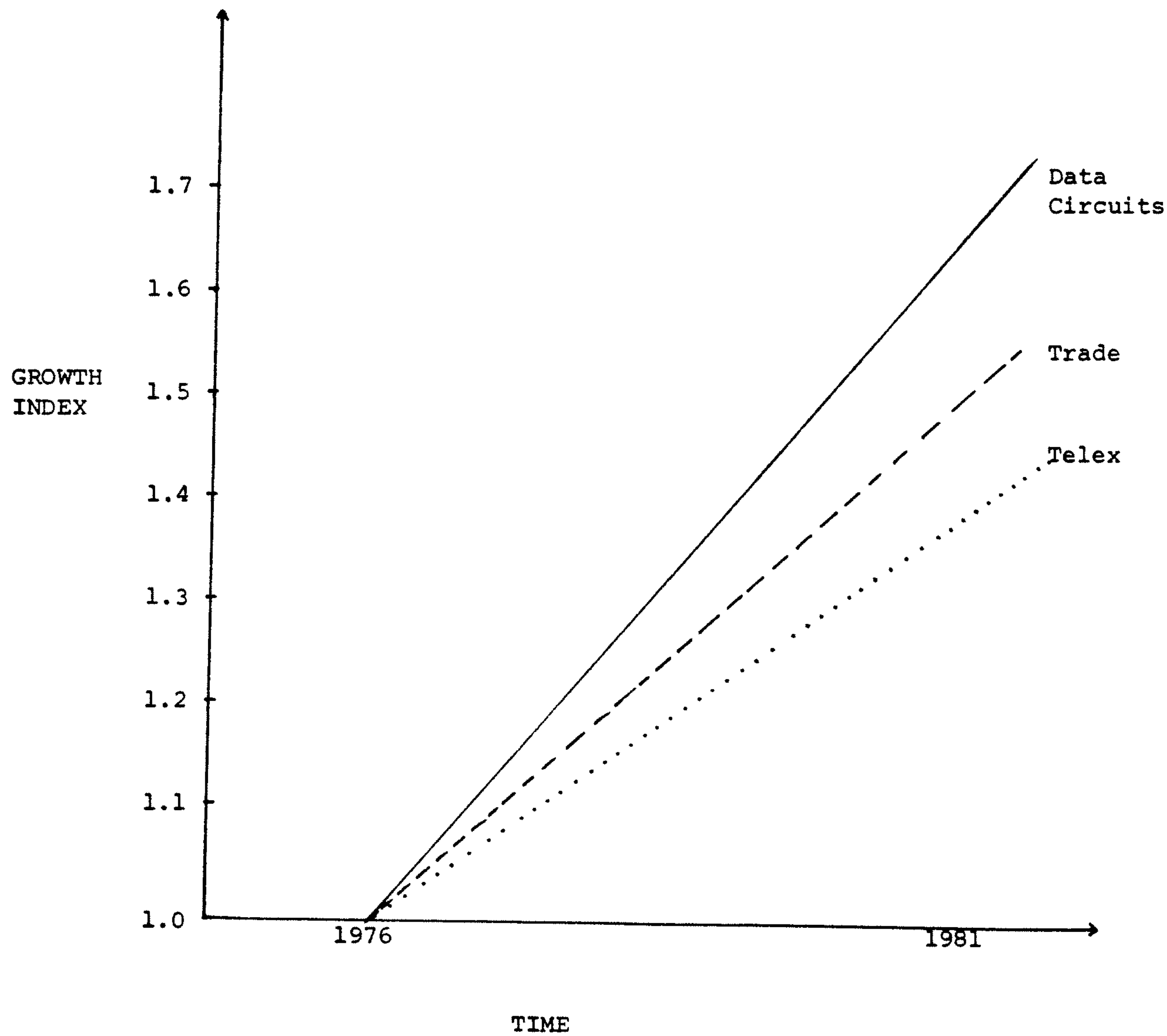
We will answer this central question by first asking the microeconomic question:

> «Which characteristics account for differences in the production of information for internal use by the different

FIGURE I

CIRCUITS, TRADE AND TELEX GROWTH

(1975=100)



MNE's? That is, what is the information intensity of production?»

The most important reason why we have not yet seen any meaningful formulation of the TBDF phenomenon is that the spectrum of government focus only very incidentally intersects that of the major TBDF users, the MNE's. This is not to suggest that its perspective is unimportant. On the contrary the issue of controlling the movement of confidential data in order to safeguard privacy, for example, should be of considerable concern to everyone. But it is not very useful to ignore the costs of this protection. And these costs will depend upon what view one accepts of the user's benefits. However, and this is central, no such clear view has as yet been formulated.

That TBDF constitutes the movement of information is of course obvious. But what has not been made clear is the way in which this information impacts on the behaviour of the TBDF user. The business economics literature[2] suggests that the advances in computer and telecommunications technology have permitted corporate reorganizations and changes in management style towards a more centralized structure. This may indeed be an accurate description but it is by no means complete. It looks only at a technological reconfiguration due to changing marginal productivities; a more efficient way to combine capital and labour for the same output.

This view does not provide a structure within which to answer a fundamental question: will production levels be affected as a result of constraints to the free flow of information?

Before going on to a more complete view of the deficiencies in existing studies, which will be presented when we look at a review of the theoretical and empirical literature, it will be useful to present the major players in the TBDF game. These include data bank operators; service organizations including banks and other financial institutions, airlines and the tourist industry; non-financial MNE's that also includes other service industries, not already mentioned under service organizations; and, as already noted, the various national governments whose mixed bag of concerns have put in place, and will continue to spawn, policies for the control of TBDF.

Data bank operators are the smallest of the concerned populations, accounting for less than 6% of all flows.[3] They trade information as a final good and can therefore most easily be analyzed within the traditional supply-demand paradigm. We know that non-neutral regulations that impose costs will drive a wedge between the buyer's price and the seller's price and less will be produced. Indeed, severe enough controls may even cause some or all of the data bank operators to withdraw from the market. But, because of their small size, and behavioural characteristics quite different from the MNE's we will be studying, they will not be given any extensive treatment. However, to the extent that they will be lumped with service organizations, in a very simple model, they will not be ignored.

With regard to the service organizations, because information is actually an integral part of their final output it does not lend itself to any straightforward treatment as a separate final good. The supply of information will depend upon the demand for, say, the airlines' main output, passenger seats, as well as the amount of information the airlines believe they must supply with each ticket sale. These issues are not intractable, but, as will become apparent, they could not be properly treated within the framework of our main model and, as such, will be lumped for analysis within a very simple model (along with the data bank operators).

Non-Financial MNE's (henceforth referred to simply as MNE) account for the bulk of TBDF.[4] The development of an information demand schedule for the MNE constitutes the heart of this analysis. We will show that the profit maximizing firm, when faced with random demand, will purchase information as long as the marginal expected returns exceed the marginal costs of such information.

Finally, there are the various national governments, for whom the main issues are privacy, the distribution of high technology employment and competitive advantage. Western governments, in particular, are concerned that domestic laws governing the confidentiality of its citizens' personal, computerized records can be contravened by moving the data to other jurisdictions with looser privacy restrictions and then back again to the information consumer. But, as already noted, while we share these same concerns, they cannot usefully be evaluated without looking at the impact the control of this information has on production.

Employment in the prestigious, high technology, data processing game is also part of the stake governments have identified in their bid to control TBDF.[5] The U.S., a data-processing-giant, would rather see centralized, main frame operations, whereby most countries operate as data gatherers while human capital expands at home, doing the skilled decoding and analysis work, much like the hewers of wood and carriers of water analogy in manufacturing. Other governments would, naturally, prefer the distributed data processing route which would allow them to grab a piece of the human capital development action.

While privacy and employment (which also has some minor implications for the balance of payments) are important concerns, they are completely overshadowed by the competitive advantage issue. Countries with a near monopoly in telecommunications, computer technology and human capital have an overwhelming advantage in the information game, which after all, is one of the key elements for success within the market economy.[6] This issue is so sensitive that some governments have taken draconian measures to try and establish, or even just maintain, a position in the «information economy».[7] Algeria, for example, allows no transmission of computer data to other countries.[8] Brazil requires the registration of foreign data links (trying to control the gateways), Mexico has introduced rigid conditions on foreign data flows and other, similar restrictions have been introduced elsewhere.[9]

Although we may sympathize with these national concerns, particularly when we view them within the contexts of trade balances and the international division of labour skills and competitiveness, the impact of such restrictive policies is not well understood. We may more easily infer that like trade in goods, trade in information, as a final good, may be seriously curtailed, by heavy handed regulations, but the effect on the behaviour of an MNE is less clear. This is so because information operates through the impact of uncertainty on production. Thus, from a policy perspective, we may inquire as to:

«The implications for MNE behaviour and the patterns of trade, in the face of restrictive government TBDF policy».

Jussawalla (1982) exemplifies the intimate connection between TBDF and the MNE when he says, «Despite many limitations, trade no longer follows the flag; it follows the communications system». This phenomenon can be better understood with reference to the literature which tries to find the raison d'être of the firm. It suggest, inter alia, that «the firm, in large part, consists of non-market institutions whose function is to deal with resource allocation in the presence of informational constraints that the market handles poorly or does not handle at all».[10]

That MNE's are growing more dependant on TBDF and that TBDF itself is a major transforming force is undeniable. Detailed descriptions of the impact of electronic information technologies on the firm are provided by Antonelli (1981) and Litvak & Maule (1980). Antonelli, in particular, examines the transition to computer based electronic communications systems for six Italian MNE's and the subsequent dramatic transformation of their respective management and organizational structures. This evidence of significant impact adds a good deal of weight to our questions concerning the demand characteristics of MNE's for TBDF, the sources of differences in this demand between MNE's and the policy implications of information flow constraints for MNE behaviour and the patterns of trade. In this regard, it is well-known that trade policy affects investment decisions. What is less understood is that information policy can have the same type of effects. If the information content of an acquired subsidiary played an important role in the acquisition decision, as some of the recent literature suggests,[11] then how will the MNE react if it is to be restrained by government regulations? Indeed, as will become apparent throughout this study, foreign direct investment, without the uncertainty mitigating flow of information (UMI), may no longer be an optimal strategy. In this respect it should be recognized that most information, whether it is called «logistics and control»[12] or «operational»,[13] is to a large extent of the UMI type. Under conditions of certainty: the correct inventory levels would always be known; the required flow of raw materials, spare parts, cash and so on are determinate. It is only the presence of uncertainty, along with a certain degree of production planning flexibility that necessitates information flow expenses. Presumably then, there is a positive payoff to the information and, as such, in the presence of constraints MNE beheviour would have to be altered in certain not unimportant ways.

From an economic efficiency perspective, constraining the free flow of information will be seen to be suboptimal. This, because information under conditions of uncertainty is shown to have real effects, so that restricting access will cause the firm to produce at a point different from the risk neutral profit maximizing point, given the true probability distribution. However, from a welfare perspective, given the existence of other distortions, such as tarrif barriers, decisions are already being made in a second best environment so that some control of information, say for the protection of privacy, may even be desirable.

In what follows we will address these issues surrounding TBDF, beginning with a detailed presentation of the main problems and a critical evaluation of the very few other studies that have come to grips with the question in Chapter II. Chapter III will present a theoretical view of the problems as well as introduce such restrictions as to allow empirical verification. Chapters IV and V will look at the empirical results. Chapter VI will provide a brief policy analysis while conclusions are presented in chapter VII.

FOOTNOTES

Chapter I

1. Governments, or the national bodies which represent them, meet quite frequently to discuss the various aspects of TBDF. Indeed the OECD even has a TBDF working group.

2. This includes work by Chandler (1975), Sherer et al (1975) and Litvak and Maule (1980) who discuss the effects of new information technologies on organizational structure and its contribution to productivity and risk reduction.

3. Lorenzi and Tolédano (1981) provide an extensive discussion on the activities and impact of several large data bank operators.

4. Antonelli (1981) surveyed and catalogued the behaviour of 24 Italian MNE's with respect to their acquisition of high technology information systems.

5. Lorenzi and Tolédano (1981)

6. North and Thomas (1973) trace the importance of information in the development of the western world between 1000 and 1700. See page 114 in particular.

7. Porat (1976) uses the expression «Information Economy in his pathbreaking development of national information flow accounts for the U.S.A. Marschak (1968) was however the first to introduce the concept of an «Information Economy».

8. Helleiner and O'Brien (1982) discuss the measures introduced by different governments to control TBDF.

9. Helleiner and O'Brien (1982).

10. Spence (1975) looks at the role of information within the context of internal organization.

11. See Arrow (1975), Spence (1975) and Marschak (1968).

12. See Antonelli (1981), Lorenzi and Tolédano (1981).

13. See Litvak and Maule (1980).

II. LITERATURE SURVEY

The literature that deals directly with the phenomenon of Transborder Data Flows is, by and large, narrative, and makes no attempt at rigour. But, since we are looking for an explanation which is at once rigourous and tractable, allowing us to reduce the phenomenon to a set of testable hypotheses, we had to look elsewhere for guidance. The literature, which provided the insight to the theoretical model, presented in Chapter III, includes two bodies of work, that on the economics of information, as well as those studies dealing with the behaviour of the firm under conditions of uncertainty. Thus, there are three themes which we will cover, TBDF research, information theory and behaviour under undertainty. This survey has been organized to treat each of these separately. However, to the extent that the information literature is often written within the context of decision making under uncertainty, it will not always be possible for us to treat them apart. In addition some of the work being done under the name of communication theory overlaps into all three themes and will be included when appropriate.

a) General: TBDF, Communication, Information

The relevant literature dealing directly with TBDF does so largely by examining how firms contrive to absorb the new communications technologies, how it impacts on their organizational structures and what role it plays in their attitude towards decision making. There is of course a good deal more that has been written on TBDF, but that body of literature looks at the issues of privacy and the equitable distribution of data processing employment, already touched upon in the previous chapter. As noted, these are interesting and important areas but are not useful for our analysis, which is concerned chiefly with the demand for TBDF by the firm in its resource allocation decisions.

To supplement the TBDF literature surrounding producer behaviour, because it is lacking in rigour, we have also surveyed some general work that looks at the larger question of information flows and communications.

In so far as the concerns surrounding TBDF relate to the broader issue of information, the phenomenon is not new. In their excellent book, D.C. North and R.P. Thomas (1973) detail the relative developments of England and the Dutch Republic on the one hand and France and Spain on the other hand, from the 11th to the 18th century, partly in terms of the appropriability laws governing gains from risky undertakings. Those countries (England and the Dutch Republic) which, through laws guaranteeing appropriability, encouraged the movement of information, embodying innovation and other useful knowledge, accross feudal frontiers, fared relatively much better. Thus, long before the advent of electronic communication, the information game held one of the important keys to success in the market economy.

The newness today involves the technology of moving information. TBDF is characterized by the movement of vast quantities of information. This explosion of information should not be viewed as an aberration. The world is a more complex place and the useful acquisition of more information to deal with this greater complexity is of considerable importance. There is, however, some debate as to whether the present organizational structure of enterprise has evolved to more productively use the increased capabilities of the new information technologies or, indeed, if the new technologies did not evolve to feed changing organizational structures.

Chandler (1975) takes the view that as business became larger with more invested in illiquid fixed assets, adding, by definition, more risk to the enterprise, it developed a preference for a more centralized organizational form. The rate of reorganization, however, was necessarily constrained by the technology of information transmission. In this view technological development is stimulated by a clear shift in demand for more information. It should, however, be understood that incipient shifts to a vertical management structure, in the earlier part of the century, were taking advantages of rapidly expanding electronic communications networks. As Chandler goes on to point out, prior to Teletype and certainly telegraph, head office would typically receive communications from branches detailing the decisions already taken, and not requests for management-owner strategic direction. In this pre-electronic age, while centralization was clearly not feasible, it was nevertheless desirable. This preference manifested itself very early in the electronic communication age, from which point the distinction between cause and effect, in this view of the world, becomes clear: the telecommunication industry was encouraged by an unambiguous preference revealed by enterprise to absorb its output, and as development progressed international traders further reorganized towards a desired central structure and continued to fuel the demand for more electronic communications.

This preference for a vertical organizational structure, where everyone communicates only through the centre, has recently been studied by Welch (1980). He compares vertical with horizontal communications processes. Vertical communication performs better than horizontal communications (no communication with the centre), in the sense that the outcome of an exchange of messages (information) between organization member results in equilibrium resource allocation (i.e. no excess demands), in large organizations, with organization-wide constraints. These constraints can be characterized by the example of a large petrochemical producer who has one plant that refines feedstocks for input into another plant that produces styrene as the third plant's input to the production of synthetic rubber.

Litvak & Maule (1980), also suggest that the information explosion is the result of technological development and the impetus provided by a preference for central organization. They divide the information flows into three main categories: operational flows which encompass what they call «control» and «logistics» functions; tactical information; and strategic flows.[1] Although the operational flows, which are concerned with day to day business make up over 90% of the information total, they make a substantial contribution towards reducing uncertainty. Indeed, Litvak & Maule interviewed five MNE's and «all five agreed that the new information technologies reduced uncertainty by increasing the flow of information, speeding up its delivery, and enlarging its range of distribution». But, strictly speaking, it can be argued that information, at positive cost, will never be acquired unless there is uncertainty and only then if it can be demonstrated to cover its costs. For example, although the mail clerk at Toyota faces very little risk that he will run out of funds every time he posts a letter, there is nevertheless some risk. However, setting up an expensive communication channel to keep him continuously updated on the financial health of the firm would likely have a negative return. There are, on the other hand, activities which would usefully be served by more elaborate operational type of information flows. Central shipping in Japan, for example, could conceivably expedite large consignments of automobiles to its foreign distributors based on some set of expectations about demand and inventory conditions without ever having recourse to updated information. However, greater «control» and smoother «logistics» would probably so reduce the risk of excess supply and/or demand as to cover the cost of the information.

This preoccupation with information can be better understood if we consider uncertainty, as per the Knightian[2] view, where it is taken to mean that the various possible states of the world cannot be characterized by a probability distribution. Risk, on the other hand implies a known distribution. The transition from a state of uncertainty to a state of risk is the consequence of information acquisition. Further, even in the case of complete risk neutrality, uncertainty is hardly a desirable state. Their is no basis for action other than the maximum uncertainty case of equal probabilities. It is, therefore, reasonable to suspect that risk is preferable to Knightian uncertainty. Indeed, the information explosion, as technology reduces its costs, attests to this preference. Marschak (1968) estimated that fully 40% of GNP in 1968 was the consequence of information activities. By 1976, Porat, in his path breaking establishment of «national information accounts» put the information portion of GNP at well over 60%. Although most of this information activity does not fall within the scope of TBDF, it nevertheless highlights the importance of information to economic activity.

Internationally, the growth of information, as can be seen in Figure I has been just as spectacular. Given the greater risks inherent in dealing beyond national frontiers, this explosion of information is not surprising. Antonelli (1981) studied the evolution of information flows for 24 Italian MNE's covering financial, manufacturing and service industries. By the 1970's information requirements had become so large that most of these firm's found their old telex-telegraph-telephone-based systems becoming prohibitively expensive. These older technologies were significantly scaled back to be replaced by the newer computer-to-computer systems; that is, by the Transborder Data Flows technologies. Their behaviour lends considerable support to the vertical communication model[3] as well as to the thesis of preferences for centralized organizational structures. This is most visibly evident in the recent phenomenon of reinvoicing centres. A multiplant operation sets up a centre with which all units communicate to the exclusion of inter-unit communications. Thus, plant A, for example, will order goods from the centre which will retransmit the order to plant B and plant B will subsequently bill plant A, indirectly, through the centre, which will choose the prices, currency of payment and means of financing. Horizontal communications are eliminated. Each transaction, in this case, obviously requires more communications. The justification lies in greater control, or, in our language, better-specified risk.

The considerable importance of information and its behavioural consequences is highlighted by Jussawalla (1982) in his study of the relation between communications and development. He suggests that a MNE's decision to invest in a remote part of the world will be heavily influenced not by the importance of its home government's presence, but rather by the quality of existing or planned communications links. Development plans should therefore not expect to succeed if they depend upon foreign investment and do not accord enough importance to a communications infrastructure.[4]

There is, however, some suggestion of a dark side to this type of development scenario. Helleiner & O'Brien (1982) express the very pessimistic view that the wider use of extensive computerized telecommunications systems will put more of information's implicit power into the hands of MNE's and serve to widen the gap between rich and poor. The ability of an MNE to extract the lion's share of any gains from trade resides in its almost monopoly control of the information technology, from the gathering of raw data through the transmission medium to the synthesis capability. However, this view may be dim only because it is taken out of context by the authors. Unless the circumstances warrant it, such as conditions of excessive risk, massive profits ultimately invite competition and normalization. Thus, while the initial price of providing a communications link may be high, if it is the only way to attract investment, it may, in the long run, prove to be a worthwhile investiment.

Thus far we have been examining a burgeoning literature that unanimously agrees information is important, it is growing at a considerable rate and that it converts Knightian uncertainty into quantifiable risk. However, there is not one study that combines all these characteristics into a model that can be usefully manipulated for purposes of prediction and policy analysis. Indeed, the various symposia, articles and studies[5] that directly discuss TBDF never go beyond the narrative stage. They simply and endlessly rehash those same concerns of confidentiality, high-tech employment and competitiveness that are detailed in the introduction of this study. This study, on the other hand, is aimed specifically at developing a tractable model useful for prediction and policy analysis. Further, since international electronic communications are dominated by private enterprise,[6] it is from that perspective that we approach the problem. Indeed, it is also the point of departure of most other writers on TBDF (albeit narrative writers).[7] And, in this regard, to provide a somewhat more tangible framework, we must look to the economics of information as well as the literature describing the behaviour of the firm under conditions of uncertainty.

b) The Economics of Information

The question of information and its value has been given a vast coverage in the theoretical literature of the past two decades. A common and undisputed feature of these studies is the acceptance of the proposition that information has value only in the face of uncertainty and its corollary, that uncertainty disappears in the face of perfect information. Beyond this comfortable, almost intuitive generalization, the theory branches into a bewildering array of special situations, such as consumer search models, insurance markets and so on. This theoretical and empirical literature does not, however, directly deal with the issue of TBDF. Instead, it provides guidelines on the treatment of information within the context of a behavioural model.

There is a growing literature that elevates the role of information in the firm to the status of the other primary inputs. Indeed, in trying to explain the «raison d'être» of the firm Spence (1975) suggests, inter alia, that «the firm, in larger part, consists of non-market institutions whose function is to deal with resource allocation in the presence of informational constraints that the market handles poorly or does not handle at all» That is, the organization of a firm is such as to provide a smoothly functioning internal information market. Arrow (1975), in this vein, describes the interaction between upstream and downstream firms where, with information lags on the production environment of the former, it is in the interest of the latter to purchase or merge with the upstream firm.[8]

Gould (1974) uses (as we subsequently do) the concept of a payoff function to evaluate the optimal quantity of information. It begins with, say, a vector of decision variables, X, for each state of nature j=1...m. Given the set of probabilities ρ_j, j=1...m, $\Sigma\ \rho_j=1$, that the various states will occur, the information free problem is to choose the vector X that maximizes (some concave function)

$$F(X) = \Sigma\ \rho_j f_j(X)$$

The solution is X* so that the maximum value is F(X*). Letting y be the information and $\tilde{\rho}_j = \tilde{\rho}_j(Y)$, F(X) is now maximized by a new vector $\tilde{X}^*$ giving a maximum value of F $(\tilde{X}^*)$. The expected value of information is then

$$V = \sum_j \tilde{\rho}_j\ [f_j(\tilde{X}^*) - f_j\ (X^*)]$$

As long as it is costless, the firm will obviously acquire information until $d\tilde{\rho}/dy=0$. Also, as long as distribution altering information is acquired, $V>0$.

To keep the following expressions simple, when we introduce information cost, let the function $f(X)$ be symmetric about a vector, $\bar{X}$, that would be chosen in the absence of any information. Thus, while the relation between information and the probability distribution $\tilde{\rho}_j=\tilde{\rho}_j(y)$ may be known, to avoid producing on the wrong side of $\bar{X}$, information is still necessary. Later on we drop this simplification.

Thus, when information has a positive cost, the problem becomes one of choosing a y to maximize,

$$NV = \sum_j \tilde{\rho}_j(y) \{f_j(\tilde{X}(\rho_j(y))) - f_j(X^*)\} - h(y)$$

$$NV = PO(y)-h(y)$$

where NV is the net expected value of information and

$$PO = \sum_j \tilde{\rho}_j(y) \{f_j(\tilde{X}(\rho_j(y)))-f_j(X^*)\} = \text{the payoff function and}$$

where $h(y)$ is the cost of information function, with the first order conditions of

$$\partial PO/\partial y = h'(y)$$

and second order conditions of

$$\frac{\partial^2 PO}{\partial y^2} < h''(g)$$

Apart from the details surrounding our suppositions concerning profit-maximizing behaviour and the form of the probability distribution, this approach is essentially the kernel of the theoretical model presented in the following chapter. That is, this is more or less the way which we will subsequently measure the value of information. But to understand what actually generates this value we must look more closely at Shannon's (1969) notion of entropy or expected information. This is a concept that has been used by Arrow (1974),[9] Marschak (1968)[10] and others. It was initially developed to minimize the signalling required in a telecommunications network, subject to the constraint of transmitting an intelligeable message. The larger the sample required from each signal, the higher would be the cost of transmission. But, given that each signal meaning has a certain probability, the higher is the value of getting more information the more equiprobable are the signal meanings. Thus you pay more, but you also get more value. More specifically, if there are n states of the world, characterized by the probability distribution

$\rho_1 \ldots \rho_n$ then an information unit guaranteeing that state i will obtain is worth $\ln(1/\rho_i)$ in the Shannon measure. It is apparent that the less likely a state the higher is the value of the information. The expected value of information over all states of the world is therefore,

$$E(VI) = -\Sigma\rho_i \ln\rho_i$$

which obviously reaches a maximum when all states are equiprobable, i.e. when $\rho_i = 1/n \; \forall i$, so that

$$\max E\,(VI) = \Sigma\; 1/n \; \ln(n) \doteqdot \ln(n)$$

In our theoretical model, at zero information level, all events are equiprobable.[11]

A study, by Richard E. Kihlstrom (1976), who specifically discusses information demand within the context of a profit maximizing firm, is in a good many ways similar to our own. He shows, just as we do, in Chapter III below, that higher profit margins due to either higher output prices or improved productivity, implies a greater demand for information. In making its choice of optimal information input, the firm has two problems: it must chose a level of information quality constrained by a non-decreasing cost of information function; and it must do so without knowing whether the information will predict conditions for higher or lower production activity, thus raising or lowering profit levels. That is, if the information predicts, ex ante poor demand then less resources will be available, ex post, for the purchase of such information. In general, without the presence of these two problems an information demand function would not be meaningful. To begin with, some notion of information value is required in order that the firm be willing to pay more for increasing amounts. Kihlstrom, to this end, uses a Bayesian posteriori probability distribution. If this becomes the only constraint imposed upon the firm's decision problem, it will not buy any information because it already knows the results, through Bayes rule, of every information quality level. Thus, to make the problem non-trivial, information, at every level of quality is composed of many messages and «at the time it (the information demand decision) is made, the firm does not know which of the many possible messages x, in X, will actually be observed». Our model is similar to the extent that both the problem of quality (or amount of information) to be purchased and the problem of the direction of any prediction (whether stronger or weaker demand) are present.

The value of information, in addition to depending upon the degree of uncertainty can also be related to the notion of flexibility. T. Marschak and R. Nelson (1962) have studied this possibility. While the exact relationship between flexibility and information acquisition is not clear there is some theoretical support for a positive correlation: more flexibility implies more information value and, therefore, more information. Inflexible firms may require a great deal more information for the initial input choices, while firms with very short processing periods would require large amounts of more frequent information. T. Marschak & R. Nelson develop three general measures of flexibility in terms of the available scope of action within a two-stage sequential decision process, after the first action has been taken. They show that under certain circumstances a more costly first-period action will be taken if more flexibility, along with an expected information stream, is the outcome. The corollary to this proposition is of course that more flexibility implies a higher value of information. This theme of making more costly choices under uncertainty is exploited by Dudley (1983) and applied by Arrow and Fisher (1974) and Henry (1974) to justify the choice of lower returns when evaluating a project with expected information on second period implications of irreversible decisions.

All of the above studies provide a good basis for the development of a theorical model of information flows. However, nothing of the sort has been done to explain the phenomenon of TBDF. The question of why MNE's actually invest in expensive electronic information systems is addressed in a very ad hoc fashion. This, despite the strong temptation of many governments, who have not already done so, to regulate TBDF. Indeed, the issue is so sensitive that some governments, having embraced D.C. North & R.P. Thomas' (1973) dictum that the information game holds the key to success in a market economy, are taking draconian measures to buy and maintain a position in the «Information Economy» through direct restrictions on the transmission of computer data to other countries.

c) Behaviour of the Firm Under Conditions of Uncertainty

The theoretical behaviour of the firm under conditions of uncertainty has been well documented. Apart from behavioural differences due to variations in market structure (in the distinction between perfect and imperfect competition) the literature can also be usefully partitioned by the assumptions concerning the flexibility of decision making. That is, how much scope does a firm have to change the value of its ex ante decision variables if they are subsequently discovered to have been ill-chosen? All three possibilities are covered in the literature: perfect flexibility; perfect inflexibility and; a mix of rigidity and flexibility. In keeping with our own subsequent line of research our principle interest lies with the degree to which the behaviour of the risk-neutral firm is altered under conditions of uncertainty.

Oi (1961) covers the case of perfect flexibility within the context of perfect competition. Here the firm can postpone the production decision until the price is known. Essentially it maximizes profits in every short term period. While Oi does not carry his analysis to predictions of output levels he does show that under his special assumptions wider variability of price implies larger expected profits. We can, however, infer from his demonstration that changes in expected profits will exactly reflect changes in the expected utility of profits when the firm is risk neutral. That is, under Oi's assumptions uncertainty does not alter the behaviour of the risk neutral firm.

But perfect flexibility is likely the circumstance in very few cases. Sandmo (1971),[12], Mills (1959),[13] Leland (1972), Holthausen (1976),[14] and others have analysed the firm, under conditions of uncertainty, that includes an ex ante decision variable with no possibility of alteration after the true state of nature is revealed. Sandmo studies the perfect competitor while the others deal with firms possessing market power.

Leland (1972) shows it is only for the case of monopolists, facing random demand, that set quantity and those that set price but have constant marginal costs that the results coincide with the risk neutral perfect competitor's behaviour. Production is equal to the certainty equivalent point[15] when the firm displays behaviour that is risk neutral. This is fundamentally equivalent to Oi's the perfect flexibility case. However, when the firm must choose either price or price and quantity before the true state of nature is revealed then it will alter its behaviour even while maintaining a risk neutral attitude.[16] This, because of non-constant marginal costs so that the firm is assymetrically affected if it over or under prices. But, to the extent that there is a built-in rigidity to altering the ex ante decision variable after the true state of nature becomes known, it makes this type of analysis true for only very few cases.

The most realist scenario is provided by Turnovsky (1973). He deals with the perfectly competitive firm so that the randomness is in price and the firm must choose that quantity which it believes will coincide with the intersection of expected price and its marginal cost. The difference here, however, is that the firm does have some flexibility in altering its initial plans after the resolution of uncertainty. But, because initial plans were presumably developed with a view to minimizing costs, the alterations must have cost characteristics only at best as favourable as the original ones. (Appendix A gives a diagrammatic explanation). This is because a cost curve, with at least one fixed factor[17] shows the minimum cost of producing any output. Once this point is chosen and the firm gears up for production it means that as deviations occur more will have to be payed for «brush-fire» hiring or firing of variable factor while the fixed factor is used more or less intensively than desirable.

The relevant result in Turnovsky's analysis is that if marginal profit increases by less than it falls when the ex post price is higher than the expected price, then the firm will plan to produce less than the inflexible risk neutral case. This is intuitive. It occurs when the drop in marginal costs is quite slow with declining production so that the firm is left with rapidly declining profits. That is, the firm would rather plan to be at a point where it has to decrease its production plans by very little since price is falling rapidly relative to marginal cost.

For our model we have chosen a variation on Turnovsky's theme. Due to potential problems with empirical verification and data collection we discard the cost function as a measure of flexibility and develop an oligopoly type model with random demand. In this scheme, if the firm produces more than its ex post market share then it must sell its surplus at a loss. The consequence is that while a firm may produce more or less than the expected value of demand, those firms with less flexibility to dispose of surplus production, as embodied in the severity of the losses they would incur if they over produce, will produce less. It turns out that producing less due to lower flexibility also implies they will purchase less information. To the extent that less flexibility of action (T. Marschak & Nelson (1962)) implies a lower value of information, this is a plausible outcome. The presence of these information flows, in our model, also suggests an organizational setting for the Turnovsky flexibility notion, whereby the firm optimizes over a series of short runs, buying information before each point where plans can be altered.

To the extent that our model is characterized by risk neutrality, imperfect competition and constant marginal costs we should expect that behaviour will remain unaltered when we introduce uncertainty. However, unlike existing studies on the behaviour of the firm under uncertainty, the probability distribution of demand facing the firm, in our model is dependant upon the acquisition of positive cost information. That is, production decisions in our model will coincide with those in existing models if and only if the firm acquires perfect information that completely specifies the random variable. It is in this regard that our model is more realistic than existing studies. All other models, in assuming known distributions must also be making the implicit assumption that perfect information has somehow been acquired. While the existence of the TBDF phenomenon shows that firms are indeed demanding vast quantities of information there is nothing to suggest that it is even close to perfect. Thus two identical firms facing identical distributions of demand will produce different quantities of output if they acquire different amounts of information. This type of divergence can easily be envisaged if both firms face different information acquisition costs.

The literature survey has examined some relevant aspects of information theory as well as highlighted certain issues surrounding its relevance to communication theory and decision-making under conditions of uncertainty. The works dealing with such decision making in an uncertain environment normally abstract from information costs and concentrate on the risk-induced divergence in production and price levels from those expected in a world of perfect knowledge. In this literature we have seen the very important cases where under certain circumstances even the risk-neutral firm will alter its behaviour under conditions of uncertainty.

While Gould (1974) shows how information value may be measured through the concept of a pay-off function, Shannon and Weaver (1969) provide a usable relation between information value and uncertainty. Unfortunately, however, the literature dealing directly with TBDF does not suggest any useful framework within which to develop a rigorous analysis of the phenomenon. As such, our subsequent model has only the mathematical and theoretical structures of the uncertainty and information literature to draw upon.

FOOTNOTES

Chapter II

1. Operational flows deal with such bread and butter issues as ensuring that revenues exceed costs, returns are reasonable, that the foundation arrives at the work site before the labour and material for interior finishing, and so on. Tactical activities involve exception reporting and variance analysis and strategic activities include forecasting and modelling.

2. Hey (1979,29) explains this view in more detail.

3. See Welch (1980).

4. Hudson (1982) and Saunder (1982) also express a similar view that a communications link is a necessity for development, although they cover the broader issues of social services and health care delivery.

5. These include, for example, the international symposium in Geneva 1978, the OECD studies by Hughes & Sasson (1980) (and Bergendorff 1982), the article by Saito, Inose and Kageyama (1983), none of which go beyond the narrative stage.

6. See Saito, Inose and Kageyama (1983,92).

7. See Litvak & Maule (1980), Hughes & Sasson (1980), Antonelli (1981).

8. Vertical integration for higher profits through better information is sufficient but not necessary. The upstream firm can appropriate the benefits of better information by simply giving it to the downstream firm. Arrow is viewing the situation in terms of market failure, as in Spence (1975), where non-market institutions, such as internalization of an externality, through merger, replace the market.

9. Arrow (1974) discusses the implied linearity restrictions when using the Shannon measure of information value.

10. Marschak (1968) points out that the Shannon measure of information value ignores the other costs of «inquiring» and «deciding».

11. De Groot [9] has a measure similar to Shannon's. Information value is

$$1\text{-max}\ (\rho_1,\ldots,\rho_n)$$

so that, its highest value obtains when all events are equiprobable.

12. Sandmo shows that, even with perfect inflexibility the risk neutral perfectly competitive firm does not alter its behaviour.

13. Mills' analysis is also covered by Leland (1972) and is discussed in the text.

14. Holthausen arrives at the same conclusions for the risk neutral firm as Leland (1972) except that his choice variables include labour inputs as a function of the capital stock.

15. This point is on the demand curve which would result if the firm knew price would equal the expected value with certainty for all levels of demand (Leland [22]).

16. These arguments are based on work by I. Horowitz, «Decision Making and the Theory of the Firm», New York, 1970.

17. The inclusion of a fixed factor, while making it easier to accept built in inflexibility, is not strictly necessary for higher costs. Overtime wages or layoff premiums are sufficient to guarantee these higher costs.

III - THEORETICAL MODEL

To explain the Transborder Data Flows phenomenon we have first observed that the non-financial MNE is responsible for a substantial proportion of these flows. As such we proposed looking at TBDF as an input to the production activity. In this section we will, therefore, develop a theoretical optimizing model whose choice variable is information.

a) Notation

$\bar{P}$:	the constant unit price of output when $z \leq \bar{q}$
$\bar{q}$:	actual demand
z:	actual production
q:	random demand
$P(\bar{q}-z)$:	the over production demand curve
c:	constant unit cost of output $\forall z$
$a=\bar{P}-c>0$:	constant unit profits for output when $z \leq \bar{q}$
$m=P(\bar{q}-z)-c=m(\bar{q}-z)\leq 0$:	variable loss function when $z > \bar{q}$
Subscript 0:	indicates initial levels of all variables
q_1:	lowest possible level of demand
q_2:	highest possible level of demand
y:	age of information
ρ_{ir}, $r=1,2$:	the probability, which increases as information y becomes newer when $r=2$ and

	decreases when r=1, that q_i will obtain, i=1,2.
$h(y)$:	the cost of information function
P_w:	an index of information prices
$P_w = P_1^e P_2^h$:	P_1 is the equipment price, P_2 is the human capital price.
d:	the difference between production and actual demand
MR:	marginal revenue
MC:	marginal cost
β:	the productivity of information
$\alpha=1-\beta$:	
$\delta_r=1,0$:	as r=1,2
γ:	the slope of the loss function
$\bar{\gamma}$:	the average, over several countries, loss function
$\hat{\gamma}\leq 1$:	an index of loss functions
T:	the importance of trade relative to a country's output

b) <u>The n state of nature case</u>:

The model is based on a profit maximizing firm (presumably a MNE) that faces random demand and must make two decisions: whether to change production levels from z_0 to z;[1] and how much information to purchase in order to minimize the risk of making the wrong production decision. This is similar to the notion developed by Dudley (1983) where an importer must decide whether or not to change import levels from the same supplier with the attendant risks of random price and too great a dependancy on a single exporter. However, unlike our model, Dudley abstracts from the information input cost to the decision process.

If we begin with a firm in an oligopolistic environment that has matured to the extent where the firm has a market which it can supply at fixed price $\bar{P}$ and constant marginal cost, c, then the firm has a constant unit profit, a, for each unit of demand it sells. The firm, however, faces periodic variation in its demand and thus faces the risk that the previous period's production level, which was presumably optimal, will no longer be suitable. There are three possibilities: the firm overproduces, underproduces, or produces to exactly meet demand.

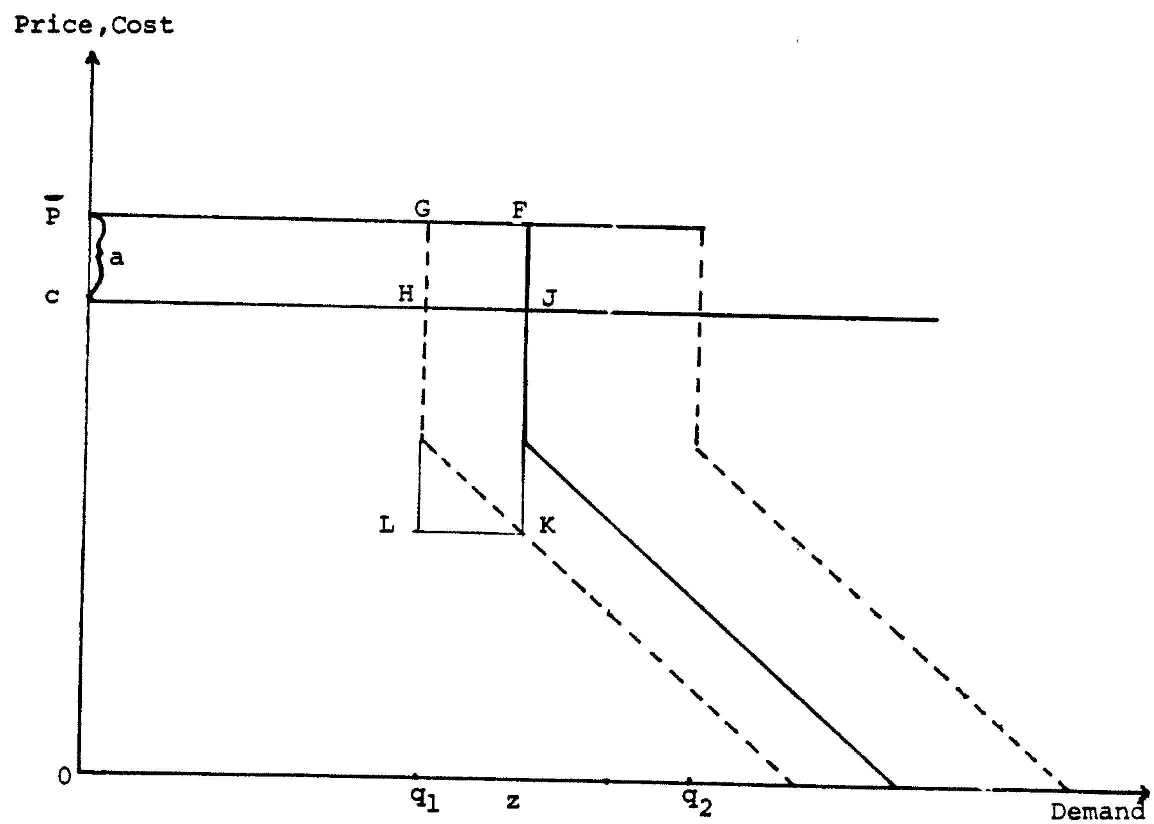
If we assume that the firm has a very simple internal flagging mechanism, whereby any unsold product, from a given production run, at a given date, is sold at a lower price then we can impose an upward price rigidity. That is, for a given production run, the firm will never raise price, but will lower it in order to rid itself of unsold goods.[2] Further since the firm is competing in an oligopolistic environment, selling a highly substitutable product, it must lower its price below cost. This phenomenon is seen in the discontinuous demand curve of figure II.

The problem for the firm is to guess at the position of its demand. If demand turns out to be weak, then its demand, at price $\bar{P}$, will extend only to q_1. Production up to q_1 will result in a per unit profit of $a=\bar{P}-c$, where c is per unit cost, which is constant. Production beyond q_1 will have to be sold at price $P(q_1-z)=P(d)$ and per unit profit for production beyond q_1 is $m(d)=P(d)-c<0\ \forall d<0$. We can read these profits off the figure as $\bar{P}$cHG-HLKJ. On the other hand, if demand is strong then at price $\bar{P}$ the firm will be able to sell q_2. Production up to q_2 will result in profits of aq_2 so that for $z \leq q_2$ profits will be az. From the figure this is equal to the area $\bar{P}$cJF. Once again, the <u>intuitive</u> notion is that the market is highly segmented and price competition will result in losses for all. However, the exact demand for any firm, at price $\bar{P}$, is unknown. This implies that, in the face of steep inventory costs (i.e. it is expensive to expand inventories beyond some, say, normal size), an overestimate of demand will force the firm to lower P in an attempt to dispose of surpluses, willing even to accept a loss of m(d) per unit.

To the extent that the firm's ex ante choice variables are price and quantity, this model has some similarity to those of Leland (1972), Horowitz (1970) and Mills (1959). They show that

FIGURE II

THE FIRM'S DISCONTINUOUS DEMAND CURVE



even under a risk neutral regime, when price, or both price and quantity are the ex ante choice variables, under imperfect competition, in the presence of uncertainty, then production will be different from that which would maximize expected profits for the quantity setting firm. The direction of difference depending on the shape of the cost function. If the firm sets only price then production for the risk neutral firm will not be effected under conditions of constant cost. However, as Leland (1972) and Mills (1959) show, for price - quantity setting behaviour, much like our model, if actual demand exceeds output only the amount produced will be sold. However, when actual demand is less than output then only the lesser amount will be sold, at the preselected price. To the extent that only part of the production is sold, their's is a disequilibrium model, unlike ours which has a mechanism to dispose of surplus production.

Then, with m=m(d) representing that loss function which depends upon the difference, d, between actual demand and production (i.e. -d = overproduction), we have an expected profit function,

$$E\pi = E[az + (z-q)m] \qquad (1)$$

$$m = o \quad \text{for } z \leq q$$

$m = m(d) < 0$; $d - (q-z)$ otherwise

$m' > 0$; $\partial m/\partial z = -m'$

Also, to minimize complexity, let $\underline{m''=0}$

At this stage (before going on to consider information), the firm's problem is to choose a level of production, z, which will maximize expected profits,

$$\text{Max. } E\pi(z) = E[az + (z-q)m]$$

$$\frac{\partial E\pi(z)}{\partial z} = E[a+m - m'(z-q)] = 0$$

It may be useful to decompose m and m' into their price and cost components,

$$E[a+m-m'[z-q]] = E[\bar{P} + P(q-z) - 2c - P'\ [z-q]] = 0 \qquad (2)$$

where $P'' = 0$ and $P(q-z)=0$ for $q \geq z$. Then

$$\frac{E[\bar{P}+P(q-z)-P'[z-q]]}{2} = c \qquad (3)$$

so that we have the standard first order conditions where z is produced at the point where E(MR)=MC. The second order conditions, as usual, require that

$$E(MR') < MC'$$

Where will the firm produce with respect to the expected value of demand and what will alter that choice? From (2) we can solve for z,

$$z = \frac{a + Em}{m'} + Eq$$

Since m''=0, let us pre-empt the empirical model of Chapter IV and substitute a linear form for m,

$$m = \gamma\,(q-z)$$

so that

$$z = \{(a+\gamma Eq-\gamma z)/m'\}+Eq$$

$$z = (a/2\gamma)+Eq \qquad (4)$$

so that the steeper is the loss function, m the closer is production to the expected value of demand. In this form we have a situation where the firm will always produce an amount $z \geq Eq$. This is a modified version of Leland's (1972) constant cost, risk neutral case where the firm never hedges and produces at the expected value of demand. Thus, had we not used a discontinuous curve, then constant profit margins would not exist and we would have $z = Eq$. The modified result that the firm will always produce at $z \geq Eq$ stems from the assymetry of constant losses equal to a from underproducing and variable losses whose rate is reflected in m, from overproducing.

Now, given that Eq depends upon some probability distribution over the n states of nature characterized by $\rho_1 \ldots \rho_n$,

$$Eq = \sum_{i=1}^{n} \rho_i q_i$$

and also that m is a function of q, then the choice of z depends upon the probability distribution of demand ρ. We can illustrate this graphically in the two state of nature, n=2, case. First, recall that when $q \geq z$ then $m = 0$ and from (1) profits are

$$\Pi_2 = az$$

and if production exceeds demand then

$$\Pi_1 = aq_1 + (z-q_1)m$$

so that

$$E\Pi = \rho_1 [aq_1 + (z-q_1)m] + \rho_2 az$$

and $$\frac{\partial E\Pi}{\partial z} = \rho_1 [(-m')(z-q_1) + m] + \rho_2 a = 0 \qquad (5)$$

and $$-\frac{\rho_2}{\rho_1} = \frac{(-m'(z-q_1)+m)}{a} = \frac{\partial\Pi_1/\partial z}{\partial\Pi_2/\partial z} \qquad (6)$$

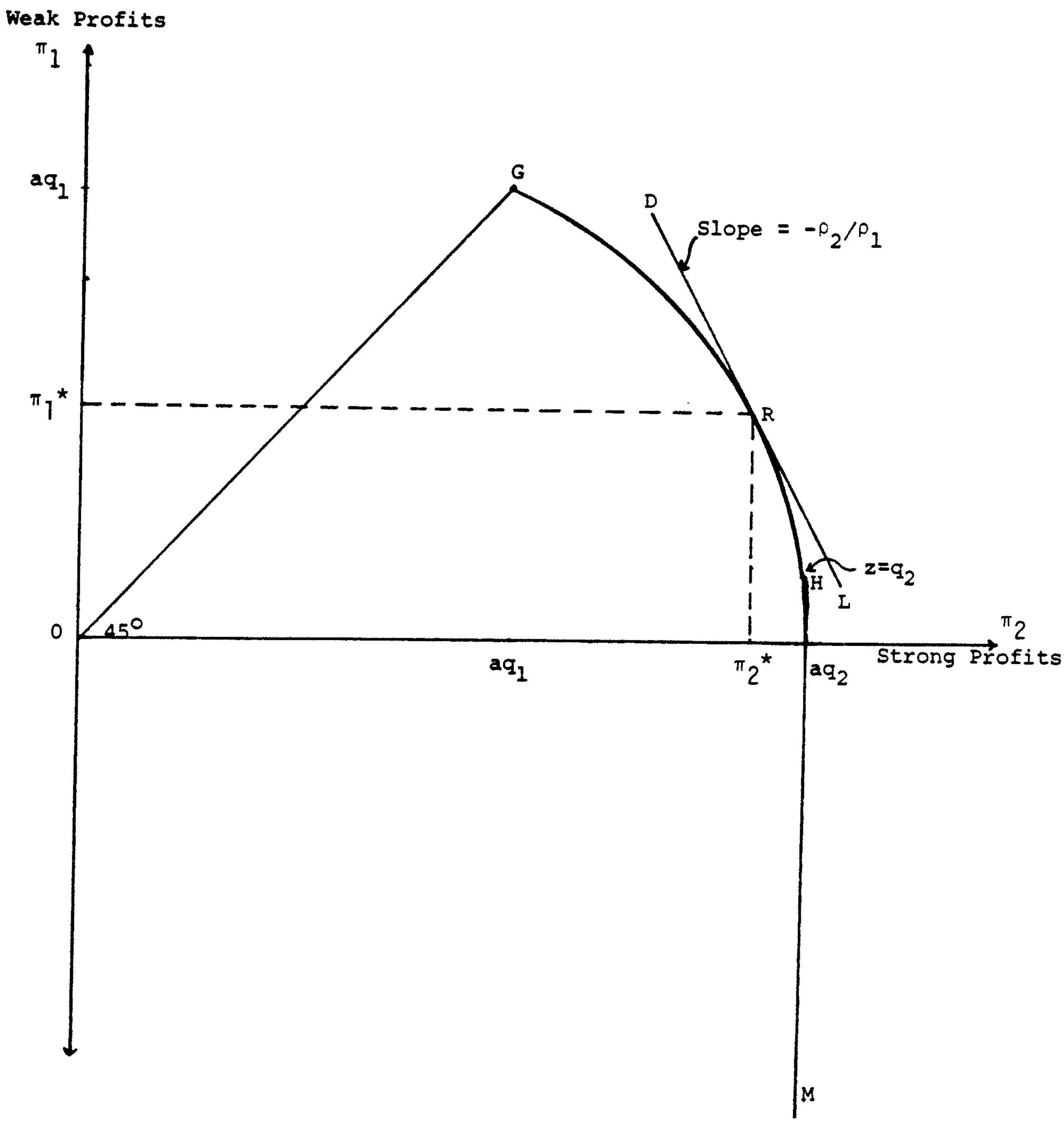
and $$\partial \left[\frac{\partial\Pi_1/\partial z}{\partial\Pi_2/\partial z}\right] /\partial z = \frac{m''(z-q_1) - m' - m'}{a} = \frac{-2m'}{a} < 0$$

recalling that $m'' = 0$ so that a marginal tradeoff between weak and strong profits, as z changes, is convex with the degree of curvature being determined by the slope of the loss function, m'.

In figure III we see that the slope of the relative probability distribution, characterized by (ρ_1, ρ_2) determines the level of profits for each possibility, given the curvature of $(\partial\Pi_2/\partial z) / (\partial\Pi_1/\partial z)$. These profit levels can then be used to

FIGURE III

THE PROFIT FRONTIER



determine the level of z. The curve $E\Pi$ can be considered as the «profits frontier» where the curvature is based on m=m*. Thus any point on $E\Pi$ gives the maximum expected profits from the various combinations of weak and strong profits, Π_1 and Π_2, respectively, as z changes. Moving from right to left on the curve, the level of z is declining and so is the level of Π_2 while Π_1 increases. This is of course true only to the point where $z = q_1$, then both Π_1 and Π_2 begin to decline at the same rate along the 45^o ray, OG. This rate is of course equal to a. A similar story can be told when we move from left to right, except that the line MH, is no longer at 45^o and is mainly in the fourth quadrant. As can be seen, as ρ_2, the probability of strong demand increases and DL becomes steeper, the point of tangency will move further right and Π_2 will increase as production, z, increases. These are, of course, results we would expect. And only the magnitude of the changes will be different with another m=m**, but the direction will remain the same. For example, if the loss function becomes steeper, i.e. m' grows, then the frontier will flatten out and less z will be produced for each (ρ_1, ρ_2) distribution. Once again this is normal because the ante goes up as the degree of loss increases with a steeper loss function. It becomes that much more difficult to dispose of surplus production.

Finally, the relative probability curves, $(-\rho_2/\rho_1)$ are also isoprofit curves so that given the value of $(-\rho_2/\rho_1)$ the problem becomes one of choosing the highest isoprofit curve tangent to the profit frontier.

Why would the firm want to change its level of production if it has already chosen an optimum z, say z_0, in the previous period? It would do so either because the probability distribution of demand and/or the values of strong or weak demand had changed giving a new Eq. If we assume that q_1 and q_2 remain constant, and allow the distribution to vary, then we know that the firm will produce z, rather than z_0 because $E\pi(z)>E\pi(z_0)$ when $E\pi(z_0)$ is evaluated under the new probability distribution.

Now, in order for the probabilities to have changed new information must have been acquired. Since information is not costless it is apparent that the firm must, besides making a decision on z, also make a decision concerning the level of information acquisition. If y represents the age of information, where a smaller y represents newer information, then $y < \infty$ implies probability altering information. This means that the value of $E\pi(\tilde{z}|y=y_0 < \infty) - E\pi(z^*|y=y_0 < \infty)$, where $\tilde{z}$ is optimal for the true probability distribution conditional upon information $y = y_0$ and z^* is optimal for the maximum uncertainty case, is really an information «payoff function», because we are comparing expected profits under the new probability regime, $E\pi(\tilde{z}|y=y_0 < \infty)$, with expected profits when the optimal z under another probability distribution z^* is evaluated with the new distribution, $E\pi(z^*$ $y=y_0<\infty)$. The firm's choice of either $\bar{z}$ or z^* can be said to depend upon the probability distribution, $z = z(\rho)$.

This concept of a payoff function is substantially the same as that described by Gould (1974). But because of its central importance to this study, it will be useful to look at it somewhat more closely. We will show that all the gains from information can be evaluated by using Gould's payoff function. That is, evaluating the loss that the firm would have incurred had it not acquired information and produced a quantity z to maximize $E\pi$ with the wrong probability distribution. In order to simplify the proofs and graphics we will also establish z as a function of Eq, $z=z(Eq) = \mu$ (for notational convenience).

The gains from information can be broken down into two parts. First of all there is some long-run concept of gain whereby the firm expects that good and bad times will occur with equal frequency so that it will compare these expected profits with those it may be able to earn when information is acquired to reveal the true mean. Depending upon the form of the firm's profit function these information enhanced profits may be greater than, less than or equal to expected profits under maximum uncertainty. This can be demonstrated by reference to our model. From (5)

$$z = \frac{\rho_2 a}{\rho_1 m'} + \frac{m}{m'} + q_1$$

and from $E q = \rho_1 q_1 + \rho_2 q_2$

so that $\rho_2/\rho_1 = [Eq/\rho_1) - q_1]/q_2$

we get

$$z = \frac{a}{m' q_2} \left[(Eq/\rho_1) - q_1 \right] + \frac{m}{m'} + q_1$$

$$\frac{\partial z}{\partial Eq} = \frac{a}{m' \rho_1 q_2} > 0$$

so that $z = z\,(Eq);\ z' > 0$

Then if we let

$$E\pi(\tilde{z}|y < \infty) = E\pi(\tilde{z}(Eq)|y < \infty) = E\pi(\tilde{\mu}|y < \infty)$$

represent the expected profits with information, from (5)

$$\frac{\partial^2 E\Pi}{\partial z^2} = \frac{-2\rho_1 m'}{a} < 0 \qquad (7)$$

so that from (7) we can infer

$$\frac{\partial^2 E\Pi}{\partial Eq^2} < 0$$

which means that over the range of $q_1 \leq Eq \leq q_2$ where

$$Eq = q_i \text{ as } \rho_i = 1; \quad i = 1,2$$

the function $E\pi(\mu|y<\infty)$ is concave with respect to changes in the probability distribution. But if we let

$$E\pi_1(\tilde{\mu}_1|y < \infty)$$

represent expected profits when information, y, pushes the probability of strong demand down, and

$$E\pi_2(\tilde{\mu}_2|y < \infty)$$

represent expected profits when information, y, pushes the probability of strong demand up, then, by Jensen's inequality,

$$E[E\pi(\tilde{\mu}|y = y_o < \infty)] < E\pi(\mu^*|y = \infty) \ \forall \ Eq$$

where, at $y = \infty$, $\rho_1 = \rho_2 = .5$, the maximum uncertainty point.
and $G_1 = E[E\pi(\tilde{\mu}|y = y_0 < \infty] - E\pi(\tilde{\mu}|y = \infty) < 0$

This means, that on the basis of differences between information enhanced expected profits and long run expected profits with maximum uncertainty, the firm will not buy any information. But, as we shall see, another, second part of the information gain always ensures that some information will be acquired.

This second part of the gain can be viewed rather as the loss not incurred by not maximizing expected profits under an erroneous probability distribution. Without proof, we can state that, in general, if the firm chooses μ' to max. $E\pi(\mu')$, given a probability distribution $\rho' = (\rho'_1, \rho'_2)$, then $E\pi(\mu') < E\pi(\mu'')$ when the probability distribution changes to $\rho'' = (\rho''_1, \rho''_2)$.[3] In this regard, the second gain would come from choosing production to maximize expected profits under the true probability distribution. Thus, if we let

$$E\pi(\mu^*| y < \infty)$$

represent the expected profits of having chosen μ^* regardless of the new probability distribution, then

$$G_2 = E\pi(\mu^*|y = \infty) - E[E\pi(\mu^*|y = y_0 < \infty)]$$

is the second part of the gain. Recalling that G_1 represents the first part of the gain, we can show that

$$G_1 + G_2 > 0 \quad \forall \text{ Eq}$$

If μ^* maximizes $E\pi(\mu)$ at maximum uncertainty where $y = \infty$ then $E\pi(\tilde{\mu} | y < \infty) = E\pi(\mu^* | y = \infty)$ only at the maximum uncertainty point where $y = \infty$, (i.e. where information reveals that the probabilities are indeed $P_1 = P_2 = .5$) otherwise, when $E\pi(\mu)$ is concave with respect to the probability distribution, $E\pi(\tilde{\mu}|y < \infty) > E\pi(\mu^*| y < \infty) \; \forall$ Eq. That is, it is everywhere else below $E\pi(\tilde{\mu}| y < \infty)$. Then, by Jensen's inequality,

$$E[E\pi(\mu^*| y < \infty)] < E[E\pi(\tilde{\mu}|y < \infty)] \; \forall \text{ Eq}$$

From this it follows that $G_1 + G_2 > 0 \; \forall$ Eq.

We can see this by substituting for G_1 and G_2 to get the total gain (TG) from information

$$TG = E\pi(\mu^*|y{=}\infty) - E[E\pi(\mu^*|y{=}y_0{<}\infty)] + E[E\pi(\tilde{\mu}|y{=}y_0{<}\infty)] - E\pi(\mu^*|y{=}\infty)$$

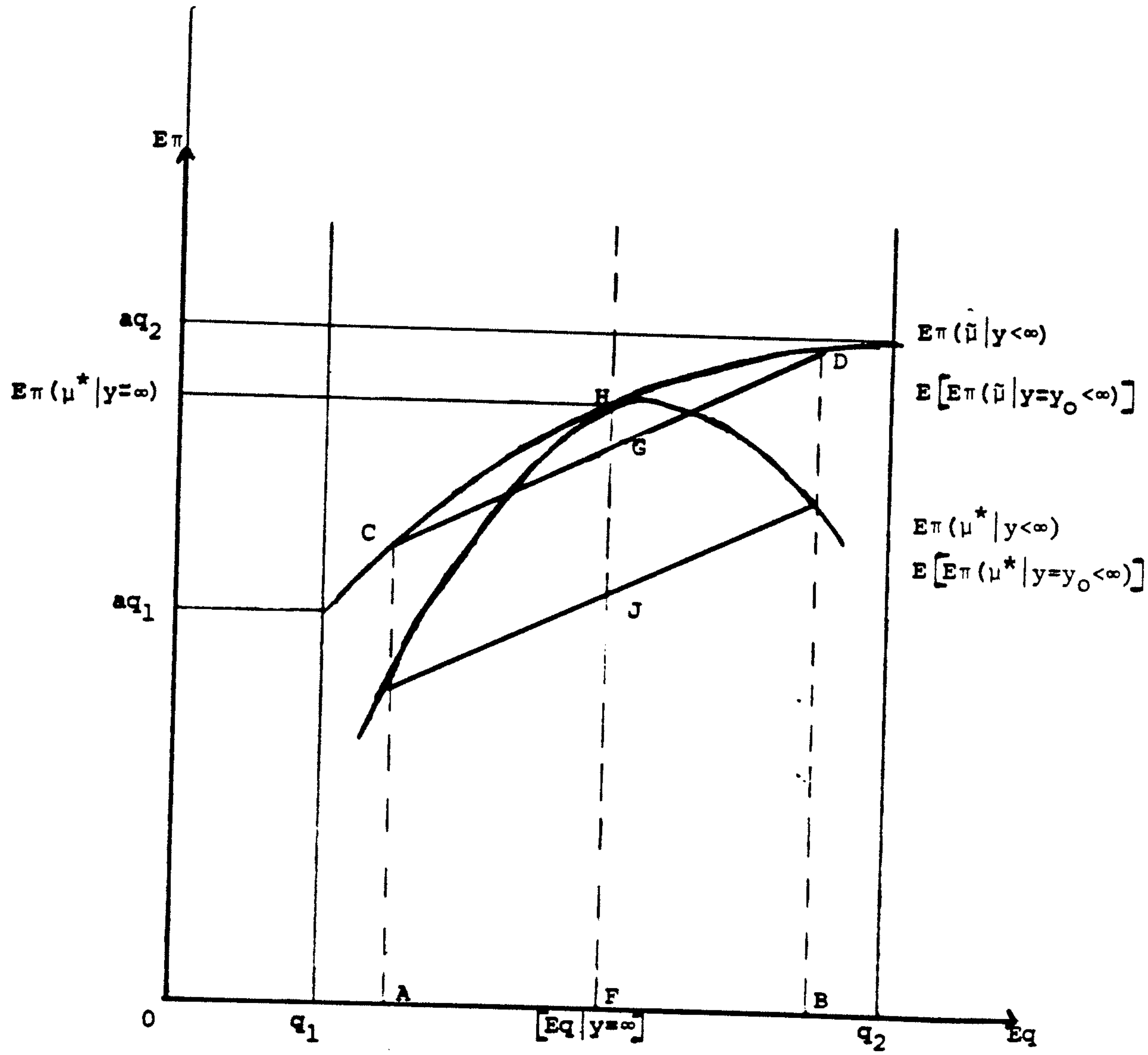
$$TG = E[E\pi(\tilde{\mu}|y{=}y^0{<}\infty) - E[E\pi(\mu^*|y{=}y_0{<}\infty)] > 0$$

This implies that the total gains from information can be measured by reference to conditional probabilities only. The fact that in the long run the unconditional probabilities are known is irrelevant to the evaluation of information returns. This result concords with the notion that the firm is interested in the sum of its future profit stream and should be concerned with maximization over as many short run periods as possible.

Figure IV illustrates the above behaviour. The firm purchases information $y = y_0$ and has demand sometimes at point A and sometimes at point B. Expected profits will lie somewhere along the straight line CD, which as can be seen is everywhere below the concave portion CD. Thus when Eq is at point F then expected profits with information is less than expected profits with no information. That is point H is higher than point G. But, expected profits under a probability distribution with information $y = y_0 < \infty$, and production μ^* where μ^* is optimal for $E\pi(\mu^* | y=\infty)$, are at J so that the total gain from information (say, net of information cost is G-H+H-J = G-J. That is, the difference between maximum expected profits with respect to the true probability distribution and suboptimal expected profits due to production with respect to the wrong probability distribution.

If we let TG = $E\pi(y)$, then the firm's problem is to choose a y to maximize $E\pi(y)$ and we can write out the full problem

FIGURE IV



$[Eq_1 | y=y_o<\infty] = \rho_1 q_1 + \rho_2 q_2$

$[Eq_2 | y=y_o<\infty] = (1-\rho_1) q_1 + (1-\rho_2) q_2$

$\rho_i = \rho_i(y)$

using our original notation (without yet considering the direction in which information actually affects the probabilities),

$$\max.\ E\pi(y) = E\pi(z^{*}(\rho(y))) - E\pi(z^{*}_{0}(\rho(y)));\ \frac{\partial z^{*}_{0}}{\partial y} = 0 \qquad (8)$$

where, if $\rho \neq \rho_0$ then $E\Pi(z^*(\rho(y))) > E\Pi(z^*_0(\rho(y)))$ where z^* and z^*_0 are expected profit maximizing levels of production under the ρ and ρ_0 distributions, respectively.

As noted earlier, these results are, in general, true. They are invariant with respect to the level of uncertainty by either the Shannon (1969) or De Groot (1970)[4] definitions. A z chosen under a distribution $\rho(\rho_1 \ldots, \rho_n)$ cannot also, ceteris parebus, be chosen under a distribution $\rho(\rho'_1 \ldots, \rho'_n)$ when $\rho \neq \rho'$ even if $\rho'_i = 1/n,\ \forall i$, signifying the greatest degree of uncertainty. This may appear a bit odd, particularly in light of the description given by Hey (1979), «In very general terms, risk and uncertainty can be described as lack of information: with complete information, appropriately defined, one would have complete certainty.» And while we do argue here that MNE's acquire information in order to concentrate the relevant probability distributions about a single point, it should nevertheless be noted that there is really nothing so far in our description which ensures the direction of change of probabilities.

In so far as probability distributions will change only through the application of information, i.e. $\rho = \rho(y)$, we can add a cost of information function $h(y)$, $h'(y) < 0$,

$$E\Pi(y) = E\Pi(z^*(\rho(y))) - E\Pi(z^*_0(\rho(y))) - h(y)$$

where z^*_0 is optimal production for $\rho_0 = \rho(y_0)$, the probability based on last period's timely information. Setting up the problem in terms of z and q we choose y to maximize,

$$E\Pi(y) = E[az + (z-q)m] - E[az_0 + (z_0-q)m_0] - h(y)$$

In this model there are some interesting consequences of defining risk strictly in terms of the slope of the loss function, m. As we saw earlier, the larger it becomes the lower is production, z. However, this implies that with non-decreasing information costs there is less product with which to create a large enough positive payoff to greater information. The upshot is that a larger m' implies less information acquisition. Using the distribution of q as a measure of risk, however, does allow us to marry our model to intuition. Here we invoke Leland's (1972) «principle of increasing uncertainty» (PIU), which tells us that the larger are revenues the higher is the risk, so that the higher the level of production, the more information will be acquired.

$$\frac{\partial E\pi(y)}{\partial y} - E[2aq'-2m'q'(z-q) + m'q'(z-q) + 2mq'-mq'-m'_0q'(z_0-q) + m_0q'] - h'(y)$$

where $q' = \partial q/\partial y$;

so that our first order condition for maximum payoff information is;

$$E[q'(2a+(m+m_0) - (m'(z-q) + m_0'(z_0-q))] = h'(y) \qquad (9)$$

where the left hand side, the marginal payoff to information must be negative, because $h'(y) < 0$.

c) The Two State of Nature Case:

It will be useful to recast the previous analysis in a two state world, strong or weak demand. This will help us to both fix ideas and also to develop a testable model. In this framework the firm still has to choose a «best bet» z, but now there are only the two possibilities, weak and strong demand.

i) Weak Demand

If demand is weak then profits are a combination of positive profits up to q_1 and the loss due to the disposal of surplus production $(z-q_1)$ at below cost prices. The firms profits are,

$$\Pi_1 = aq_1 + (z-q_1)m(d) \ ; \quad m(d) < 0$$

ii) Strong Demand

In this case we count only the profits of selling all the firm's production at positive unit profit, a.[5] Its profits are,

$$\Pi_2 = az$$

Combining weak and strong demand with the probability distribution characterizing demand the firm's expected profits are,

$$E\Pi(z) = \rho_2 az + \rho_1 [aq_1 + (z-q_1)m(d)]$$

Now, with $dq_{it}/dt = 0 \ \forall t$ and $i=1,2$, the only way that $E\Pi$ can possibly differ from $E\Pi_0$ is if the ρ_i change. Presumably then this new distribution of q_1 based on updated probabilities is due to new information. z_0 is the solution of the problem

$$\text{Max } E\Pi_0(z) = \rho_{2_0} az + \rho_{1_0} [aq_1 + (z-q_1)m(d)]$$

Then z will be chosen if and only if

$$E\Pi(z) - E\Pi_0(z_0) > 0$$

Because information is not generally free, for any $y < \infty$, i.e. information less than infinitely old, $h(y) > 0$. Indeed, $h'(y) \leq 0$ so that information cost is here assumed to be non decreasing.

The firm must make three decisions:

(a) how much information should it purchase;

(b) what is the optimal production, z, under the information updated probability distribution of q and;

(c) should it change production levels from z to $z_0 \neq z$.

As regards the probabilities themselves, we are on pretty safe ground when we relate them directly to the information variable. Bayesian posterior probabilities, for example, are based on information about event i in order to calculate the probability of event j.

In our two state of nature world we let

$$\rho_1 = \rho_1(y), \quad \rho_2 = \rho_2(y)$$

and since $\rho_1 + \rho_2 = 1$ then

$$\rho'_i \geq 0 \text{ as } \rho'_j \leq 0 \quad \text{for } i,j = 1,2,\ i \neq j$$

Information can of course affect ρ_i either positively or negatively so that we can define

$$\rho_{i2} = \rho_{i2}(y) \text{ where } \rho_{i2}' < 0 \qquad i = 1,2$$

and $\rho_{i1} = \rho_{i1}(y)$ where $\rho_{i1}' > 0 \qquad i = i,2$

We can also avoid some considerable complexity, without any loss of generality, by letting our function have the property that,

$$\rho_{ir}'(y) = \rho_{jr}'(y); \quad \forall y,i,j = 1,2;\ i \neq j,\ r = 1,2$$

In addition we let $\rho_i(\infty) = 0.5$.

That is, the probability function is symmetric about the point $\rho_i = 0.5$ and $y = \infty$. This is the Shannon (1969) notion of maximum uncertainty when all probabilities are equal. Recall that it tells us that a message which points to state i with certainty has a value of ln $(1/\rho_i)$. Clearly, the lower is ρ_i the more valuable is the information. The expected value of information is

$$E(VI) = -\Sigma\rho_i \ln(\rho_i)$$

and, in the two state case E(VI) has a maximum value of ln(2) when $\rho_1 = \rho_2 = 0.5$. This notion has been used by Arrow (1974) and J. Marschak (1968).[6]

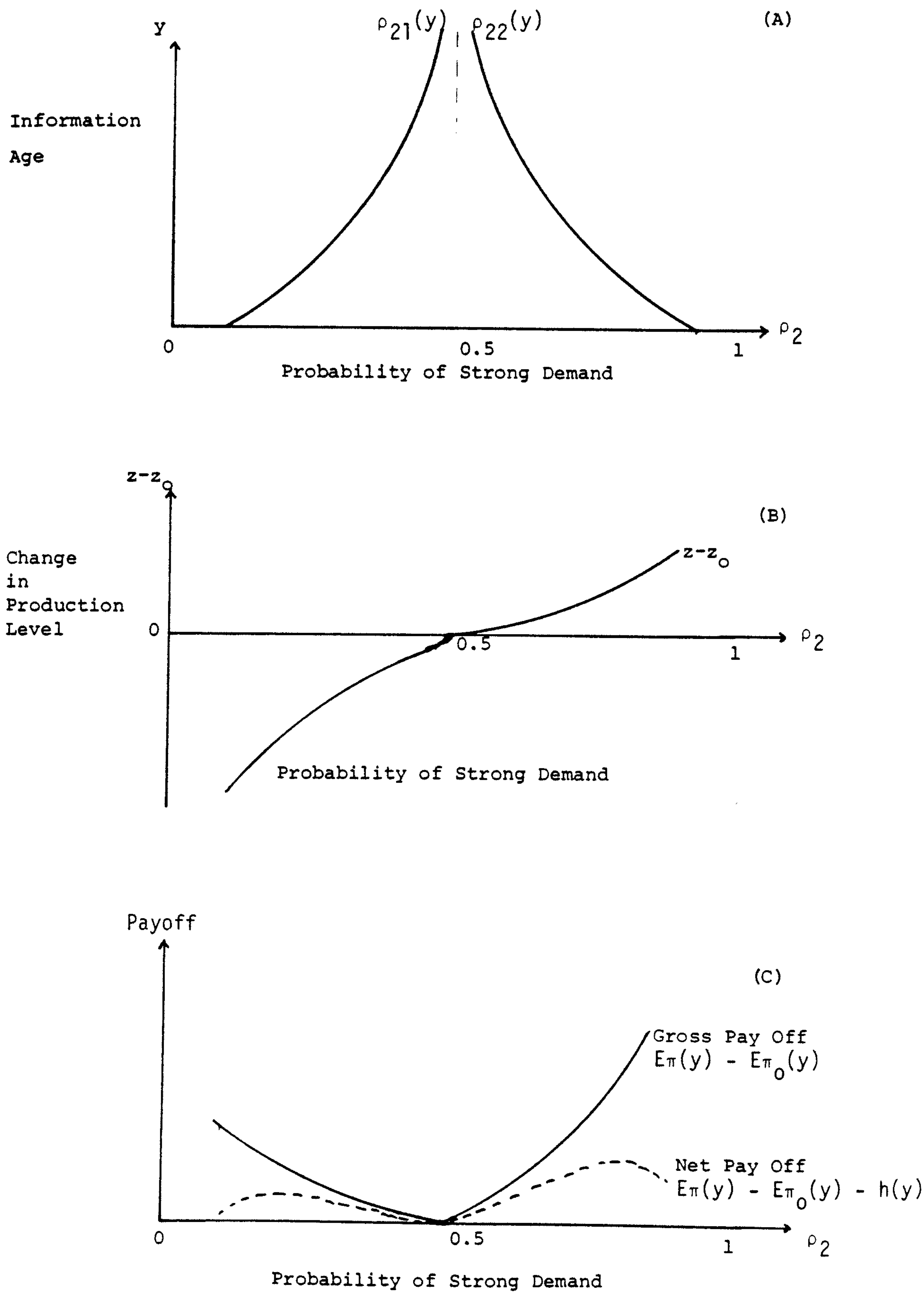
Figure V A shows how information age may impact on the probability distribution of demand. It depicts a symmetrical function that has information progressively concentrating ρ_2 at zero or one depending upon whether $\rho_2'(y) \gtrless 0$, respectively.

As regards the choice of z, with our assumptions of $(dq_{it}/d_t) = 0$, it depends directly on the probability distribution, and can therefore be cast as a function of information,

$$z = z(\rho(y)) = g(y)$$

Recalling that z_0 is a production level that would be chosen in complete ignorance with infinitely old information so that it is optimal for $\rho_1 = \rho_2 = 0.5$, Figure V B relates the difference $(z-z_0)$ to information based probabilities. As can be seen $(z-z_0)$ intersects the abscissa at $\rho_2 = 0.5$, indicating no

FIGURE V


(A)
y
Information
Age
$\rho_{21}(y)$
$\rho_{22}(y)$
0
0.5
1
ρ_2
Probability of Strong Demand
(B)
$z-z_o$
Change
in
Production
Level
0
0.5
1
ρ_2
$z-z_o$
Probability of Strong Demand
(C)
Payoff
Gross Pay Off
$E\pi(y) - E\pi_o(y)$
Net Pay Off
$E\pi(y) - E\pi_o(y) - h(y)$
0
0.5
1
ρ_2
Probability of Strong Demand

change in production levels. Now, it should be understood that this does not necessarily mean that production z_0 is a choice without any information, but, rather, in the absence of any information it is the amount that would have been chosen, and should properly be the point of comparison. We could include provisions for calculating the gain not only of choosing information based production but also that of adjustment cost savings by not going to ignorance based production from some previous information based level. Such an approach would introduce considerable complexity without adding to the analysis. We are saying that without any updated information, a firm will produce according to last period's probability distribution which is based on even probabilities.

Figure V C, relates the expected gross payoff for the possibilities, $\rho'(y) \gtreqless 0$, to the information based probability distributions. In addition, by assuming some non-decreasing cost of information function, $h(y)$, where $h'(y) < 0$ and $h''(y) \geq 0$, the net payoff curve can also be traced. At $\rho_2 = 0.5$ there is no information acquired and there is consequently no information payoff.

Finally we note that $\partial z/\partial y$ must be able to account for information that affects the probabilities of strong and weak demand in two ways. Since an increase in the probability of strong demand, ceteris paribus, will induce the firm to choose a larger z,

$$\frac{\partial z}{\partial y} \gtreqless 0 \text{ as } \rho'_2 \gtreqless 0$$

We are now in a position to formulate the firm's problem entirely in terms of information acquisition. While the firm is assumed to know the probability distributions $\rho_{i2}(y)$, $\rho_{i1}(y)$, it does not know which one will obtain. Thus if

$$E\Pi_i(z_0 | y<\infty) = \rho_{2i}(y)az_0 + \rho_{1i}(y)\ [aq_1+(z_0-q_1)\ m_0(d_0)] - h(y) \qquad (11)$$

$i = i,2$

$d_0 = (q_1-z_0)$; $\partial z_0/\partial y = 0$

and $$E\Pi_i(z | y<\infty) = \rho_{2i}(y)az + \rho_{1i}(y)\ [aq_1+(z-q_1)\ m(d)] - h(y) \qquad (12)$$

$i = 1,2$

$d = (q_1-z)$; $\partial z/\partial y \neq 0$

Then the firm wants to choose a y to

$$\text{Max. } E\Pi\ (y) = \rho_2\ [E\pi_2(z|\,y<\infty) - E\pi_2(z_0|\,y<\infty)] + \rho_1[E\pi_1(z|\,y<\infty) - E\pi_1(z_0|\,y<\infty)] - h(y) \tag{13}$$

where ρ_j is the probability that $\rho'_2 = \rho'_{2j}(y)$; $j=1,2$.

Substituting (11) and (12) into (13) the firm's problem is to choose y to

$$\text{Max. } E\Pi(y) = \rho_2\{\rho_{22}az_2+\rho_{11}[aq_1+(z_2-q_1)m_2] - \rho_{22}az_0-\rho_{11}[aq_1+(z_0-q_1)m_0]\} + \rho_1\{\rho_{21}az_1+\rho_{12}\ [aq_1+(z_1-q_1)m_1] - \rho_{21}az_0-\rho_{12}\ [aq_1+(z_0-q_1)m_0]\} - h(y)$$

The detailed derivation is in Appendix B. We only state the results here. By using the symmetry conditions

$$\rho'_{i2}(y) = -\rho'_{j1}(y)\ \forall y,\ i,j=1,2,\ i\neq j$$

and $\rho'_{ir}(y) = \rho'_{jr}(y)\ \forall y,\ i,j=1,2,\ i\neq j$, for $r=1,2$

also from $z_r = z_r(\rho_{2r}(y))$; $r=1,2$

$$z'_r = \partial z_r/\partial\rho_{2r} > 0 \quad \text{for } r=1,2 \tag{14}$$

then $$z'_r = z' \tag{15}$$

i.e. z' is independant of the direction in which information affects probabilities

so that $\partial z_r/\partial y = z'\rho'_{2r}$

and $z'\rho'_{22} = -z'\rho'_{21}$

or $\partial z_2/\partial y = -\partial z_1/\partial y \quad \forall y$

That is, the symmetry of probabilities extends to the production variable. We can now write the first order conditions as,

$$\rho'_{22}\{a[(\rho_2 z_2-\rho_1 z_1)+z'(\rho_2\rho_{22}-\rho_1\rho_{21})] - [\rho_2(z_2-q_1)m_2-\rho_1(z_1-q_1)m_1]$$

$$-z'(m'[\rho_2\rho_{11}(z_2-q_1)-\rho_1\rho_{12}(z_1-q_1)] - [\rho_2\rho_{11}m_2-\rho_1\rho_{12}m_1]) -$$

$$[az_0-(z_0-q_1)m_0]) \; (\rho_2-\rho_1)\} = h'(y) \tag{16}$$

Where the left hand side is the marginal payoff to the incremental acquisition of information, dy. In effect the condition says that the expected value of the marginal payoff must equal the marginal cost of information at the optimum. As can be seen in (16), the expected price, or expected marginal payoff revenues constitutes a weighted average of unit profits, unit losses and the gains from changes in production. If we let $\rho_2 = \rho_1 = 0.5$ then

$$.5\rho'_{22}\{D\} = h'(y) < 0 \tag{17}$$

where

$$D = \{a[(z_2-z_1)+z'(\rho_{22}-\rho_{21})]-[\rho_{22}(z_2-q_1)m_2-(z_1-q_1)m_1]$$

$$-z'(m'[\rho_{11}(z_2-q_1)-\rho_{12}(z_1-q_1)]-[\rho_{11}m_2-\rho_{12}m_1])\}$$

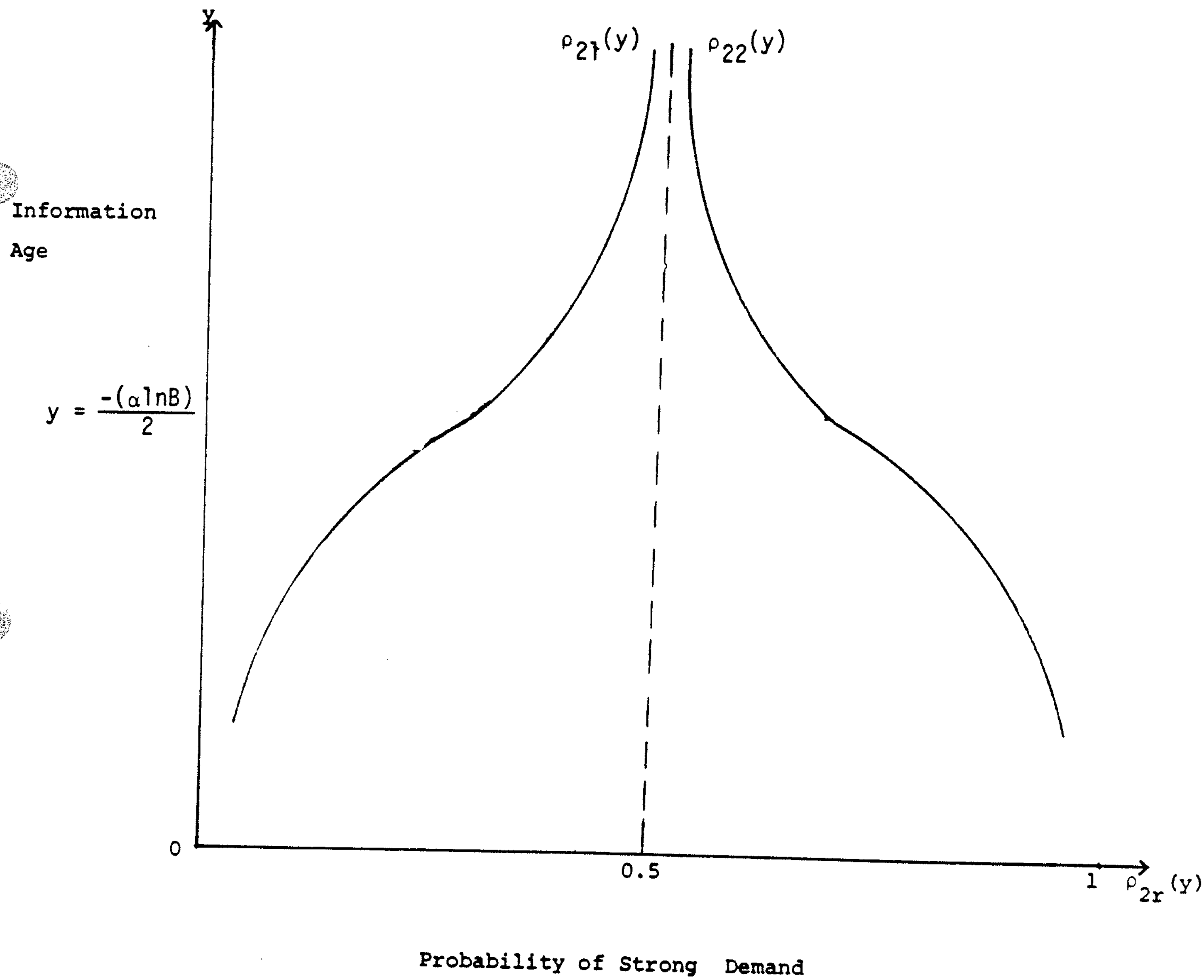
Taking second derivatives of (17), and, from (4), $z''= 0$, we get,

$$.5[\rho_{22}''(D)+\rho'_{22}z'\{4a\rho'_{22}-2\rho'_{22} + (m_2-m_1)+2m'\rho'_{22}(z_2+z_1-2q_1)$$

$$+ m'(\rho_{12}-\rho_{11})(z'-1)\}] < h''(y) \tag{18}$$

as the second order optimality condition. The left hand side depends on the shape of ρ and the reaction of z to changes in ρ. For example a flat response of z to ρ and increasing rsponsiveness of ρ to newer information will likely result in a positive left hand side. For example, this is the case if $z'=0$ and $\rho''>0$.

FIGURE VI


y
$\rho_{21}(y)$
$\rho_{22}(y)$
Information
Age
$y = \frac{-(\alpha \ln B)}{2}$
0
0.5
1
$\rho_{2r}(y)$
Probability of Strong Demand

d) Functional Forms

In order to test our hypotheses concerning the way in which information is acquired and used by the firm and whether this information is indeed approximated by Transborder Data Flows, we will have to endow our functional forms with a somewhat more detailed set of specifications. Since no such work has previously been done our guiding principles must include: the theoretical results that

$$MP' < h''(y)$$

the common sense notion that the concentration of a distribution is probably a declining function of information, and, finally, we want to have a good dose of simplicity.

A specification for the probability function must include the restriction of symmetry about the point 0.5. In addition, since we are dealing with an MNE, wherein the purchase of information is equivalent to the acquisition of a communications channel (or system) of specific capacity, we must also include some measure of the efficiency of such a channel. This is important from both a demand and supply perspective. For example, given the level of precision with which an MNE desires to have the distribution of random demand described, the capacity of a communications instrument necessary to transmit the required information will be determined by the state of technology. It is also in this sense, as we will see further on that the demand for and cost of information behaviour are dependant on the same parameters. After all, if more precision requires more capacity, the same technological considerations would also be expected to affect costs. Indeed, Marschak (1974, 104-111) shows that when the precision of information is an issue (as it is in our model where newer information better specifies an originally unknown distribution of demand), the demand price (or value) of information is functionally related to its cost.

A plausible form that meets our criteria is,

$$\rho_{ir} = \delta_r(.5\beta^{\alpha/y}) + (1-\delta_r)\,(1-.5\beta^{\alpha/y});\ i=1,2$$

where $\delta_r = 1$ when $r = 1$

$\delta_r = 0$ when $r = 2$

and $\alpha = 1-\beta$

which means that β can be any positive number and ρ stills remains restricted between 0 and 1. Because of its role in the decision process of the MNE we also closely examine the marginal behaviour of ρ_{ir} with respect to y and β. Letting $\rho'_{ir} = \partial\rho_{ir}/\partial y$,

$$\rho'_{ir} = -\delta_r(.5\alpha\beta^{\alpha/y}\ln\beta)/y^2 + (1-\delta_r)(.5\alpha\beta^{\alpha/y}\ln\beta)/y^2;\ i=1,2$$

$$\delta_r = 1 \text{ when } r = 1$$

$$\delta_r = 0 \text{ when } r = 2$$

Then, with $\beta > 0$, $\alpha \ln\beta < 0\ \forall\beta$, so that

$$\rho'_{i2} < 0 \text{ and } \rho'_{i1} > 0$$

This means that the symmetry restrictions are met and the distribution does not distinguish between impact of information on either weak or strong demand, as long as it is in the same direction. That is

$$\rho_{ir} = \rho_{jr} \quad i,j=1,2,\ i\neq j$$

so that we have

$$\rho'_{i2} = \rho'_{j2} = -\rho'_{i1} = -\rho'_{j1} \text{ for } i,j=1,2\ i\neq j$$

From $$\rho''_{22} = \frac{(-1)^{(r+1)}.5\alpha\beta^{\alpha/y}\ln\beta}{y^3}\left[\frac{\alpha\ln\beta}{y} + 2\right] \text{ for } r=1,2$$

and $\rho''_{22} \gtreqless 0$ for $y \gtreqless -(\alpha \ln\beta)/2$

It therefore follows that ρ'_{22} reaches a maximum at $y = -(\alpha \ln\beta)/2$, increases at higher y and decreases at lower y. This means that we have a point of inflection at $-(\alpha \ln\beta)/2$ for the probability function ρ_{ir}, r=1,2. Figure VI shows the graph of $\rho_{2r}(y)$. The functions, $\rho_{i2}(y)$ and $\rho_{i1}(y)$ reach their maximum returns to information, for $y \geq 0$, at $y = 0$ and $\rho_{i2}(y) = 1$, $\rho_{i1}(y) = 0$, respectively.

To appreciate the role of technology in the precision (of specifying the probability distribution of demand) of any given level of information we look at the effect of varying the state of technology, β. Letting $\rho_{ir,\beta} = \partial\rho_{ir}/\partial\beta$,

$$\rho_{ir,\beta}=\delta_r \{.5\beta^{\alpha/y}[-\ln\beta]\}+(1-\delta_r)\{-.5\beta^{\alpha/y}[-\ln\beta]\}$$

where $\delta_r = 1$ when r=1

$= 0$ when r=2

and $\rho_{i1,\beta} > 0$ as $\beta < 1$

$\rho_{i2,\beta} < 0$ as $\beta < 1$

which means that as β approaches 1 with a given amount of information, say, y_0, the level of precision, in the sense that ρ_{ir} approaches the maximum uncertainty point of 0.5, declines. This has important supply side implications. Pre-empting the discussion on the cost of information function, we should expect that the lower is the precision of information, as β approaches 1, the less capacity that is required and so, the lower the cost for any given y.

As regards z, we saw in (4) that it depends upon the expected value of demand constrained by the risk inherent in the slope of the loss function, m. A plausible and simple form is,

$$z_r(\rho) = [q_1 + \rho_{2r}(q_2-q_1)]/f(m'); \; r = 1,2; \; f' \geq 0$$

which leaves the direction of response to the slope of the loss function identical to that of equation (4) in the theoretical model where m' is the slope of the loss function so that a steeper slope implies a lower level of production relative to the expected value of demand. If we let γ=m' it will be convenient to choose $0<f(m')\leq 1$ so that $z_r(\rho) \geq Eq$ for any value of f(m'). It will be convenient at this point to pre-empt the cross section estimations, using world trade, of the following chapter and introduce country subscripts. Letting γ_i be the slope of the ith country's trade demand curve (either exports or imports), i = 1...M, then define

$$f(m') = \hat{\gamma}_i = \frac{\gamma_i/(\Sigma\gamma_i/m)}{\text{Max}\ [\gamma_i/(\Sigma\gamma_i/m);\ i=1\ldots M]} = \frac{\gamma_i/\bar{\gamma}}{\text{Max}\ [\gamma_i/\bar{\gamma};\ i=1\ldots M]}$$

so that when

$$\text{Max. } [\gamma_i/\bar{\gamma};\ i=1\ldots M] = \gamma_i/\bar{\gamma};\ \hat{\gamma}_i = 1 \text{ and } \frac{\partial\bar{\gamma}_i}{\partial\gamma_i} = 0$$

$$\text{Max. } [\gamma_i/\bar{\gamma};\ i=1\ldots M] = \gamma_j/\bar{\gamma};\ i \neq j;\ \hat{\gamma}_i = \gamma_i/\gamma_j$$

$$\text{and } \partial\hat{\gamma}_i/\partial\gamma_i = 1/\gamma_j > 0 \qquad \forall\ i \neq j$$

In order to avoid cluttering we will leave out country subscripts until later.

For any given level of probability, a steeper loss function will pull production down towards its expected value as per the theoretical conclusions.[7]

And just as was shown earlier in the theoretical section, (equations (14) and (15)),

$$z'_r(\rho_{2r}) = (q_2-q_1)/\hat{\gamma} > 0; \quad r = 1,2 \text{ so that}$$

$$z'_2 = z'_1 = z'$$

and $z''_r = 0$

Finally, we must also specify $m(d)$. A fairly straightforward, ad hoc specification, which maintains $m'' = 0$ and $m < 0$; $\forall z > q_1$, is,

$$m_r = \gamma d_r;\ m'_2 = m'_1 = m' = \gamma > 0$$

and $d_r = q_1 - z_r$, $r = 1,2$

In our development of the empirical model we will maintain the simplification, introduced earlier, whereby the events that information will increase or decrease the probability of strong demand, are equiprobable so that $\rho_2 = \rho_1 = 0.5$. While we may add somewhat to the reality of the decision process by dispensing with this simplification, it would not be justified by the quality of our data. We can therefore substitute our ad hoc specifications into the first order conditions for an optimal choice of information age, y^*, which is equation (17)[8] to get

$$\frac{.5\alpha\beta^{\alpha/y}(\ln\beta)(q_2-q_1)(1-\beta^{\alpha/y})}{y^2\hat{\gamma}}\left[a+\frac{\gamma}{\hat{\gamma}}(2q_1[1-\hat{\gamma}]+.5[q_2-q_1])\right]=h'(y) \qquad (19)$$

The actual derivation is in Appendix C. (19) incorporates the risk elements directly in the choice of optimal information flows. These include: γ, which defines risk to the firm in terms of any given level of overproduction, whereby a larger γ implies a larger loss brought about by excess supply; a, which defines risk to the firm in terms of unit profit levels for every unit of undersupply; and (q_2-q_1) which defines risk to the firm along the lines of Leland's PIU (principle of increasing uncertainty) whereby a larger firm with a larger (q_2-q_1) will have a lot more at risk. What we have then is an average value of information weighted by a probability distribution which varies as more information is applied. The behaviour of the payoff can be seen in the second derivative of the left hand side, which, as in the theoretical section we will designate as MP. Thus

$$MP' = (J\beta^{\alpha/y})/y^4][\alpha \ln\beta(2\beta^{\alpha/y}-1) - 2y(1-\beta^{\alpha/y})] \qquad (20)$$

where $J = \dfrac{.5\alpha(\ln\beta)(q_2-q_1)}{\hat{\gamma}}\left[a+\frac{\gamma}{\hat{\gamma}}(2q_1[1-\hat{\gamma}]+.5(q_2-q_1])\right] < 0; \forall y$

because $\alpha \ln(\beta) < 0 \ \forall\ \beta$

Thus the sign of MP' depends upon the sign of

$$\alpha \ln\beta(2\beta^{\alpha/y}-1) - 2y\ (1-\beta^{\alpha/y}) = K$$

where $2y(1-\beta^{\alpha/y}) > 0 \ \forall y$ so that

$$MP' \gtreqless 0 \text{ as } \alpha \ln \beta (2\beta^{\alpha/y}-1) \lesseqgtr 2y(1-\beta^{/y})$$

$$\lim_{y\to\infty} K < 0 \text{ and } \lim_{y\to 0} K > 0$$

so that, just as in the case of $P_{2r}(y)$, the payoff increases at very old information, changes direction at some $y=y^0$ and begins to decline at newer and newer information levels. This result was of course to be expected given that we have made ρ the driving force in the choice of optimal z (recall $dq_{it}/dt = 0; \forall t, i=1,2$).

It now remains only to specify h(y). Our only real constraint is that at optimal information, y^*, $MP'<h''(y^*)$. Also, in keeping with our earlier discussion on the role of the technology parameter, h(y) should be understood as varying over y, given the state of technology $\beta=\beta_0$. To emphasize this point let us temporarily rewrite the cost function as $g(y,\beta)$ where $g' = \partial g/\partial y$ and $g_\beta = \partial g/\partial\beta$. Recalling that costs are expected to decline for a given level of y as the precision of the instrument declines, i.e. β approaches 1, then our function should have the property that

$$g_\beta \lesseqgtr 0 \text{ as } \beta \lessgtr 1$$

Since β is an exogenous technological parameter, not prone to rapid change, we will continue to use $h(y)$ as our cost function, so as to provide continuity with our theoretical model. Indeed, in testing our empirical model we assume that all the OECD countries in the sample are at the same communications technology level and, consequently, have the same β values. As such the same conditions that we expected for g, are also expected for $h(y)$ as β varies,

$$h_\beta \lesseqgtr 0 \text{ as } \beta \lesseqgtr 1$$

A special case that meets this condition as well as incorporates our a priori belief that $h'' > 0$, is,

$$h(y) = P_W[-(\alpha \ln\beta)/y + \beta^{\alpha/y}]$$

Where P_W is some index of input prices, W, for the production of information. The relevant results are,

$$h_\beta = P_W\,[\tfrac{\alpha}{\beta}\text{-}\ln\beta]\;[\beta^{\alpha/y}-1] \lesseqgtr 0 \text{ as } \beta \lesseqgtr 1$$

$$h'(y) = P_W(\alpha\ln\beta)\;(1-\beta^{\alpha/y})/y^2 < 0 \quad \forall y \tag{21}$$

and $$h''(y) = P_W(\alpha\ln\beta)[(\alpha\ln\beta)\beta^{\alpha/y}-2y(1-\beta^{\alpha/y})] > 0 \quad \forall y \tag{22}$$

so that costs are always increasing. One may argue that the transmission and processing costs of information, in terms of hardware, have in fact been decreasing with, in addition, significant exploitable economies of scale. Thus, an increasing cost of information function may not be realistic. However, as J. Marschak (1968) points out there are other quite costly aspects to the information game such as collection and interpretation. True, the frontiers of <u>bounded rationality</u> have been pushed back by advances in computer technology, but it is inescapable and will always put downward pressures on the amount of information that can usefully be handled.

Substituting (21) into (19) we can solve for y^*, optimal information input,

$$y^* = (\alpha \ln \beta)\{\ln P_W - \ln[.5(q_2-q_1)/\hat{\gamma}][a+.5(\gamma/\hat{\gamma})(4q_1(1-\hat{\gamma})+(q_2-q_1))]\}^{-1} \tag{23}$$

where the second term in the second brackets represents risk. The key elements are the range between maximum and minimum demand, (q_2-q_1), and the profit margin, a. The larger is, a, the higher is the risk of loss of not purchasing information in order to determine the correct probability distribution of demand. As a practical matter one may consider that firms with larger exploitable scale economies will buy more information. Similarly, the larger is the range, (q_2-q_1), the larger is the scope of loss of not acquiring distribution revealing information. Also, to the extent that uncertainty and information value are positively related (as per Shannon and Weaver (1969)), this expression can be considered as an expected value of information. It is in this sense, if we let

$$\ln \phi = \ln P_w - \ln[.5(q_2-q_1)/\hat{\gamma}][a+.5(\gamma/\hat{\gamma})(4q_1(1-\hat{\gamma})+(q_2-q_1))] \quad (24)$$

then

$$\ln \phi < 0$$

Thus $y^* > 0$. The requirement that $MP' < h''(y)$ means that from (20) and (22) we must have,

$$P_w(\alpha\ln\beta)[(\alpha\ln\beta)\beta^{\alpha/y^*}-2y^*(1-\beta^{\alpha/y^*})] - \{(J\beta^{\alpha/y^*})/y^{*4}\}$$

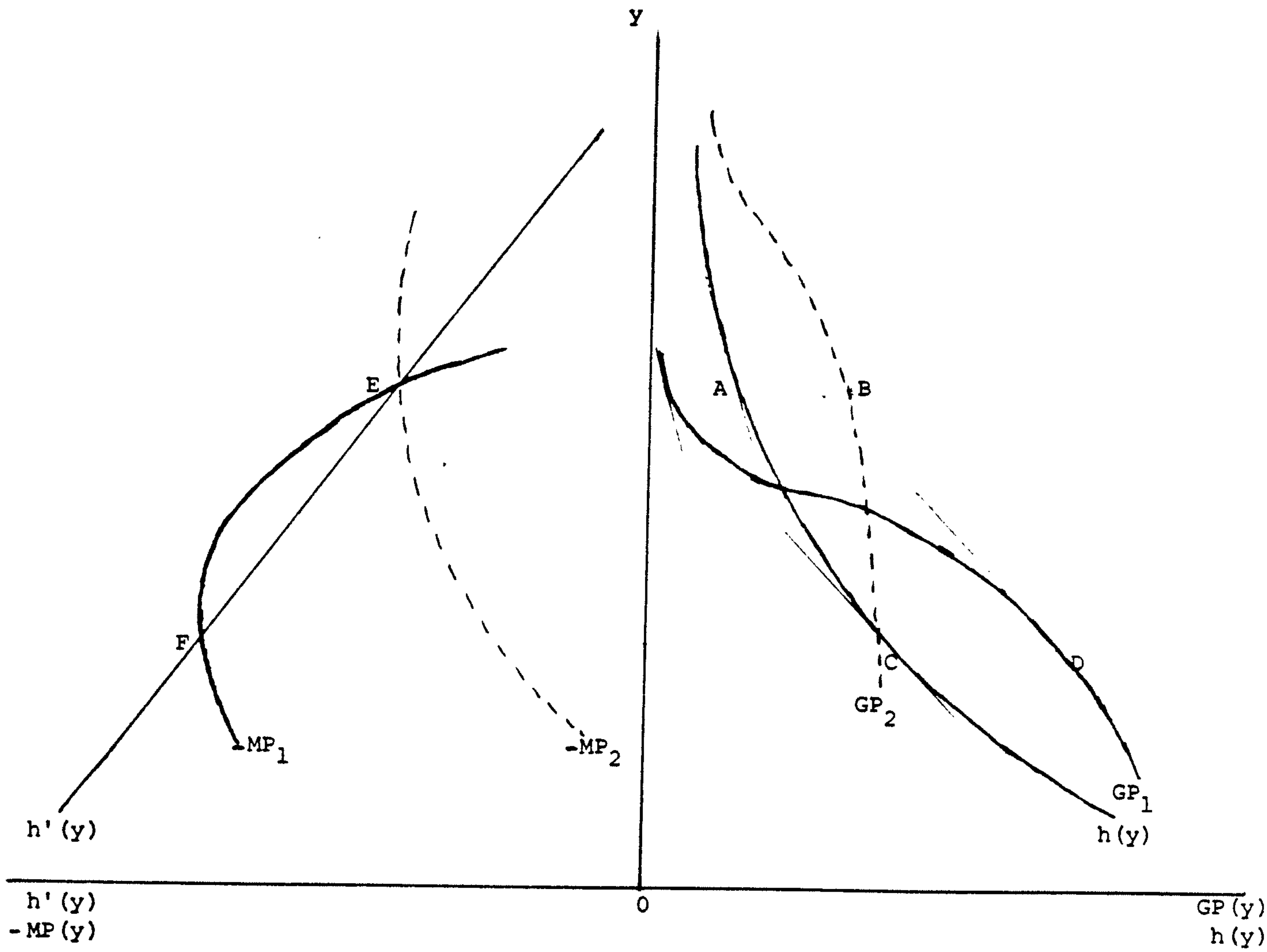
$$[\alpha\ln\beta(2\beta^{\alpha/y^*}-1) - 2y^*(1-\beta^{\alpha/y^*})] > 0$$

Since $h''(y) > 0 \ \forall y$ it is sufficient for a stable optimum that $\alpha\ln\beta(2\beta^{\alpha/y^*}-1) \geq 2y^*(1-\beta^{\alpha/y^*})$. As can be seen this is more likely to occur at smaller y^*, i.e. at new information. This of course corresponds with the shape of MP which is negative at lower y. There is also a possibility of intersection at an unstable equilibrium at higher y. Indeed there are the two possibilities of either stable or unstable intersections given that they intersect at all at higher y). A necessary condition for an unstable intersection is

$$\alpha \ln \beta (2\beta^{\alpha/y^*} - 1) < 2y^*(1 - \beta^{\alpha/y}) \tag{25}$$

so that $h''(y) < MP'$ is possible. But at this unstable point, the pressure is towards the stable point at lower y where $h''(y) > MP'$ as inequality (25) changes direction. And because MP does indeed change direction as y declines, there can be only one equilibrium point when inequality (25) holds and $h''(y) < MP'$ at high y. These results are shown in Figure VI. The curve MP_1 intersects $h'(y)$ at two points F and E. If the firm begins at E, on the marginal curves, and A on the total curves, it will never decrease the amount of information (i.e. increase y) because it will add more to costs than payoff. The pressure will be towards lower y until points F and D are reached on the marginal and total curves, respectively. As can be seen from the tangent lines, the slopes of $GP_1(y)$ (the total payoff function) and $h(y)$ are equal, indicating the maximum return to information. A similar story can be told for $GP_2(y)$, except that in this case there is only one stable intersection at higher y. The reason why we are getting higher payoffs at equivalent levels of y for $GP_2(y)$ is that information is more productive in terms of the technology parameter β.

FIGURE VII



GP(y) = Gross Pay Off Function

Before going on to the empirical verification it may be useful to examine the response of optimal information levels to changes in the traditional price variable, P_w, as well as the risk element, γ.

$$\partial y^*/\partial P_w = -\alpha \ln\beta/[P_w(\ln\phi)^2] > 0;\ \forall\ P_w > 0$$

which gives us the demand curve (although not downward sloping) for a normal input, information becomes newer as price declines.

As regards the effect of changes in risk, we calculate,

$$\frac{\partial y^*}{\partial \gamma} = \frac{\alpha \ln(\beta) P_w}{(\ln(\phi))^2(\phi)(R^2)} \frac{\partial R}{\partial \gamma} = V \frac{\partial R}{\partial \gamma} \quad ;\ V < 0$$

where, since R is country specific we must use

$$R_i = \frac{.5(q_2-q_1)}{\hat{\gamma}_i}\left[a + .5\frac{\gamma_i}{\hat{\gamma}_i}(4q_1\ [1-\hat{\gamma}_i] + [q_2-q_1])\right]$$

from which

$$\partial R_i/\partial \gamma_i < 0 \qquad \forall i$$

This result follows from the theoretical results in (4) and the ad hoc specification for z, where

$$z_r(\rho) = [q_1 + \rho_{2r}(q_2 - q_1)]/\hat{\gamma}$$

Since the firm will produce less as the loss function grows steeper (i.e. larger $\hat{\gamma}$), then the payoff to information must necessarily also shrink. Since R embodies this payoff we get the result that $\partial R_i / \partial \hat{\gamma}_i < 0$.

Further, considering R as the expected payoff to information for any level of risk the following result is apparent:

$$\frac{\partial y^*}{\partial R} = \frac{-[\alpha \ln(\beta)/\phi]\frac{\partial \phi}{\partial R}}{(\ln(\phi))^2} < 0$$

Finally, because our model deals explicitly with the acquisition of information by the profit maximizing firm, it does not cover all international data movement. We must therefore, introduce a second model which will cover the mixed bag of behaviours representing other users of TBDF. These include those other groups mentioned in the introduction, governments, data bank operators and service firms such as banks, other financial institutions and tourist and airline industries. Since this is not our principal concern but is necessary only because we will be explaining TBDF on a country basis in the empirical section, we use only a very general model. We suggest the not unreasonable relation that the extent of this non-MNE TBDF will vary positively with total country trade (i.e. current account transactions), relative to the country's total output. Referring to this type of information as y_g we can use the following, admittedly simple, ad hoc behavioural relation,

$$y_g = (\theta T)^{-1} \tag{26}$$

where T is the trade variable.

Combining the two models, (23) and (26), we have a single explanatory equation for international information flows,

$$x = x^* + x_g = (\alpha \ln\beta)^{-1}\{\ln P_w - \ln[.5(q_2-q_1)/\hat{\gamma}][a+.5(\gamma/\hat{\gamma})(4q_1(1-\hat{\gamma})+(q_2-q_1))]\} + \theta T$$

$$= (\alpha \ln\beta)^{-1}\ln\phi + \theta T \tag{27}$$

where $x^* = 1/y^*$ and $x_g = 1/y_g$

By viewing information as an input to the production activity of the firm facing random demand we have been able to derive an explicit demand-for-information function inversely related to price and positively to risk and income, as represented by the importance of trade. By judiciously choosing a cost-of-information function, whose price component mirrors the value of information we have also been able to simplify the demand equation into an easily estimable log-linear form. Since the firm is risk neutral, the risk variable is rather an uncertainty variable which is continuously transformed into risk through the application of information. Our model is thus one where the presence of uncertainty alters the behaviour of the risk-neutral firm. Empirical work in the following two chapters confirms the importance of our risk variable in the demand for information.

FOOTNOTES

Chapter III

1. The firm has presumably made a minimum cost input configuration choice to produce z_0 and would have made another choice for $z \neq z_0$. Thus, changing production levels from z_0 to z must imply some adjustment cost. However, because this adjustment cost does not enter any of the marginal conditions we choose to ignore it, knowing that it will not alter any of our essential results.

2. While we see the prices of goods in great demand going up, these are usually new production runs or, what may be considered as the same thing, extensions of the old run, which would presumably no longer be operating at minimum cost.

   When we say that the firm would lower price to rid itself of unsold production we presume that optimal inventory levels have already been taken into account.

3. Gould (1974) proves this result.

4. See footnote 11, Chapter II.

5. While we do not do so here, we could, at the cost of considerable more complexity, introduce a discount factor accounting for future losses due to the firm's inability to service all demand.

6. Gould (1974) objects to this notion because, within our context, the firm's decision problem is defined in terms of production choices whereas $E(VI) = -\Sigma\rho_i \ln\rho_i$ is defined strictly in terms of the probabilities on the stochastic variable. However, we do get around this difficulty by defining the stochastic variable in terms of information so that the firm really has only one problem, to choose information as an input to the production decision.

7. As noted in the theoretical section, the level of production with respect to the expected value of demand depends upon the relative size of unit profits and the expected unit loss from the disposal of surplus production. In our empirical model we did try defining z as

$$z_r = [q_1+\rho_{2r}(q_2-q_1)]\, f(m');\; r = 1,2;\; f' \geq 0$$

However, this formulation gave poor results probably because the slope of the loss function, in our empirical data was very small relative to unit profits.

8. We could have begun with equation (8), imposed the equiprobable distribution of $\rho_2 = \rho_1 = 0.5$ and $z'' = 0$ and the results would have been identical.

IV. EMPIRICAL MODEL

We have argued that Transborder Data Flows are principally uncertainty mitigating flows of information. As such we will use the information demand function developed in Chapter III as the TBDF demand estimating equation.

a) The Estimating Equation

The estimating equation will be derived from equation (27). Substituting for $\ln\phi$ from 24 we have,

$$X = -\frac{1}{\alpha\ln\beta}\ln R + \frac{1}{\alpha\ln\beta}\ln P_W + \theta T \tag{28}$$

with R, which is defined as,

$$R = \frac{.5(q_2-q_1)}{\hat{\gamma}}\left[a+.5\frac{\gamma}{\bar{\gamma}}(4q_1[1-\hat{\gamma}]+[q_2-q_1])\right] \tag{29}$$

considered as the risk variable. There are two elements to this risk variable. First of all we have the interval (q_2-q_1) which gives the range between highest and lowest possible demand. It represents what Leland (1972) has called the Principle of Increasing Uncertainty (PIU). PIU essentially says that risk varies, inter alia, positively with size. We would therefore expect

$$\frac{\partial X}{\partial V} = - \frac{1}{(\alpha \ln \beta)R} \frac{\partial R}{\partial V} > 0$$

where $V = (q_2 - q_1)$ and $R = \frac{.5V}{\hat{\gamma}} [a + .5\gamma(\lambda V)]$
$\bar{\gamma}$

where $\lambda V = q_2 - q_1(4\hat{\gamma} - 3)$ so that $\lambda \geq 0$ since $\hat{\gamma} \leq 1$.

The second element is the per unit loss or gain represented by a and γ whereby if a, constant unit profit for production up to and including actual demand, remains the same between firms, risks vary negatively with γ, the slope of the loss function for overproduction.

J. Marschak (1968) points out that information involves the triple activity of «Inquiring Communicating and Deciding». To the extent that we are dealing with the introduction of a new technology, whereby Transborder Data Flows is supplanting the older, mature telex technology it is not unreasonable that «Inquiry» and «Deciding» require the complimentary factor, human capital. And if the price of this factor does affect Telex (the older technology) demand it would only be in a positive direction, particularly if we consider that TBDF and Telex may be substitutes. Indeed, as can be seen from Table II, the price of human capital has a negative impact on TBDF and a positive impact on Telex.

In its present form, the model of equation (17) shows only one price of information, P_w. We would therefore like to have a price of information that reflects the human capital elements of inquiring and deciding as well as the physical elements of communicating. A Cobb-Douglas price variable has the advantage of easily substituting into the logarithmic model as well as allowing us to directly estimate price elasticities with respect to both physical and human capital. We can thus represent P_w as,

$$P_w = P_1^{e} P_2^{h}; \quad \partial P_w / \partial P_1 > 0, \quad \partial P_w / \partial P_2 > 0 \tag{30}$$

where P_1 is the price of telecommunications equipment and P_2 is the price of human capital required for the inquiring and deciding activities.

Substituting (28) into (29) and adding firm (i) country (j) and time (t) subscripts we have our estimating equation,

$$X_{ijt} = -\frac{1}{\alpha_t \ln\beta_t} \ln[\frac{.5(q_{2ijt}-q_{1ijt})}{\hat{\gamma}_{ijt}} (a_{ijt} + .5\gamma_{ijt}$$

$$[4q_{1ijt}(1-\hat{\gamma}_{ijt}) + (q_{2ijt}-q_{1ijt})])]$$

$$+ \frac{e_t}{\alpha_t \ln\beta_t} \ln P_{1ijt} + \frac{h_t}{\alpha_t \ln\beta_t} \ln P_{2ijt} + \theta_t T_{ijt} + \varepsilon_{ijt}$$

where i, j and t refer to the ith firm in the jth country at time t, respectively. As can be seen we suppose the same information response from the independant variables regardless of firm or country but allow it to vary over time. If we aggregate over firms we get,

$$x_{jt} = -(A_t \ln\beta_t)^{-1} \ln\{.5[(q_{2jt}-q_{ijt})/G_{jt}][A_{jt}+(5G_{jt}/\hat{G}_{jt})(4q_{ijt}(1-\hat{G}_{jt})$$

$$+(q_{2jt}-q_{1jt}))]\}+(E_t/A_t \ln\beta_t)\ln P_{ijt}+(H_t/A_t \ln\beta_t)\ln P_{2jt}$$

$$+F_t T_{jt}+\varepsilon_{jt} \tag{31}$$

where $q_{kjt} = \Sigma q_{kijt}$ for $k=1,2$ and $j=1,\ldots,m$

$A_{jt} = A_{jt}(a_{1jt},\ldots a_{njt})$ for $j=1,\ldots,m$

$G_{jt} = G_{jt}(\gamma_{1jt},\ldots \gamma_{njt})$ for $j=1,\ldots,m$

$P_{sjt} = P_{sjt}(P_{s1jt},\ldots P_{snjt})$ for $j=1,\ldots,m$ and $s=1,2$

$T_{jt} = T_{jt}(T_{1jt},\ldots,T_{njt})$ for $j=1,\ldots,m$

These aggregator functions remain undefined, but when we take our aggregate data for estimation we assume that they do exist.

We require only one further adjustment before (31) becomes fully estimable. Since G_{jt} is the slope of the loss function and exports and imports may have different demand characteristics we must break

$$[.5(q_{2jt}-q_{ijt})/\hat{G}_{jt}][A_{jt}+(.5G_{jt}/\hat{G}_{jt})(4q_{1jt}(1-\hat{G}_{jt})+(q_{2jt}-q_{1jt}))]$$

into two components so that the final estimating equation is,

$$X_{jt} = -(A_t \ln \beta_t)^{-1} \ln\{.5[(q_{2xjt}-q_{1xjt})/\hat{G}_{xjt}+(q_{2mjt}-q_{1mjt})/\hat{G}_{mjt}](A_{jt}$$
$$+.5[(G_{xjt}/\hat{G}_{xjt})(4q_{1xjt}(1-\hat{G}_{xjt})+(q_{2xjt}-q_{1xjt}))+(G_{mjt}/\hat{G}_{mjt})$$
$$(4q_{1mjt}(1-\hat{G}_{mjt})+(q_{2mjt}-q_{1mjt}))])\}+\{E_t/(A_t \ln \beta_t)\}\ln P_{1jt}$$
$$+\{H_t/(A_t \ln \beta_t)\}\ln P_{2jt}+F_t T_{jt}+E_{jt}$$

which, for notational convenience, can be rewritten as

$$X_{jt} = \beta_1 \ln R_{jt}+\beta_2 \ln P_{1jt}+\beta_3 \ln P_{2jt}+\beta_4 T_{jt}+\epsilon_{jt} \qquad (32)$$

where, we expect,

$\beta_1 > 0$; $\beta_2 < 0$; $\beta_3 < 0$; $\beta_4 > 0$

where q_x = exports and q_m = imports so that we can use the separately available slopes G_m and G_x.

While the data and sources are listed in Appendix D, it will be useful here to describe each variable in some detail.

b) <u>The variables and their proxies</u>:

The q_{rjt}, r=1,2 are the upper and lower limits of the random demand distributions facing firms in each country j, j=1,...,m, for the two periods t=1976 and t=1981. We estimated these bounds by choosing the highest and lowest annual growth rates, in constant dollars, of total trade, over the previous five years for each of 1976 and 1981, and then applying these rates to the 1975 and 1980 trade figures, respectively, for each country. If $r_{j,t-1}$, is the rate of growth of actual total trade, $q_{j,t-1}$ in the (t-1th) period, then the upper and lower limits of total trade in period t are,

$$q_{2jt} = (q_{j,t-1})(\mathrm{Max}[(1+r_{j,t-5}),\ldots,(1+r_{j,t-1})])$$

and $$q_{1jt} = (q_{j,t-1})(\mathrm{Min}[(1+r_{j,t-5}),\ldots,(1+r_{j,t-1})])$$

While this may seem primitive, it is strongly representative of firm behaviour when they look at the three scenarios of most pessimistic, most probable and most optimistic forecasts with the most probable being some average rather than a highest or lowest value. In any event, we do take this method as a plausible way of approximating the upper and lower limits of the demand distribution.

The A_{jt} are approximated by the operating surplus[2] per unit of Gross Domestic Product in each country. We used GDP instead of trade because there is no data on operating surplus (or profits) from trade as separate from other economic activity. There is data on dividend rapatriation but no data on the profits from exports or imports directly.

Approximating the G_{xjt} and G_{mjt} is a bit more involved. Most of the data available for such a large number of countries is in the form of elasticities. Our problem then is to transform those elasticities into pure slopes. From our definition of $m(q_1-z) = P(q_1-z) - c \equiv \gamma[q_1-z]$ we must solve for z and then find $\partial z/\partial P$:

$$z(P) = (\gamma q_1+c-P)/\gamma$$

and $\partial z/\partial P = -1/\gamma$

so that the elasticity of excess demand with respect to price is

$$E_{zp} = - P/z\gamma$$

and $\gamma = -P/zE_{zp}$

Here we are considering z=q for all periods prior to the estimating years 1976 and 1981 so that E_{zp} is indeed the elasticity of demand.

P_{ljt} is the price of the relevant telecommunications equipment, which, in this case, are leased private circuits.[3] To collect those prices from all the countries in this study would have been quite an expensive proposition (far beyond the financial resources dedicated to this study) so that we had to estimate these prices based upon the price of leased circuits to and from Canada for each of the other countries (which was kindly and quickly furnished by Teleglobe Canada). The basic strategy was to take the price of a leased circuit from each country to Canada and use that as the price of a leased circuit in that country. However, since these prices are, to some extent, distance sensitive, if applied as is, they would certainly have distorted the results. For example, if the price of a leased circuit from Australia to Canada is used then the overall price for Australia would most certainly be exaggerated. We therefore had to factor out the distance component from the price. If we let $L_1,\ldots,L_m$ be the prices that the m countries charge for leased circuits to Canada, then a plausible representation of these prices is,

$$L_j = (\frac{d_j}{\bar{d}}) s_j\bar{L} \qquad i=1,\ldots,m$$

where d_j is the distance from country j to Canada and $\bar{d}$ is the mean distance, $(\Sigma d_j)/m$, and $(d_j/\bar{d})^{\sigma i}$ is the distance factor in pricing. s_i represents local pricing peculiarities in country i and $\bar{L}$ is $\Sigma L_j/m$. As a proxy for $d_i/\bar{d}$ we choose

$$P_{cj}/\bar{P} \sim (d_j/\bar{d})^{\sigma}j;\ j=1,\ldots,m$$

where P_{cj} is the price from Canada to country j and $\bar{P}_c = \Sigma P_{cj}/m$. We can now eliminate the distance factor while leaving s_i, the local pricing peculiarity, intact, giving,

$$P^*_{1jt} = (L_j)/(P_{cj}/\bar{P}_c)$$

which is the price per leased circuit for country j at time t.

The price of human capital, P_{2jt}, is defined as the inverse of a Harbison-Myers (HM) index, already used by Balassa

(1979) in this connection. The HM index is a weighted average of educational levels within any country. It weights the percentage of the 20 to 24 age group enrolled in third level education by five and the percentage of the 15 to 19 age group enrolled in secondary education by one. The logic here being that the more human capital available the lower is the price of inquiring and deciding. We use the inverse because returns to human capital are assumed to be diminishing.[4] This variable characterizes the diffusion argument discussed above, whereby human capital is the complimentary factor in the introduction of a new communications technology.

Finally, since we are interested in international telecommunications, we should represent T by a variable that in some sense relates local production and world trade. For this we have chosen $T_i = GDP_i^{S_i}$ where S_i = the share of country i's trade in total world trade. (This is a compromise between using GDP or Trade, both of which introduce unacceptable degrees of multicollinearity into the estimating equations).

FOOTNOTES

Chapter IV

1. We recognize that an information transmission channel does not necessarily have to involve physical capital. It could very easily be a description of how the individuals of an organization signal their respective attributes to each other without ever resorting to physical capital. However, since we are trying to explain the movement of computer data across national boundries, physical capital would reasonably be expected to play a prominent role.

2. Operating Surplus is defined as per the OECD National Accounts as: «the excess of the value added of resident industries over the sum of their costs of employee compensation, consumption of fixed capital, and indirect taxes reduced by subsidies».

3. TBDF is generally believed, up to 1981, to flow mainly over leased private circuits. This belief is explicitly stated in Bergendorff (1982).

4. Regressions using the non-inverted HM index did not prove satisfactory. The results were all insignificant or of the wrong sign.

V. EMPIRICAL RESULTS

As its principal aim this thesis is attempting to explain the international movement of data, known as Transborder Data Flows (TBDF). It contends that the generation of TBDF, at positive cost is, inter alia, motivated by the need for uncertainty mitigating information. We would thus expect the risk variable, R, in equation (32), to vary positively with information quantity (or negatively with information age which, in our model is simply the inverse of information quantity).

Our model, equation (32), has three other variables (including a random error term, ϵ_t) which are believed to influence the movement of TBDF. Price, an integral part of any demand model, is separated between the price of human capital, P_2, required for data collection and interpretation and the price of transmission, P_1. If we believe information to be a normal good then these price variables should have negative coefficients.

Since our model derives from the profit-maximizing-under-uncertainty behaviour of the firm, the risk variable would not explain those data flows resulting from other economic activity. Our data, however, covers total national flows and could not, without great expense be partitioned by economic activity. We therefore also include a very general variable, national GDP adjusted for the relative importance of trade to the national economy, to explain the «non-profit-maximizing firm» data flows.

None of the data, except for the GDP and trade figures is of very good quality. The worst of the lot is the human cost of information variable. We used a Harbison-Myers (1964) index to represent the human capital concentrations which should mirror the price of information interpretation through the notion of factor abundance. However, it is not clear that the HM index is the appropriate price variable. For this reason the model has been estimated both with and without P_h, the price of the human component.

In 1976 and 1981 the number of data circuits underestimates both the total amount of TBDF and the relative disparities between countries. This is more so the case in 1981. Data communications over leased circuits is typically effected by attaching modems at the transmission and reception points. These modems also determine the speed of transmission. Technological innovation has it that by 1981 modems would move data at 9600 bits per second. In 1976, 1200 to 2400 BPS was fast. Now it should be understood that while data may be moving faster the circuits may not necessarily be in use for as long, but still must be leased on an annual basis because of the pricing structure. We are, at best, probably safe in assuming that a doubling of the number of leased circuits means at least a doubling of data communications. However, without considerable expense it is not possible to know by how much TBDF growth has outstripped that of leased circuits. Further, the degree to which different countries move data at different speeds is not known.

Another reason for the underestimation of TBDF is due to the widening capacity of dedicated public data networks integrated accross international frontiers. Because Canada and the USA have pushed integration further than any other set of countries, their data circuits are a less accurate representation of these two countries' TBDF than the rest of our sample. Integration in other countries, however, is also proceeding, as can be seen from Table I.

Finally, the move to an Integrated Services Digital Network which moves data at speeds of 56000 to 64000 BPS (six to seven times faster than the latest high speed modems) is another source of TBDF underestimation. In 1981, however, digitalization, on an internationally integrated basis had not yet become important enough to be a major source of error.

The price of leased circuits, P_c, as noted earlier, is not an exact series. It had to be estimated from available records of prices to and from Canada. While this probably gives us a

TABLE 1

PLANNED CONNECTION DATES BETWEEN DATA NETWORKS IN SELECTED OECD COUNTRIES

To / From	Austr.	A	Can	DK	SF	F	D	I	NL	N	Japan	E	S	CH	UK	USA
Australia (Austr.)		NA	IE	NA	NP	83	NP	NP	NP	NA	NA	NP	NP	NP	IE	IE
Austria (A)	NP	-	IE	NA	NP	82	81	83	82	83	NA	NP	83	82-83	82	IE
Canada (Can	IE	NA	-	NA	NP	82	82	PL	82	NA	NA	IE	IE	82	IE	IE
Denmark (DK)	IE	NA	IE	-	81	83	82	84	NP	81	NA	NP	81	83	82	IE
Finland (SF)	NP	NA	IE	IE	-	82-83	82	84	NP	81	NA	NP	81	83	82	IE
France (F)	IE	NA	IE	NA	NP	-	IE	83	82	82	NA	IE	81	82	82	IE
W. Germany (D)	IE	NA	IE	82	82	IE	-	83	82	81	NA	81	IE	82	IE	IE
Italy (I)	NP	NA	IE	NA	NP	83	82-83	-	NP	83	NA	81	83	83	NP	IE
The Netherlands (NL)	IE	NA	IE	NA	NP	82-83	82	83	-	82	NA	NP	82	83	83	IE
Norway (N)	IE	NA	PL	IE	81	82-83	82	83	NP	-	NA	NP	81	83	82	IE
Japan	IE	NA	PL	NA	NP	82	82	NP	NP	NA	-	NP	NP	83	82	IE
Spain (E)	IE	NA	IE	NA	NP	IE	82	83	NP	82	NA	-	82	83	82	IE
Sweden (S)	IE	NA	IE	IE	81	82	81	83	NP	81	NA	NP	-	83	82	IE
Switzerland (CH)	IE	NA	IE	NA	NP	82	82-83	83	83	83	NA	81	83	-	82	IE
UK	IE	NA	IE	NA	NP	82	81	83	83	82	NA	IE	IE	82	-	IE
USA	IE	NA	IE	NA	NP	IE	81	PL	82	NA	IE	IE	IE	83	IE	-

NP = no plans; IE = in existence 1981; NA = no specific answer; PL = planned but no date indicated.

Source: Bergendorff (1982)

reasonable approximation, it nevertheless cannot account for the importance that pricing peculiarities may have in the aggregate prices of different countries. For example, pricing between commonwealth countries, as between the U.K., Canada and Australia is governed by their special relationship.

With regard to the actual empirical results, (given the data limitations), these tend to support our hypothesis concerning the importance of risk in the generation of TBDF, for 1981, but not for 1976. It may have been the case that perceived risk was lower in 1976 and much of the data flows were meant for other purposes. Alternatively, it may have been the case that the technology to incorporate so much information as was made possible through the use of leased circuits, was not available. This latter, more plausible reason, is the case of bounded rationality where the technology existed for moving a lot of information very quickly but the interpretive capacity, in the form of human intellect and computer software, was not available. Under these circumstances another information form of more manageable proportions would have been used. This is why we also looked at Telex traffic as a risk mitigating information variable.

As a result we tested our model with three different forms of information volume (which is the reciprocal of information age): Data Circuits Only (DC); Telex Only (TO) and; Combined Data

Circuits and Telex (DCT).[1] The basic estimating equation for both 1976 and 1981 is (32). Each of DC, TO and DCT were tested with and without P_h. In addition, there were two other alterations to our data. One being that Japan was considered as an outlier and was, as such, left out of all estimations. While Japan showed spectacular growth in data circuits, just as many of the other countries, the ratio of data circuits to size of national economy remained very small relative to those other countries. This is also the case with telex traffic which does not seem to correspond to size either. It is not clear how a major trading nation like Japan moves its information, but given its «no answer» responses for Table I, it is entirely possible that our Data Circuit information on Japan is simply very inaccurate.

As a second alteration, the U.K. Data Circuit figures were all scaled down by 30%. This is because the U.K. serves as a major transit and switching point for international telecommunications so that the U.K. specific risk and trade variables would bear no relation to part of the U.K.'s measured TBDF. The 30% factor is arbitrary and the result of trial and error. Further study would be required for a more accurate figure.

From Table II we can see that the series using Telex only performs relatively poorly with very low corrected coefficients of correlation. However the results are very useful in that they

TABLE II

A MODEL[a] OF THE DEMAND FOR TRANSBORDER DATA FLOWS, CROSS SECTION FOR 15 COUNTRIES, 1976 AND 1981

	DATA CIRCUITS ONLY				TELEX ONLY				DATA CIRCUITS AND TELEX (Combined)			
	1976	1981	1976	1981	1976	1981	1976	1981	1976	1981	1976	1981
Characteristics	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b
R (Risk)	1.84 (.19)	-26.20+ (-1.67)	3.28 (.28)	-27.55+ (-1.76)	-13322.0* (-3.12)	-20530.8* (-4.04)	-13771.7* (-2.59)	-19738.8* (-3.53)	-11995.7+ (-1.47)	-39392.3* (-2.66)	-11407.8+ (-1.37)	-39572.1* (-2.79)
P_2 (Human Capital)	-305.44* (-2.56)	-230.11 (-1.05)			95309.3* (1.84)	135083.0* (1.91)			-12461.1 (-1.26)	-30668.7 (-.15)		
P_1 (Physical Capital)	-26.15* (-1.51)	-53.37* (-1.90)	-3.10 (-.17)	-35.85+ (-1.58)	-7037.7 (-.94)	-8703.6 (-.96)	-14230.9* (-2.03)	-18983.7* (-2.34)	-25865.5* (-1.80)	-47130.4+ (-1.77)	-16460.8 (-1.31)	-44796.5* (-2.18)
T (Trade/Income)	72.34* (8.60)	83.01* (5.20)	84.62* (10.13)	91.08* (6.47)	3969.2 (1.09)	4130.3 (.80)	135.3 (.04)	-601.4 (-.12)	56051.3* (8.02)	638993* (4.23)	61063.9* (10.39)	64973.6* (5.72)
$\bar{R}^2$ (Adjusted)	.9490	.8887	.9254	.8878	.5663	.6558	.4804	.5815	.9442	.8627	.9415	.8739

a The Model $x_{jt} = -\overset{(-)}{\frac{1}{A_t \ln B_t}} \ln R_{jt} + \overset{(-)}{\frac{E_t}{A_t \ln B_t}} \ln P_{ijt} + \overset{(-)}{\frac{H_t}{A_t \ln B_t}} \ln P_{2jt} + \overset{(+)}{F_t} T_{jt} + E_{jt}$

* Coefficient significantly different from zero at the .05 level.

\+ Coefficient significantly different from zero at the .10 level.

t - Statistics in parentheses.

point out the importance of risk and price P_1 in the demand for telex born information. Indeed, the trade variable, contrary to its performance elsewhere, exerts no significant influence on Telex demand. The human price factor has the wrong sign (in columns 3a and 3b) and is barely significant. But, in light of the relatively low volumes of information that can be moved by the ponderous and slow telex network, we would in any event not expect an important interpretive component. Once it is removed, the equipment price variable becomes significant (columns 4a and 4b). We suggest that telex is, like TBDF, another form of uncertainty mitigating information, predominant in 1976 because of the bounded rationality phenomenon.

The argument is entirely microeconomic based. If we can reduce the firm's production decisions to an information base, which we have done in our model, then we can safely state that with non-decreasing information costs the profit maximizing firm will never produce information where its marginal return is smaller than its marginal cost. Thus if presented with the possibility of a manifold increase in information production without an equivalent increase in the bounds of its rationality, the firm should, theoretically refuse such an offer. While by 1981, a good deal of software, able to condense and rationalize massive amounts of information, had become available, this was not the case in 1976. This reticence on the part of enterprise to buy because its faster, without regard to bounded rationality is exemplified by the relatively slow market penetration of digitalization. Although the technology has been available since the 1950's and actually installed in some areas by 1970, the more optimistic view is for widespread used only by the 1990's.

In table II we see that risk provides a singularly unimportant explanation for DC demand in 1976, but assumes the correct sign and becomes a lot more prominent in 1981. The risk variable, R, is dependant upon the variation in demand and the risk of loss as per the slope of demand. As such it is linked to a larger body of info than that specifically represented by Data Circuits. This, much more so in 1976 than 1981. Indeed, for 1981, DC can almost stand alone as the link to risk. Also, the risk variable does better when P_2 is excluded. This is probably due to the poor quality of the P_2 variable. The signs, in 1981 are all correct.

When we combine DC and TO we see a major improvement for both 1976 and 1981. The risk variable, when P_2 is excluded, even becomes significant at the 99% level (column 6b). It is the general demand for information that our risk variable is explaining. While the t value of the risk coefficient is improved for both 1976 and 1981 the impact of adding telex is far more prominent in the earlier period. Data Circuits, in effect, seem to assume a dominant position in the information game by 1981. This relative importance is mirrored in Figure I where the growth between 1976 and 1981 for Trade, Data Circuits and Total Telex is graphed. The 69% growth in DC far overshadowed the 52% and 41% growth rates of Trade and Total Telex, respectively.

The move into the very high technology, high priced rapid information age has widened the gulf between the certainty levels of the smaller countries, with less information resources, and the larger countries (in terms of trade levels). Table III calculates, the B, E and H values for the corresponding lines of Table I. And from the B values and the number of leased Data Circuits and Telex minutes, using the formulae $\rho_{22}=1-.5B^{A/y} = 1-.5B^{AX}$ and $\rho_{11}=1-\rho_{22}$ we calculate the probabilities for the smallest number of circuits and largest number of circuits. The range between the highest and lowest probabilities widens in 1981 from .5 to .16. The explanation is very likely to be found in the fact that Telex was more equally accessible to all countries than the higher technology computer to computer TBDF. Telex has been around long enough to reach saturation, as an information source, for all countries.

The empirical results support our contention that TBDF is an input to the production activity inversely related to its own price and directly prportional to risk, which is defined in terms

TABLE III

PROBABILITY RANGES IN THE MODEL[a] OF THE DEMAND FOR TRANSBORDER DATA FLOWS

	Data Circuits Only								Telex Only								Data Circuits and Telex (combined)							
	1976		1981		1976		1981		1976		1981		1976		1981		1976		1981		1976		1981	
	1a		1b		2a		2b		3a		3b		4a		4b		5a		5b		6a		6b	
	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low
$\rho^{b}_{12}, \rho^{b}_{22}$	-	-	1.0	.85	-	-	1.0	.84	-	-	-	-	-	-	-	-	1.0	.95	1.0	.86	1.0	.95	1.0	.86
$\rho^{c}_{11}, \rho^{c}_{21}$	-	-	0.0	.15	-	-	0.0	.16	-	-	-	-	-	-	-	-	0.0	.05	0.0	.14	0.0	.05	0.0	.14

a see Table II for model.

b ρ_{12} is the probability that demand is weak and it increases with more information.

ρ_{22} is the probability that demand is strong and it increases with more information.

c ρ_{11} is the probability that demand is weak and it decreases with more information.

ρ_{21} is the probability that demand is strong and it decreases with more information.

\- the estimated coefficients of the model were not significant so that the probabilities were not calculated.

of the forgone profits of underproducing as well as the range of demand fluctuations.

FOOTNOTES

Chapter V

1. DCT is a weighted combination of Data Circuits and Telex Minutes. One voice grade circuit (which are the Data Circuits), can be multiplexed into 6 Telex grade circuits. Further, we assume that each circuit operates for 8 hours or 480 minutes per day for 250 days per year so that each Data Circuit must be weighted by (6 x 480 x 250) ÷ 1000 = 720. For example a country with 30 Data Circuits would have 21,600 equivalent telex minutes which would be added to its total Telex traffic to yeild a value for DCT.

VI. POLICY IMPLICATIONS

Base on the theoretical specifications of our model, the empirical results suggest that policies to constrain or otherwise modify Transborder data flows would have real consequences, affecting the size and pattern of international trade.

As specified, the model hypothesized that the profit maximizing, risk neutral firm, facing random demand (uncertainty), acquired information as long as the net marginal payoff remained positive. Since the firm was risk neutral, changes in the variance of its demand distribution did not influence its production decisions. Thus a mean preserving change in variance would leave the firm's behaviour unaltered. However, since its production decisions were made to maximize expected profits, which are a function of expected demand, the perceived probability distribution of demand was crucial. Thus, in so far as information served to reveal the true probability distribution of demand and so permitted the firm to avoid producing at levels which did not maximize the true expected profits, it had value. And, as already noted, it was acquired only to the point where its marginal contribution to the avoidance of losses from production at less than profit maximizing levels exceeded its marginal cost. The upshot being that as long as information is acquired it changes the probability distribution of demand, changing the firm's production decisions and so is an input with real effects.

To the extent that the model specified the same cost of information function for all firm's, regardless of size, larger firms, with larger expected demand, would always acquire more information (unless, of course, the firm's loss function is so steep as to significantly reduce production and so the amount of information it might profitably acquire). But the channel through which the information has a real influence on the firm's behaviour is still the probability distribution of demand and so its expected value.

The empirical results confirm these hypotheses. This means that policies designed to constrain or modify Transborder Data Flows will have real effects. This being said, the question arises whether or not governments should pursue strong interventionist policy, as is already being done in some cases (such as Algeria and Brazil) and as is being advocated by some OECD countries.

Spence (1975) tells us that the firm exists, inter alia, to act as the vehicule by which an externality, due to the non-existence of a perfect information market, is eliminated through internalization. The consequent internal information market is then, if not perfect, presumably approaching perfection. Now if this was the only externality, or imperfection, in the international economy, we could mount a very strong efficiency argument against intervention. However, the existence of tariff barriers, erratic exchange rate fluctuations, differential tax rates and so on detract considerably from that sort of laissez-faire invisible hand policy suggestion. A more persuasive argument is to be found in our rather limited knowledge about the consequences of intervention. We know that the effects will be real, but we can only vaguely guess as to their ultimate desirability. Knowing that something will happen is just not sufficient, we must also be able to quantify magnitude and direction. An example from the theory of multinational enterprise (MNE) behaviour will illustrate these points.

Horst (1971) describes the optimizing conditions for an MNE with two plants in two countries selling identical products and facing downward sloping demand curves. From these conditions it is possible to determine the direction of trade, the volume of trade, the production and price levels in both countries and, the transfer prices. While we will use the same criterion as Horst to establish values for these important variables it will be instructive to begin with a potential MNE.

The firm in country A is analysing whether or not to acquire a plant in country B. The one under scrutiny meets all the requirements. At the no-trade point B has higher costs and consequently higher prices which opens the possibility of profits from price discrimination. If he acquires the plant then local production will expand until the point where his marginal cost plus all the attendant transfer prices and tariffs just equals the marginal cost of plant B. This of course means that he will sell less locally at higher prices (since he still wants to maintain the equality between marginal revenue and marginal cost, which has gone up), but he will export the remainder of a larger output. In country B, the opposite is true, more is sold at lower prices (this being the consequence of a downward sloping demand curve). Under these conditions there is no question but that if he does not acquire plant B the MNE will miss an exploitable profit opportunity. However, if we introduce random demand in country B into the acquisition debate then the firm must look at expected exploitable profits. To the extent that he can move information between his two plants and still earn enough to cover the cost of that information then the acquisition decision will remain unaltered. But, if it turns out that the expected gains in profits from information are large enough, then any attempt to control or alter the flow of the MNE's intra-firm information may be enough to stop acquisition entirely.

An MNE already operating in both countries and dependant upon the flow of intra-firm information, would have to make certain hard choices if information is constrainted. He could maintain both plants and stop or considerably reduce, the intra-firm trade and simply collect dividends from an otherwise profitable firm. However, a narrow enough expected profit margin may mean the complete pullout of his investment. Either course implies that a constraint on information flows is equivalent to an effective tariff. But in the latter instance, there could be other undesirable effects such as a lack of investment funds or an end to technology transfers.

It is apparent that if we know the firm's payoff function we would be able to evaluate the trade effects of constraining information. The cost of assuring, say, confidentiality, becomes quantifiable. The choice of information constraint as an alternative to traditional trade policy can be clearly evaluated. An interventionist policy is conceivable. However, without such knowledge information policies could prove to be economic suicide, and should be avoided.

VII. CONCLUSIONS

In trying to explain the phenomenon of TBDF we adopted, as our principle hypothesis, that Transborder Data Flows are uncertainty mitigating information flows. As such we developed a theoretical model based on a profit-maximizing multinational enterprise (MNE) which acquires information as long as the marginal payoff from that information remains larger than its marginal cost. Our MNE faces random demand to the extent that he does not know his exact market size, within which his profit margin, in the face of constant output prices and costs, remains constant. However, beyond his true market size he faces a downward sloping demand curve along which his per unit loss becomes larger as his excess production grows. Naturally, the size of his per-unit loss, for any excess supply depends directly on the slope of this «loss» function, and the steeper the slope of his loss function, the lower is production.

We have shown that uncertainty affects behaviour even when the firm is risk neutral. This for reasons other than those proposed by Mills (1959), Leland (1972) and Turnovsky (1973). In the Leland and Mills work, choosing price (or price and quantity) as the ex ante choice variable causes the risk-neutral monopolistic competitor to alter its behaviour. Turnovsky shows that even the risk-neutral perfect competitor will alter its behaviour when it has the option of altering its initial production plans. Unlike these studies we have shown that introducing positive cost information alters the behaviour of the risk-neutral firm. The firm still maximizes expected profits but because information is not free it may be willing to do so at a point which does not reflect the _true_ probability distribution of information. It is in this sense that the firm will produce more or less than would be the case in a risk-neutral model which does not include information as a choice variable.

In the empirical model, the expected payoff maximizing information on a country basis, turns out to be a function of a risk variable depending on the upper and lower limits of demand and the slope of the loss function; price of information variables and; the size of the national economy adjusted for the relative importance of the country's trade.

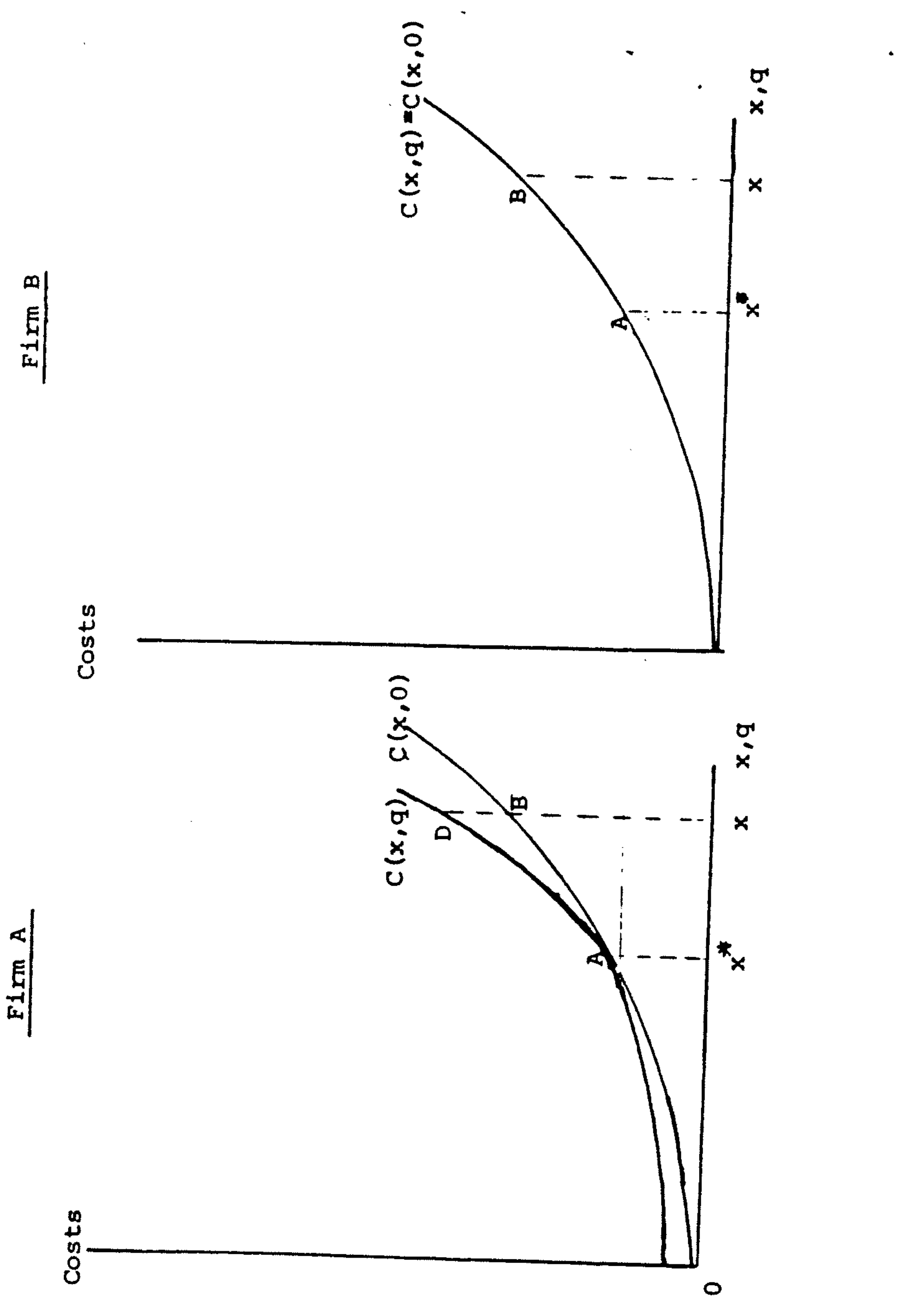
The salient empirical results are that in 1976 information defined only as TBDF moving over leased Data Circuits is not explained by our risk variable. However, in 1981, risk is significant in explaining TBDF.

In order to link risk to the demand for information, an expanded information variable, composed of both Telex traffic and Data Circuits was tested. Risk assumed importance for 1976 and became even more significant for 1981. This led us to speculate that the constraint of bounded rationality was responsible for the differing composition of information between the two periods 1976 and 1981. Telex became less important in 1981 and served only to increase the significance of risk as an explanatory variable for information demand. In 1976 however, not only is the risk variable totally insignificant without telex but it also has the wrong sign in some cases. We suggest that TBDF, high volume, high speed information movement became prominent with respect to risk mitigation only after the software was developed to push back the frontiers of bounded rationality.

Since information serves to realign the probability distribution of demand, and the risk-neutral firm makes production decisions based upon the expected value of profits, our empirical results confirm that information, or more specifically, TBDF, has real effects. This of course has implications for policy oriented towards the regulation of TBDF. Such policy will have real effects, and it has been argued in Chapter VI that it should be avoided, simply because the consequences of intervention are not now predictable. What is missing is the knowledge of the firm's payoff function which reveals the relative importance of information to its profit picture.

APPENDIX A

TURNOVSKY'S FLEXIBILITY NOTION



From the above figures it is apparent that firm B will have greater flexibility to react given any level of information. The explanation is straightforward. Suppose the firm plans to produce x^*. The cost of this plan is denoted by the point A, in both figures, on the planned cost curve $C(x,o)$, i.e. where there is no unanticipated demand. The actual costs incurred, including those resulting from changing these plans after the resolution of uncertainty, is illustrated by the curve $C(x,q)$, and there will be one such curve corresponding to each point on the planned cost curve $C(x,o)$. Naturally, when $q=0$ the two slopes are equal, as at the tangency point A. Otherwise $C(x,q)$ lies every above $C(x,o)$ for $q \neq 0$. Suppose that after learning actuel demand, the firm wishes to produce an additional quantity $x-x^*$, firm B will do so at a cost of XB and firm A at a cost XD where XB < XD. This is the meaning of flexibility, operationally residing in the difference between the cost curves $C(x,o)$ and $C(x,q)$, $\forall q$.

APPENDIX B

DERIVATION OF FIRST ORDER CONDITIONS

$$E\Pi(y) = \rho_2\{\rho_{22}az_2+\rho_{11}[aq_1+(z_2-q_1)m_2]-\rho_{22}az_o-\rho_{11}[aq_1+(z_o-q_1)m_o]\}$$

$$+\rho_1\{\rho_2-az_o+\rho_{12}[aq_1+(z_o-q_1)m_1]-\rho_{21}az_o-\rho_{12}[aq_1+(z_o-q_1)m_o]\}-h(y)$$

$$\partial E\pi(y) = \rho_2\{\rho'_{22}az_1+\rho_{22}az'\rho'_{22}+\rho'_{11}[aq_1+(z_2-q_1)m_2]-\rho_{11}m'z'\rho'_{22}(z_2-q_1)$$

$$+\rho_{11}m_2z'\rho'_{22}-\rho'_{22}az_o-\rho'_{11}[aq_1+(z_o-q_1)m_o]\}+\rho_1\{\rho'_{21}-az_1+\rho_{21}az'\rho'_{22}$$

$$+\rho'_{12}[aq_1+(z_1-q_1)m_1]+\rho_{12}m'z'\rho'_{22}(z_1-q_1)+\rho_{12}m_1z'\rho'_{21}-\rho'_{21}-az_o$$

$$-\rho_{12}[aq_1+(z_o-q_1)m_o]\}-h'(y)$$

Using the symmetry relations we get,

$$\rho_2\{\rho'_{22}az_2+\rho_{22}az'\rho'_{22}-\rho'_{22}[aq_1+(z_2-q_1)m_2]-\rho_{11}-m'z'\rho'_{22}(z_2-q_1)$$

$$+\rho_{11}m_2z'\rho'_{22}-\rho'_{22}az_o+\rho'_{22}[aq_1+(z_o-q_1)m_o]\}+\rho_1\{-\rho'_{22}az_o-\rho_{21}az'\rho'_{22}$$

$$+\rho'_{22}[aq_1+(z_1-q_1)m_1]+\rho_{12}m'z'\rho'_{22}(z_1-q_1)-\rho_{12}m_1z'\rho'_{22}+\rho'_{22}az_o-\rho'_{22}$$

$$[aq_1+(z_o-q_1)m_o]\}=h'(y)$$

Regrouping terms,

$$\rho'_{22}\{a[(\rho_2 z_2-\rho_1 z_1)+z'(\rho_2\rho_{22}-\rho_1\rho_{21})-q_1(\rho_2-\rho_1)]-[\rho_2(z_2-q_1)m_2-\rho_1(z_1-q_1)m_1]$$

$$-z'(m'[\rho_2\rho_{11}(z_2-q_1)-\rho_1\rho_{12}(z_1-q_1)]-[\rho_2\rho_{11}m_2-\rho_1\rho_{12}m_1])$$

$$-(az_o-[aq_1+(z_o-q_1)m_o])(\rho_2-\rho_1)\}=h'(y)$$

APPENDIX C

SUBSTITUTION OF AD HOC SPECIFICATIONS INTO FIRST ORDER CONDITIONS

From (17), by substituting for ρ'_{22}, z_2, z_1, z', ρ_{22}, ρ_{21}, m_2, m_1 and m' we get,

$$.5\rho'_{22}\{za[(q_2-q_1)(\rho_{22}-\rho_{21-})]-\gamma(-[q_1(1-\hat{\gamma})+\rho_{22}(q_2-q_1)]^2+$$

$$[q_1(1-\hat{\gamma})+\rho_{21}(q_2-q_1)]^2)-(q_2-q_1)\ \gamma(\rho_{11}[q_1(1-\hat{\gamma})+\rho_{22}(q_2-q_1)]-\rho_{12}$$

$$[q_1(1-\hat{\gamma})+\rho_{21}(q_2-q_1)]-\rho_{11}[q_1(1-\hat{\gamma})+\rho_{22}(q_2-q_1)]-\rho_{12}$$

$$[q_1(1-\hat{\gamma}\rho_{21}(q_2-q_1)])\}=h'(y)$$

$$.5\rho'_{22}\{2a[(q_2-q_1)(\rho_{22}-\rho_{21})-\gamma[-2q_1(1-\hat{\gamma})\rho_{22}(q_2-q_1)+2q_1(1-\hat{\gamma})\rho_{22}(q_2-q_1)$$

$$-\rho^2_{22}(q_2-q_1)^2+\rho^2_{21}(q_2-q_1)^2)-(q_2-q_1)\ \gamma(2\rho_{11}[q(1-\hat{\gamma})+\rho_{22}(q_2-q_1)]$$

$$-2\rho_{12}[q_1(1-\hat{\gamma})+\rho_{21}(q_2-q_1)]\}=h'(y)$$

and because $(\rho_{22}-\rho_{21})^2=(\rho_{22}-\rho_{21})$

$$.5\rho'_{22}\{2a[(q_2-q_1)(\rho_{22}-\rho_{21})]+\gamma(q_2-q_1)(\rho_{22}-\rho_{21})[2q_1(1-\hat{\gamma})+(q_2-q_1)]$$

$$+(q_2-q_1)\quad\gamma(\rho_{12}-\rho_{11})[2q_1(1-\hat{\gamma})]\}=h'(y)$$

$$.5\rho_{21}(q_2-q_1)(\rho_{22}-\rho_{21})\{2a+\gamma[2q_1(1-\hat{\gamma})+(q_2-q_1)]+\gamma 2q_1(1-\hat{\gamma})\}=h'(y)$$

$$.5(\alpha\ln\beta)\beta^{\alpha/y}(q_2-q_1)(1-\beta^{\alpha/y})\{a+.5\gamma[4q_1(1-\hat{\gamma})+(q_2-q_1)]\}=h'(y)$$

APPENDIX D

DATA AND SOURCES

TABLE D1

EXPECTED TRADE

Billions of U.S. Dollars (1975=100)

	Minimum Trade 1976	Maximum Trade 1976	Minimum Trade 1981	Maximum Trade 1981
Australia	27.0	34.1	32.7	38.9
Austria	25.3	28.0	37.0	42.0
Canada	74.8	88.7	97.4	107.3
Denmark	17.2	19.7	21.2	24.4
Finland	14.1	17.2	20.7	23.6
France	108.4	129.1	173.5	194.4
Germany	158.3	179.0	233.5	251.2
Italy	105.8	121.1	156.2	181.5
Neth.	70.4	81.5	89.7	100.1
Norway	25.6	29.4	28.0	33.3
Japan	136.0	172.4	204.9	246.1
Spain	96.6	116.9	131.1	147.0
Sweden	38.1	46.2	46.4	53.3
Switz.	29.1	35.1	49.5	52.6
U.K.	145.1	170.2	179.0	199.8
U.S.A.	235.2	287.0	350.8	405.7

Expected Trade = Expected Imports + Expected Exports

Source: See Section, «The Variables and Their Proxies».

TABLE D2

EXPECTED MINIMUM IMPORTS AND EXPORTS

Billions of U.S. Dollars (1975=100)

	Minimum Exports 1976	Minimum Exports 1981	Minimum Imports 1976	Minimum Imports 1981
Australia	13.5	15.8	13.5	16.9
Austria	12.2	19.1	13.1	17.9
Canada	35.6	51.4	39.2	45.8
Denmark	8.6	11.4	8.7	9.8
Finland	5.8	11.7	8.3	8.7
France	56.6	84.4	51.8	89.0
Germany	80.4	119.6	77.9	113.9
Italy	56.5	73.3	49.3	83.0
Neth.	36.6	45.3	33.8	44.4
Norway	12.0	15.7	13.7	12.4
Japan	72.8	118.5	63.2	86.4
Spain	42.0	66.5	54.6	65.6
Sweden	18.3	23.9	19.8	22.5
Switz.	15.9	23.4	13.1	26.0
U.K.	72.3	90.5	72.9	88.6
U.S.A.	130.7	184.0	104.5	166.9

Source: See Section, «The Variables and Their Proxies».

TABLE D3

SLOPE OF LOSS FUNCTION

($\gamma = X10^{-6}$)

	γ Exports 1976	γ Exports 1981	γ Imports 1976	γ Imports 1981
Australia	94	104	168	135
Austria	85	74	61	130
Canada	33	25	19	16
Denmark	117	70	14	90
Finland	192	118	239	209
France	15	9	20	11
Germany	13	8	18	10
Italy	16	14	14	12
Neth.	32	23	48	33
Norway	104	80	61	59
Japan	10	7	17	14
Spain	16	50	16	50
Sweden	25	21	62	53
Switz.	58	43	53	34
U.K.	23	23	17	17
U.S.A.	5	4	5	4

Source: See Section, «The Variables and Their Proxies».

TABLE D4

DATA CIRCUITS, TELEX MINUTES, COMBINED CIRCUITS & TELEX

	Data Circuits 1976	Data Circuits 1981	Telex* Minutes (Millions) 1977	Telex* Minutes (Millions) 1981	Combined** (Millions) 1976	Combined** (Millions) 1981
	1	2	3	4	5	6
Australia	22	36	16.2	27.5	31.1	53.4
Austria	39	66	35.7	43.4	63.8	90.9
Canada	397	503	37.6	49.6	323.4	411.7
Denmark	105	172	34.2	41.2	109.8	165.0
Finland	18	41	15.6	21.5	28.5	51.0
France	176	297	121.4	171.3	248.1	385.2
Germany	324	663	189.7	242.1	423.0	719.5
Italy	32	155	78.6	128.8	101.6	240.4
Neth.	103	338	85.4	135.5	159.6	378.9
Norway	33	96	26.0	41.3	49.7	110.4
Japan	7	31	35.6	42.7	40.7	65.1
Spain	54	76	37.1	51.6	76.0	106.4
Sweden	54	245	39.8	46.6	78.7	223.0
Switz.	90	171	77.3	95.0	142.1	218.1
U.K.	271	724	177.2	268.9	372.3	790.5
U.S.A.	1522	1755	124.2	194.7	1220.1	1458.4

Telex Minutes = Total Inwards Minutes + Total Outward Minutes.

** The weighting scheme to combine Data Circuits and Telex Minutes is in the Section «The Variables and Their Proxies».

Source: 1,2: Bergendorff, H., «International Data Communications in the OECD Area: 1976 and 1981, Expert Group on Transborder Data Flows, OECD, DSTI/ICCP/82.27, Paris, 1982.

3,4: ITU, «International Telex Connections», 1977 and 1981.

TABLE 5D

TOTAL TRADE, GDP

(Billions of U.S. Dollars (1975=100))

	Total Trade 1975	Total Trade 1980	GDP 1975	GDP 1980
Australia	28.6	34.7	95.3	109.0
Austria	25.0	36.6	37.5	45.5
Canada	78.8	98.4	164.0	190.5
Denmark	17.7	21.7	29.0	32.9
Finland	15.1	20.4	27.5	32.0
France	112.9	168.2	294.0	345.8
Germany	161.6	224.8	344.7	496.3
Italy	109.3	159.7	240.2	290.1
Neth.	73.0	90.8	72.2	81.8
Norway	25.7	29.8	28.4	35.9
Japan	139.9	208.9	547.3	696.7
Spain	97.8	131.9	320.1	353.8
Sweden	41.0	48.2	72.2	77.1
Switz.	32.6	47.2	54.3	58.9
U.K.	152.6	189.6	284.4	302.3
U.S.A.	251.2	352.4	1538.8	2587.4

Total Trade = Exports + Imports

Source: OECD, «National Accounts», Detailed Tables, 1963-1980.

TABLE 6D

OPERATING SURPLUS, GDP

(Current Value, Local Currency)

	Operating Surplus (Billions) 1975	Operating Surplus (Billions) 1980	GDP (Billions) 1975	GDP (Billions) 1980
Australia	17.8	34.8	72.8	131.1
Austria	133.2	210.8	656.7	995.9
Canada	36.6	70.5	116.8	296.2
Denmark	48.1	77.6	216.3	374.1
Finland	21.1	38.0	101.9	186.1
France	334.8	564.4	1452.3	2754.9
Germany	223.3	318.0	1034.0	1488.9
Italy	33263	95718	125378	337402
Neth.	42.8	73.0	209.4	333.3
Norway	24.2	68.7	148.7	283.5
Japan	40.9	60.7	148.3	234.9
Spain	1921.0	4778.0	6018.3	15075.9
Sweden	53.2	82.5	299.8	523.1
Switz.	32.3	38.0	140.2	170.0
U.K.	14.4	31.4	106.6	225.0
U.S.A.	269.8	440.6	1538.8	2587.4

Source: OECD, «National Accounts, Detailed Tables, 1963-1980.

TABLE D7

PGNE, PPP/EXCHANGE RATE, CIRCUIT PRICE, HARBISON MYERS INDEX

	PGNE (1975=100) 1980	PPP/ Exchange Rate 1975	Circuit Price (1975=100) 1975	Circuit Price (1975=100) 1981	HM Index 1976	HM Index 1981
	1	2	3	4	5	6
Australia	157.4	0.764*	4159	3820	.62824	.60000
Austria	127.8	17.500	5062	3624	.51153	.49868
Canada	152.9	1.017*	3788	2953	.84006	.72105
Denmark	152.4	7.460	4063	4798	.68876	.61447
Finland	157.1	3.700*	4473	4776	.51009	.50132
France	161.3	4.940	4243	3522	.62536	.56842
Germany	120.9	3.000	6045	4088	.58357	.54474
Italy	222.9	522.000	4209	9964	.60375	.58158
Neth.	140.4	2.900	6263	2464	.62392	.62763
Norway	151.0	5.230*	4354	4893	.59222	.57895
Japan	124.4	271.000	6269	3745	.62824	.63816
Spain	226.7	18.800	16120	10754	.55043	.55658
Sweden	163.4	4.150*	4766	3181	.67435	.72237
Switz.	111.8	2.580*	3144	4155	.45879	.46132
U.K.	198.5	0.375	2171	2684	.54035	.50132
U.S.A.	142.0	1.000	4630	2588	1.00000	1.00000

* Exchange was used since PPP was not available.

Source: 1,2: OECD, «National Accounts», Detailed Tables, 1963-1980.

3,4: Teleglobe Canada.

5,6: UNESCO, «Statistical Yearbook», 1981, Table 3.2.

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