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I. Introduction

This paper discusses some of the basic economic issues concerning the public role in provision of scientific information (SI). Governments have a wide range of involvement in the provision of SI, ranging from meteorological information (MI) and weather forecasting through other kinds of forecasting (air pollution, ice, climate, avalanches, earthquakes) to health and product safety information. We leave aside the latter and concentrate on SI about the natural world.[1]

The first issue we face is whether scientific information (SI) should be provided publicly or privately. If the decision is to provide it publicly one must then choose (i) whether to also *produce* it publicly, or to contract out, (ii) how much to produce, and (iii) how to allocate SI among users. The last heading includes the decision of whether to charge a price, and if so how much. If the decision is to allow SI to be provided wholly or in part by the private sector then there are questions of whether this private activity should be regulated in some way. Clearly, there are many important decisions to make.

There has been a significant amount of previous work on the economics of SI. (See e.g. Zillman and Fairbairn, 2001; Lazo and Chestnut, 2002; and Weiss, 2002.) Much of this has been concerned with MI. Lately the field has broadened as the advent of the internet has made it technically possible to disseminate information more cheaply (see e.g. Stiglitz et al., 2000). Much of the work on MI seeks to establish its economic value. It is well-established that the benefits of MI are sizable, and much greater than the costs incurred by typical national meterorological services to produce it.[2] This is important information but lacks the immediate policy significance that it might at first glance appear to have. That is because a high benefit-cost ratio is evidence of the average

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[1] There are important parallels between government provision of physical SI and social SI. Gathering basic weather data, for example, is analogous to conducting surveys of households or firms. There are parallel issues re the diseemination and pricing of data, the extent to which public agencies should conduct “value added” studies with the data collected, and so on.

[2] Lazo and Chestnut (2002), for example, estimate that the aggregate national value of weather forecasts in the U.S. is $11.4 billion per year, which gives a benefit-cost ratio of 4.4 to 1. This ratio is at the low end of the range of international estimates, which range up to 10:1.

payoff to existing services rather than of the return to additional, that is marginal, services. Marginal returns may differ considerably from average returns.

The existing literature has drawn a distinction between "basic" and "value-added" SI. Many authors have argued that basic SI, for example raw weather data, is a public good and should be freely provided by government or its agencies. They sometimes go on to say that it would in principle be appropriate to charge a fee equal to the marginal cost of disseminating this information, but that collection costs are often too large to make this advisable. We agree with this advice but find that there is more to say. For example, if scientific information has positive externalities it can be argued that the public sector should do more than make basic SI freely available. In some cases it should take steps to reduce the private costs individuals bear in accessing information even when no charge is levied for it.

In contrast to basic SI, the literature has not reached a consensus about public provision of "value added" services, such as custom forecasts for particular enterprises, e.g. NAV Canada.[3] To some it seems clear that this kind of work is best left to private firms. This is the official view in the U.S., for example, where the national weather service is explicitly prevented from providing any service that *could* be provided privately. (See Stiglitz et al., 2000.) Adoption of a similar approach in Canada was urged by CMOS (2001). Others see the provision of commercial services by public agencies as beneficial. This view is reflected in the increasing level of commercial activity undertaken by many national weather services around the globe in recent years. The lack of consensus in this area has contributed to confusion about the demarcation between public and private spheres and to calls for clear and firm guidelines on that division to be provided.[4]

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[3] NAV Canada has owned and operated Canada's air navigation system for the last seven years. It is a non-share private corporation owned by its "stakeholders", principally the aviation industry and the federal government. NAV Can is a major purchaser of services from the Meteorological Service of Canada (MSC).

[4] Such calls provided part of the impetus for the formation of the Committee on Partnerships in Weather and Climate Services in the U.S., which had representatives from the National Weather Service (NWS), universities, and the private sector. The Committee rejected the call for rigid demarcation, calling for more flexibility in order to ensure that activities are located where most efficient. See National Research Council (2003).

Most past economic analysis of SI has used a "first best" approach. First-best results tell us what we should do to achieve efficiency assuming there are no distortions aside from those directly related to SI. While first-best results are interesting and important, modern public economics checks to see if "second-best" results differ. Second-best analysis asks what is the best that can be done, recognizing the existence of other distortions. In this paper we bring in second-best results.[5]

We begin our discussion below by reviewing the different kinds of SI and their important economic properties. We go on to discuss some of the classic reasons that have been advanced for public intervention: public goods, natural monopoly and externalities. We then examine some of the implications of risk and insurance, and conclude by discussing the current Canadian situation.

It should be noted that the basis for the analysis in this paper is the *public interest* view of government. This view assumes that the government and its civil service attempt to maximize public welfare. They are not pursuing purely political goals or the expansion of government for its own sake. In the real world those in the public sector may not be as high-minded as we assume. However, our analysis is still relevant and necessary. It tries to say what governments *should* do. The results of such analysis may provide ammunition and insight for those attempting to push government toward acting in the public interest.

[5] An interesting attempt to inject some second-best thinking into the debate was made by HLB Decision Economics Inc. (2001, pp. vii – viii) in the context of determining an appropriate price for meteorological services.

II. Kinds of Scientific Information and Their Properties

Basic vs. Value-Added Services

SI exists on a continuum from raw to highly processed. To illustrate consider "met" information (MI). An example of raw MI would be the observation that it was 8 degrees C at Pearson International Airport at a certain time. Slightly less raw MI would be a list of temperatures observed at stations across the nation or around the world, organized according to geography - - for example plotted on a map. More highly processed MI could take the form of a standard weather map, with highs, lows, fronts and other features charted. Weather forecasts would represent even more highly processed MI.

It is often pointed out that early stages in the chain of SI production tend to be more capital intensive than later stages, since e.g. they involve the use of sophisticated equipment for detection and measurement. In the MI case this is seen very clearly, where an expensive measurement infrastructure must be maintained. Computers and other equipment are, of course, necessary at later stages, but so are the inputs of many meteorologists, computer programmers, and technicians. The result is that later stages of MI production are labor intensive relative to earlier stages.

A distinction is made in the MI literature between *basic* services and more specialized or *value added* services. The term basic services is used to refer to those services which it has been determined should be provided for free, or for a small fee, by government or its agencies. Examples are basic weather or other environmental data, general weather forecasts, and storm or disaster warnings. Since the services that do not fall in the basic category generally combine basic SI with other inputs to produce more highly processed information, they are referred to as “value added” services.

The view that certain forms of SI should be provided publicly must be based on the belief that there is a “market failure” that prevents private markets from being able to provide these services efficiently. The most common reasons given for failure in the case of basic

SI, “SIB”, are (i) use of SIB is non-rival; that is it is a “public good” in economists’ language and it is inefficient to charge more than a small dissemination fee for access to it, and (ii) production of SIB may exhibit increasing returns to scale, making it a natural monopoly. The public goods argument says that private provision is a bad idea since a private firm would have to charge an inefficiently high price to break even. The natural monopoly story says that an unregulated private firm would charge an inefficiently high price. It is sometimes also claimed that private provision is impossible since public goods are “non-excludable”. However, it is perfectly possible to exclude people from access to information, as we shall discuss below. The public goods argument must therefore rest on the non-rivalness of SI consumption.

Like basic SI, value-added SI, “SIV”, is also in the excludable public goods category. The difference is that it is usually of interest not to the general public, but to a single user or user group. While in the case of SIB attempts to achieve cost-recovery may be very inefficient, if it is socially efficient to provide some form of SIV then its provider should be able to negotiate a contract with the client group that will cover costs without creating inefficiency. If such a contract cannot be concluded it must be that the clients’ willingness to pay is less than the total cost of the service, in which case it would be socially inefficient to provide it. Since cost-recovery need not cause inefficiency for SIV, private provision is not ruled out. Indeed, as mentioned earlier, some observers believe that private provision is preferable to public in this case. We discuss this point further in Section V.

Scientific Information and Risk

Much SI is valuable because it can be used to reduce risk. There are two major categories: risk assessments and warnings. Risk assessments may be highly specialized. When a bridge is built, for example, it may be important to know the risks of damage due to wind, ice, or earthquakes. Risks of environmental damage due to the construction or the presence of the bridge may also need to be evaluated, as may the change in risks borne by users.[6] Similar assessments are needed when major buildings are constructed. In these cases much of the information required is specific to a particular project. However, analyses of the risk from earthquakes or severe weather may also be valuable to a large number of users in a particular city or region.

Risk assessments are important in making long-term decisions. In contrast, *warnings* have a critical impact in the short-run. Much SI can provide explicit or implicit warnings.[7] Weather forecasts are interesting partly because they may predict weather conditions with adverse consequences. Information about the air or water may also provide warnings: e.g. smog or UV alerts and warnings not to swim at a particular beach or to boil water for drinking purposes. Warnings are valuable because they reduce the risks faced by those who hear and heed them. This can lead to reduced chances of accidents, death and injury, and it can also reduce costs and increase output in industries such as agriculture, fishing, and transportation.

Quantity vs. Quality

Should we distinguish between the quantity and quality of SI? At first it might appear the answer is yes. Weather forecasts may differ in detail or reliability, that is in quality. On the other hand, saying that a forecast is better means that it is more informative. That is, it contains more information, which is a question of quantity. We believe that while it is useful to talk about the quality of forecasts, reports, or data, it is not useful to think in terms of the quality *of SI*. More information and better information are the same thing from the economic viewpoint.

[6] Note that the latter change may be negative. A new or expanded bridge may easily reduce risks for travellers.

[7] We are using the term "warnings" in a broad sense. In meteorological operations the term of course has a specific technical meaning, which is much more limited. A forecast of rain will warn organizers of outdoor events to consider their options, but it does not occasion an official weather warning.

Final vs. Intermediate Goods

Intermediate goods are used in the production of other goods while final goods are consumed by end-users. The treatment of these goods recommended by modern public economics differs significantly. For example, for final private goods optimal commodity tax theory says that differences in tax rates on different goods and services are generally desirable. The goal is to ensure that the marginal distortion caused by taxing different goods is equalized. (See Atkinson and Stiglitz, 1980, Ch. 12.) But for intermediate goods the recommendation is very different. Either they should not be taxed at all, which is the ostensible aim in most OECD countries[8], or they should all be taxed at the same rate. The goal is to prevent distortions in production, which would push society below its production possibility frontier (PPF). The prices of intermediate private goods should be proportional to their marginal costs. This statement, which is due to Diamond and Mirrlees (1971) is known as the *production efficiency theorem*.

Some SI goes directly to consumers and represents a final good. For example, many of those monitoring weather forecasts are doing so in their private role as householders or consumers. What price they should pay is theoretically a complex issue, but in practice there are good reasons to provide this information freely. On the other hand, SI being used by private firms as part of their business operations is an intermediate good and should be approached differently.

Recently, careful attention has been paid to the optimal pricing of excludable final public goods (Hellwig, 2004). While we are not aware of any parallel investigation for excludable intermediate public goods, our conjecture is that the implications of the production efficiency theorem would be preserved in such a study. That is, the goal would be to keep society on its PPF. If private intermediate goods are not being taxed, which is roughly the situation in Canada and most other OECD countries today, and

[8] The major form of commodity tax in most OECD countries is a consumption-type VAT. Canada's GST is an example. Such a tax removes the burden from intermediate goods through the operation of the credit-invoice mechanism. Attempts are also made to prevent retail sales taxes, levied e.g. by some Canadian provinces and U.S. states, from falling on intermediate goods. These attempts are less successful.

assuming competitive markets, the price of these goods will tend to equal their marginal cost. Marginal cost reflects the true opportunity cost of these goods. In order to maintain a level playing field and stay on the PPF, the price of public intermediate goods should also equal opportunity cost.

What is the opportunity cost of a public intermediate good? It is the true cost of allowing access to the public good. If there is a single user, or users are organized into a group that contracts with the public supplier, this cost equals the total cost of producing the good, *TC*. This corresponds to average cost (*AC*) pricing in an accounting sense.[9] But if there are multiple (perhaps many) users, the cost of allowing access to an additional user is simply the marginal cost of dissemination, MC_F. In such a case SI should be provided to private firms at a price, *P*, equal to MC_F .

Above we said that in order to maintain a level playing field and stay on society's PPF, the price of public intermediate goods should equal opportunity cost. It pays to consider this statement a little more closely. One reason it is true is that private firms are combining SI inputs with other inputs, and if, say, SI is priced too high, too little will be used relative to other inputs. But we should also note that the public sector uses basic SI as an input. Raw data is used as an input into forecasting, and basic forecasts are an input for value-added products. The "price" of basic SI to the public sector is automatically given by its opportunity cost. This means that if private firms were, say, charged more than this cost, they would be at a competitive disadvantage. This would result in too much SI production being located in the public sector.

The above arguments are static. They could be reinforced by some dynamic considerations. The larger the private SI sector, it could be argued, the more innovation is likely to take place. Thus, if basic SI were overpriced and the private sector was as a

[9] Note that in this setting it is generally not efficient to set a price equal to average cost and allow the customers to choose the quantity they will consume freely. Rather a contract is negotiated specifying a total payment and a quantity. (See the discussion below in Section V.) The unit cost to the purchasers will be *AC*, but this is the price only in an accounting sense.

result too small, there could be not only a static welfare loss but a dynamic one as well, due to a reduced rate of technical change and product development in the industry.

III. Public Goods, Natural Monopoly and Public Provision

Economists are hesitant to prescribe public intervention in markets. They only do so when market failure is credibly established. Such failure occurs when the conditions that would prevail in private markets prevent the achievement of economic (i.e. "social") efficiency. Market failure does not necessitate the replacement of the private market for a good or service by public provision. In some cases special taxes, subsidies, or regulation may provide better solutions. However, in the case of SI it has been widely argued that there are two sources of market failure that justify public provision: public goods and natural monopoly.

The case of pure public goods provides the strongest justification for public provision. Pure public goods are defined as those goods that are both non-rival in consumption and non-excludable. If the government does not provide them, a few individuals who value these goods highly may pay for them privately, but the amount so provided will generally be too small. (See Bergstrom, Blume and Varian, 1986.) The widely recommended solution is for the government to provide the good, and to try to do so at an optimal level. Given non-excludability it is not possible to charge a fee for use of the publicly provided good. Instead the required funding must be obtained through some form of taxation.[10]

Even in the case of a pure public good, it is important to note that the good does not necessarily have to be produced publicly. The government may purchase from private suppliers and provide to the public. The argument for public provision is that private

[10] In the public economics literature there has been discussion of the use of "Lindahl prices" to fund a pure public good. These are not prices in the normal sense. They are individually-differentiated taxes based on individual benefits from the good. Lindahl prices are of theoretical rather than practical significance. See Atkinson and Stiglitz (1980, Ch. 16).

financing will not lead to sufficient provision of a pure public good. Government must come to the rescue since it has the power to tax in order to raise the required funding.

Excludable Public Goods

In the real world there are few truly pure public goods. The textbook list of candidates includes a few services like national defence, but often goods that are non-rival turn out to be excludable, and non-excludable goods turn out to be rival.[11] Such goods are termed impure public goods. Most forms of SI fall into the non-rival but excludable category: one person's consumption of information does not reduce the amount that may be consumed by others, but use of information can be limited to those who have obtained the legal right to use it.

Sandmo (1973) provides an example of how excludability can work that is relevant here. He considers a model where pure public goods are consumed jointly with technologically private goods. Pure SI, which is a public good, and dissemination of SI, which is a private good, provide an example of this. If the producer of a pure public good controls the production of the jointly consumed private good then it can exclude people from the public good by withholding the associated private good. In the SI case, since government can control its dissemination, SI becomes an excludable public good.

Excludability makes charging a price for access to a public good viable. Take the provision of weather forecast information via a telephone dial-up service for example. Rollins and Shaykewich (2003) studied the provision of such a service with a user fee by the Meteorological Service of Canada (MSC) in Toronto. The service did a brisk business. If MI were non-excludable this would have been impossible. Another example is provided in the often lucrative operations of satellite or cable TV, where the signal is a non-rival good but access can be finely controlled.

[11] Non-excludable rival goods can generate the "tragedy of the commons", where a common resource, such as a fishery, forest, or water supply, is over-used.

Suppose that an excludable public good is provided publicly. What price should be charged? We will answer this question in stages. Note first that it is not appropriate to charge for basic services if (i) collection or compliance costs are too high or (ii) consumption of these services has sufficiently large positive externalities (as discussed more below). Collection and compliance costs for many services have been greatly reduced by changes in technology. In those cases, if externalities are not sizable, charging for access would be efficient. There is no doubt ample justification for continuing to make freely available most forms of basic SI that are already disseminated freely. However, we believe that careful consideration should be given to levying user charges for access to new services. For example, if new weather forecasts of interest to producers in particular industries or to specific types of recreational users are being considered, a user charge could be appropriate.[12]

In first-best analysis the user fee should be set at the true marginal cost of providing the information to an additional user. Where there are multiple users this cost is the marginal cost of dissemination, MC_F, rather than the marginal cost of producing the underlying information, MC. (See Sandmo, 1973.) In second-best analysis, a higher price might be recommended since the distortion caused by increasing P a small amount is zero when $P = MC_F$. The difference $P - MC_F$ is equivalent to an extra tax on the service. Theoretically, the idea should be to set this "tax" optimally relative to the treatment of other commodities.[13] In the absence of some strong argument to discriminate between SI vs. other goods and services, however, setting $P = MC_F$ is the right approach. Normal sales taxes - - GST and provincial sales tax - - would then be added to P just as they are for other commodities.

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[12] A tactical advantage of levying such a fee, from the viewpoint of SI promoters, is that proposals for new services get a better reception from government and may be introduced more quickly if they are at least partially self-funding.

[13] In optimal commodity tax theory higher prices should be levied on goods whose elasticity of demand is lower, those which are more complementary with leisure than other goods (in order to offset the labor-leisure distortion caused by the tax system as a whole, or those consumed more heavily by higher-income groups (if there is an equity as well as efficiency goal). See Atkinson and Stiglitz (1980, Ch. 12). Bös (1994) shows that the argument applies to private goods produced in the public sector, and Hellwig (2004) extends the argument to excludable public goods.

Finally, note that by allowing a price to be charged, excludability also makes a private market more viable and makes the issue of public vs. private provision a potentially hotter one. It is therefore not surprising that there has been considerable debate in a number of countries about where to draw the line between public services and private initiative in the provision of scientific information, for example.

Natural Monopoly

While excludability weakens the case for public provision, the possibility of natural monopoly works in the other direction. A natural monopoly exists where, if a good were provided privately, in equilibrium there would only be one firm. This may occur if there are economies of scale[14] that are not exhausted when the market is served by a single firm. The typical cost-structure that will produce this result has large fixed costs and low operating costs, as seen for example in an automated system of environmental observation and forecasting.

Monopolies are inefficient since they charge a price above marginal cost in order to maximize profits. In cases of natural monopoly (or perceived natural monopoly) governments either take over the service and provide it directly (e.g. nationalized railways, airlines and telecommunications in many countries in the past), or regulate prices and other variables (as in cable systems, natural gas or electricity in most Canadian provinces at present).

Claims that a particular industry is a natural monopoly should always be treated critically. Natural monopoly is dependent on technology and may disappear with technological change. At one time it was widely accepted, for example, that telephone service was a natural monopoly. With current technology, however, competition between providers is possible and is now widely allowed. In many transportation and communications markets there appears to be a natural monopoly in much of the basic infrastructure but no reason not to have sustainable competition between firms using that infrastructure. It may be that markets for SI are headed in this direction. In the MI case, the data collection operation is likely still a natural monopoly and needs to be publicly provided or regulated. Specialized forecast services, however, can be competitively provided, as is illustrated by the growing operations of private forecasters in Canada, the U.S. and other countries. It is unclear to us, however, whether basic weather forecasting can still be considered a natural monopoly. Major national weather services like the MSC, or NWS in the U.S., use large supercomputers to prepare their general forecasts. If this implies a large sunk cost for an entrant to the industry, there is a barrier to entry that could make basic forecasting a natural monopoly. (See Baumol et al., 1982.) On the other hand, if supercomputer time can be readily leased, entry should be feasible. The market for basic forecasting would be contestable and there would not be a natural monopoly.

When the natural monopoly possibility is added to the non-rival nature of basic SI, one obtains a stronger argument for public provision. Still, it should be noted that this does not preclude contracting-out in the production of such SI. Given the wave of privatization and contracting-out that has swept so many countries in the last two decades, it is perhaps surprising that calls for such an approach in the provision of basic SI have largely not been heard. What could be the reason for this omission on the part of private sector advocates? The answer is unclear. It may be, in part, just that the private sector sees gaining exclusive sway in value-added services as a more realistic and attractive goal for the present. There could also be concerns that if basic services were privatized their price could increase. Downstream SI firms are intensive of basic SI services, and might therefore oppose the privatization of basic SI.

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[14] Economies of scale in the production of a good exist when long-run average cost, LAC, declines with the level of output, Q. LAC is defined as the lowest AC of producing Q that can be achieved when all input characteristics, including plant size, are freely variable.

Optimal Level of Basic SI

How much basic SI should be provided, and how should it be funded?[15] The "how much" question is easy in theory, at least in a first-best world. There is a simple rule for efficient provision of a pure public good, known as the Samuelson Rule.[16] Suppose there will be *n* users of the good, indexed $i = 1, \ldots, n$. As illustrated in Figure 1, the public good should be provided up to the point where the sum of the marginal benefits to users, ΣMB_i, equals the marginal cost of producing the good, *MC*.[17] In practice the rule is often difficult to apply since it is hard to measure the MB_i 's. But we will ignore this problem for the time being.

In first-best theory the funding question is also easy. If the government can levy lump sum taxes (e.g. poll taxes), then it could do so to pay for the pure public good without causing inefficiency. Since true lump sum taxes are unpopular or impossible to impose, in practice some less efficient arrangement must be made. This brings us into the world of the second-best. In effect, provision of the public good becomes more expensive. Each dollar spent on the public good costs society more than a dollar, since it imposes distortionary damage on the economy. The true cost of a dollar spent by the government, or marginal cost of public funds, *MCPF*, has been estimated to lie anywhere between $1.07 and $2.50 depending on which tax is being used to raise additional revenue.[18] A rough average rate would be in the neighbourhood of $1.40 - $1.60. Taking this into account, the public good should be provided at the level where $\Sigma MB_i = MCPF \times MC$. Since this requires that marginal benefits should be higher, and marginal benefits are declining with the level of provision as illustrated in Figure 1, the socially optimal level of the public good is lower when the *MCPF* is taken into account.

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[15] In answering this question we abstract here from dissemination costs. The latter may be incorporated in the analysis, without changing the essential conclusions, by assuming that the public good is jointly consumed with a private good, dissemination. See Sandmo (1973).
[16] The rule originated in Samuleson (1954).
[17] Note that the negative slope of the ΣMB_i curve reflects the assumption that the marginal benefit of SI is declining. This reflects the economic principle of imperfect substitution. It is also supported by empirical evidence, e.g. on people's willingness to pay for increased weather information. See Gunasekera (2003).

Finally, we should note that a prior question should be asked, which is whether the SI service should be provided at all. We skipped over this question, since it is hard to imagine society deciding to do without SI entirely. However, the analysis we have been doing could be applied to particular *types* of SIB. It might not be efficient to produce some of these. For example, we forecast ice cover and movements for some bodies of water in or around Canada but not all. The costs of doing so would exceed the benefits.

In order to answer the question of whether some form of SIB should be provided at all, we have to think in terms of total benefits, *TB*, and total costs, *TC*. In Figure 1 the total benefits of providing SI at the level *SI** equals the area under the ΣMB_i curve from the origin to point D, that is area OBCD. The diagram also shows a portion of the total costs; the area under the *MC* curve, that is OACD, gives us total variable cost, *TVC*. But the diagram does not reflect fixed costs, *FC*. If they are not too large, we will have $TB > TVC + FC = TC$. But it is possible for the inequality to go the other way, in which case although *SI** would be the optimal amount to provide *if the service were provided*, it would be better not to provide the service at all.

IV. Externalities

When people consume SI they may confer benefits on others as well as themselves. They may also impose costs. These effects are known as externalities. There are two broad types: pecuniary and technological. Pecuniary externalities are the result of price changes. For example, if better weather forecasts make skiing more popular, the equilibrium prices of ski passes and other services in ski areas may increase. But this has no implications for whether the better forecasts are socially desirable. A price increase benefits producers but harms consumers by an offsetting amount. The two effects net out. In contrast, technological externalities must be included in cost-benefit analysis

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[18] See e.g. Dahlby (1994). It is widely believed that the *MCPF* is largest for corporate income tax and other taxes falling on capital income. The *MCPF* for labor income taxes is generally estimated to lie between

since they confer benefits or impose costs that are not automatically offset by opposing impacts on others.

Technological externalities result when the welfare of an agent or agents is affected by the choice of real variables by others, and this effect does not occur through the market. (See e.g. Myles, 1995, Ch. 10.) An example of a positive technological externality occurs as a result of rational reactions of drivers to weather warnings. If I decide not to drive when I hear that snow and ice are forecast those who do drive have a slightly reduced risk of accident. (They can't collide with *me*.) On the other hand, a negative technological externality is created if I dam my property when a flood is forecast and this reduces a neighbour's drainage. Clearly, making forecasts more accessible will increase the likelihood of positive externalities in the one case and of negative externalities in the other. If we believe that, on balance, the positive externalities are more important, this provides an argument for reducing the price of SI.[19] If that price has already been set at zero, there is then a possible argument for expending resources to reduce the private costs of accessing forecasts that consumers would otherwise bear - - in effect subsidizing the consumption of forecasts. Such subsidies can take many forms, for example delivering special warnings through text running across the bottom of TV screens, interruptions of radio broadcasts, or warning signs posted at the entrance to motorways.

Figure 2 illustrates. We assume that the marginal cost of disseminating forecasts, $MC_{F,}$ is zero, and government charges a zero price for access to SI. SI will be represented by weather forecasts, and the amount of SI the individual consumes is given by the frequency with which he/she checks the forecast. Private costs of accessing SI may be thought of as reducing the marginal private benefit, MB_i . The individual consumes forecasts up to the point where $MB_i = P = 0$. Due to externalities, as the diagram illustrates and as we argued above, it may be socially optimal for an individual to listen to more weather forecasts than he would listen to voluntarily even with a zero price. This implies the need to *subsidize* listening to forecasts, by reducing the individual's access

about $1.10 and $1.30.

costs. Conceptually, this raises the private MB_i curve in Figure 2 to bring it closer to the SMB_i curve, reducing the gap between voluntary private monitoring of forecasts and socially optimal behavior. Still, there is a limit to how much private costs can be reduced, so it may not be possible to achieve complete efficiency in this way.

The externalities argument also has some impact in an area we haven't discussed yet, the determination of the optimal *quality* of forecasts or SI reports. Again consider the case of warnings. Warnings will be more valuable the more detailed or reliable they are. A reliable warning that there is a 10% probability of an avalanche at a particular mountain resort would be more valuable than a vague warning that avalanches may occur in a wide area. People should be more likely to monitor forecasts if they believe they are reliable, and if they are targeted better by location. But of course there is an increasing cost of producing more reliable and detailed forecasts, and beyond some point it will be inefficient to raise forecast quality further.

While the externalities argument appears powerful, it has long been known that externality problems can, in principle, be addressed by assigning enforceable property rights.[20] Our legal system denies, for example, that others have the right to smash their cars into mine. I have a right to compensation. If fair compensation is enforced that is enough to make rational drivers internalize their impacts on others, resulting in socially efficient decisions about whether to go on the road, how fast to drive, and so on, in view of actual and forecast conditions. With socially optimal decisions being made there is no longer any argument for subsidizing the dissemination of weather forecasts or boosting their quality relative to what would otherwise be desirable. However, there is a good argument that even though compensation must be paid when accidents are inflicted, drivers do not properly internalize the costs they inflict on others. This is because of insurance.

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[19] In principle one should also ask if the *production* of SI has any externalities. Externalities on the SI production side are, on average, likely small and we will leave them aside in our discussion.
[20] This point was originally made by Coase (1960).

All drivers are legally required to carry insurance. In addition, a large part of the medical expense that will be incurred due to injury is covered by public health insurance. These insurance aspects defeat the internalization of externalities; insurers pay compensation, not the individual driver. This means that the externalities argument made above does have force. In short, despite the assignment of enforceable property rights, there is an argument from externalities for public subsidies to dissemination of weather forecasts and a possible argument for boosting their quality to induce greater public attention to be paid to them.

V. Value-Added SI : Provision, Pricing, and Interactions with Basic SI

How much SIB is produced has implications for the market in value-added SI, or SIV. And, in turn, the amount of SIV produced affects the optimal provision of SIB. In a nutshell, an exogenous increase in the provision of either form of SI tends to increase the benefits of, and demand for, the other form. Thus the two forms of SI are mutually reinforcing.

The more SIB is produced the easier, and cheaper, it becomes to produce SIV of given quality. For example, in the weather case the more observing posts there are, or the better the computer programs used to generate basic forecasts, the more information is contained in basic weather records and forecasts. Improved basic services should make it cheaper to provide value-added forecasts or weather risk assessments. This means that the socially optimal amount of SIV will tend to rise when there is an independent increase in SIB.

In practical terms, we know that over time the amount of basic scientific information produced by public agencies, universities, and other organizations has increased greatly. With the advent of the internet and other IT developments, dissemination of basic data and analyses has also become cheaper. The result is that the optimal amount of SIV has likely increased significantly. Observed growth in publicly provided value-added services, and also in the private SI sector, indicate that, qualitatively, our public institutions and markets are responding appropriately. Whether the response has also been appropriate quantitatively is an open question.

Independent growth in SIV has a feedback effect on the optimal output of basic services. A larger SIV industry means that the benefits of having any given amount of SIB are greater. In terms of our Figure 1, the ΣMB_i curve is higher, and optimal SIB output is greater. Hence if there is increased demand for SIV this provides justification for increased output of basic SI services.

Who Should Provide SIV?

Some believe that SIV should be provided exclusively by the private sector. (See e.g. CMOS, 2001.) Such a conclusion could be based on the following: (i) there is no distortion in excluding non-payers since SIV is typically of interest to a single user or user group, and (ii) private sector firms may be more "x-efficient"[21] or more innovative than a public agency, that is they can do the same job more cheaply or can deliver different products or services. There are problems with this argument. Most seriously, there is reason to believe that the public sector may sometimes be able to provide SIV more cheaply than the private sector due to economies of scope in producing basic and value-added SI jointly.[22]

Why should there be economies of scope in producing SIB and SIV jointly? One reason is that some of the inputs used in producing SIV are the same as those used in producing SIB. If the same organization produces both, it may be able to share those inputs across SIV and SIB in order to achieve lower costs. For example, in order to provide a prediction about the distribution of wind speeds, temperatures, and precipitation for a

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[21] An organization is more x-efficient if, for given available inputs and input prices, it can produce given output more cheaply. The concept was originated by Leibenstein (1966).

[22] Let the total cost of producing the amount SIB of basic services be $TC_B = C_B$ (SIB), and let $TC_V = C_V$ (SIV) correspond for value-added services. Further, let $TC_{B,V} = C_{B,V}$ (SIB,SIV) be the total cost of producing the amounts SIB and SIV jointly. Then economies of scope exist when $TC_{B,V} = C_{B,V}$ (SIB,SIV) $< C_B$ (SIB) + C_V (SIV).

particular location by day, month, and time of day over the next 50 years one would need to have a very sophisticated computer model. While runs could be performed on a contract basis for a private firm, making efficient use of such a model depends on close communication with modelers and programmers. Experience shows that this can be done more conveniently and cheaply when the participants are in-house.

From the efficiency viewpoint, a public agency should be open to providing value-added SI where it can do so more cheaply than private firms. Above we argued that the appropriate price for SIV sold to a single user or user group is the total cost of the service provided, *TC*. On a unit basis the user charge equals average cost, *AC*. However, when negotiating with potential users it is important not to suggest that additional units of the service can be added to the contract at a price of *AC*. The total amount charged for the entire contract should be raised by the marginal cost of additional units negotiated.[23]

In some cases private firms will still be able to supply services at a lower price than a public agency, and in some cases the reverse will be true (due to economies of scope). This means that a mixed public/private SIV industry is desirable from the viewpoint of economic efficiency. Private sector advocates may object, however, that (i) we cannot trust public agencies to do their sums correctly; they may under-price their SIV and we will end up with too much public sector production, and (ii) in the absence of clear restrictions on public SIV activities private entry and effort will be discouraged due to the risk of unexpected public entry. While we are doubtful that the first argument has much force (under-pricing SIV results in robbing the agency of resources to conduct its more basic mission), given the disparity in size between the public sector and private firms it is understandable that the latter are nervous about unexpected moves by the former. We would argue, however, that the best policy is not to prohibit public SIV activities, but to insist that (i) sudden entry should not be allowed, (ii) sufficient warning of entry should

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[23] Average cost pricing of SIV by a public provider is urged by HLB Decision Economics Inc. (2001). The literal use of this approach would lead to inefficiency, however, since users would cut back too much on the number of units of service. The approach we suggest - - being prepared to add additional units of service at marginal cost, within an overall negotiated price - - is analytically the same as a two–part tariff in which there is a lump sum payment for access and a per-unit charge according to marginal cost. It is a standard proposition that a two-part tariff can allow both efficiency and cost-recovery to be achieved.

be given to the private sector, and (iii) consultations should occur with private sector representatives to ensure that public entry only occurs where it is genuinely cost-reducing. In cases where public entry would compete directly with private activities, joint public/private initiatives could also be encouraged.[24]

The advocates of "clear guidelines" may not be impressed by the above prescription. It may seem to them to be just a recipe for confusion. We would point out that the argument for a clear line of demarcation between public and private activities in the present context could be viewed as anti-competitive. Private firms are not allowed to make agreements to divide up markets, in order to maintain competitive conditions. Restricting the public sector to a narrow range of activities could have the same effect as such an agreement.

Practical Difficulties in Mixed SIV Industry

While the principles of how a public agency should participate in a mixed public/private industry supplying value-added SI are fairly clear, in practice various difficulties arise, some of which are matters of considerable, and legitimate, concern to private firms. Here is a partial list of problems that can arise:

- Public agency prices its SIB too high: Private firms sometimes feel that public agencies charge too much for access to their detailed raw data. If SIB is priced, for example, at the average cost of production, AC, then the cost of producing SIV will be too high, and the private SI industry will be too small. HLB Decision Economics Inc. (2001) examined the pricing policies of MSC and reported that a price close to AC was being charged for "infrastructure services", which appears to correspond to our concept of SIB.
- Public agency prices its SIV too low: This is a legitimate concern, not only because it will restrict opportunities for private firms, but because it means that the government is, in effect, subsidizing SIV. It will be producing too much SIV, and in effect

[24] The advice provided in this paragraph agrees strongly with that of the National Research Council (2003) *Fair Weather* report in the U.S. The latter was generated by a select committee engaged to determine how responsibilities for meteorological services should be divided between government, the universities, and the

transferring real income to its purchasers. Furthermore, the pricing policy is counterproductive if one reason the public agency has gone into commercial work is to raise revenue to support its core functions. HLB Decision Economics Inc. (2001) reports that the price charged by MSC for value-added services was somewhat below AC due to the omission of an imputed cost of capital. CMOS (2001) adds that an imputation for business taxes borne by private firms but not MSC should also be added in order to ensure a level playing field. These are legitimate points.

- Public agency changes its policy on producing SIV too often: Again this is a legitimate concern, as we have argued above. If there is uncertainty about whether the public agency will participate in the market, or how it will do so, this can deter entry by private firms, leading to too little private production of SIV.

Cross-Subsidy of SIB via Commercial Activities of Public Agencies

It might appear that the above discussion ignores an additional benefit of commercial activities of public agencies that has some implications for the optimal pricing of their services. Sometimes with encouragement from higher levels, public agencies have pursued SIV opportunities in order to obtain additional revenues that can be used to subsidize core functions, that is production of SIB. (Note, however, that the usual allegation is that they under-price their SIV.) The public agency would earn a pure profit in its SIV operations. Is there a double-dividend from this profit? Does its availability justify a higher level of basic SI than would otherwise be the case? For practical purposes, the answer is no.

In standard economic analysis, profits earned by commercial operations do not justify extra output of the core public good produced by a public agency. The reason is that the government should be adjusting all sources of finance, including profits on commercial operations, so that they impose equal marginal distortions on the economy. Thus, when set appropriately, profits on commercial operations are no less distortionary than any

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private sector. The committee recommended flexibility and cooperation rather than rigid demarcation, in order to allow activities to be located according to efficiency considerations.

other form of public finance. In determining the optimal level of SIB we have already taken into account the distortionary nature of public finance by multiplying MC by the marginal cost of public funds, *MCPF*. Now, *if* profits on commercial operations were large they could reduce the need for other forms of public finance enough to reduce *MCPF* and expand the justifiable level of SIB. The problem is that the operations of government are so huge that the profits earned by e.g. value-added meteorological or hydrological services are a tiny fraction of total revenue. Hence, there is no appreciable change in *MCPF*, and no justification for anything other than the smallest increase in SIB over what would otherwise be planned.

Note also that any efficiency gain from collecting revenue via commercial profits should be spread over *all* government provision of public goods and services. Thus, if the profits are non-negligible, there should be a small increase in SIB, but there should also be a small increase in all other public goods. According to standard economic analysis, most of the commercial profits should flow through to support the operations of other areas of government rather than staying with the unit that produces them. This would no doubt appear “unfair” to imaginative civil servants finding ways of earning commercial revenues. A more sophisticated second-best approach would take into account the need to motivate civil servants to generate commercial revenues. This might allow for greater retention of profits in the units producing them, in order to provide appropriate incentives to public managers.

VI. Risk and Insurance

Much work in economic theory and public economics in the last thirty years has been concerned with asymmetric information. In simple economic theory all agents have the same perfect information - - about technology, prices, risks, and so on. Of course the real world isn't like that. A purchaser of insurance, for example, may have a better idea about his true risks than the insurance provider. This leads to problems of adverse selection and moral hazard - - phenomena that extend beyond insurance markets. In the insurance context adverse selection refers to the tendency for higher risk individuals to have higher demand for any given insurance policy, drives up premiums and discourages lower risk people from purchasing insurance. Moral hazard is the tendency for people to take less care once they are insured, which again drives up rates and discourages some people from taking out insurance. Deductibles and co-payments are an attempt to reduce moral hazard.

Once people are insured, they will put less time and effort into reducing or avoiding risks - - even though this tendency is reduced by such devices as deductibles. As we discussed in Section V, this provides added reason, in terms of our Figure 2, for the MB_i curve to lie below the SMB_i curve. That is, private benefits of monitoring information on weather and other risks will be even smaller relative to social marginal benefit. And this tendency will be reinforced if governments adopt the practice of compensating people for catastrophic damages - - which is now general practice in most advanced countries.[25]

If people are highly insured -- by a combination of private insurance and public compensation - - it is possible that the private benefits from information may sink so low that, rather than increasing the quality of information, making it more readily available and so on, as we have discussed above, the best thing for government to do is just to stop providing the information. If people ignore all warnings, then there is no point expending resources to generate them, is there? Less pessimistically, while people will take less care if they are better insured, it may remain efficient to provide them with forecasts. However, Davies and Slivinski (2004) show that in this case the optimal quality of forecast provided will decline under plausible assumptions about technology

[25] To take the example of Ontario, in the absence of federal relief, those suffering damage in natural disasters are eligible for assistance under the Ontario Disaster Relief Assistance Program. Under some circumstances this will even cover insurable damage that victims did not insure. Larger disasters bring federal relief under the Disaster Financial Assistance Arrangements (DFAA) which have been in force since 1970. DFAA assistance is on a sliding scale based on population. As of late 2003, provinces were responsible for all expenses up to $1 per head of population. This means that Ontario received no assistance unless a disaster cost more than $12.6 million. At the top end of the scale, the federal government paid for up to 90% of costs after the province has contributed $5 per capita. In contrast to the provincial scheme, DFAA does not cover risks that can be insured privately at a reasonable cost.

and behaviour. This is due to the fact that the benefit-cost ratio is lower when people are less responsive to forecasts and warnings.

Other important, and frustrating, issues are raised by decisions to locate homes, businesses and other assets in areas with a high risk of property damage due to the forces of nature - - floods, hurricanes, rush or forest fires, and the like. These decisions may sometimes be encouraged by private insurance, and (especially) public compensation schemes. However, it is also worth noting that they have been facilitated by the great improvements in weather and flood forecasting over the last century. The path and behaviour of every tropical storm is now plotted minute-by-minute and broadcast widely, together with predicted path, wind speed, precipitation and so on. Similarly, residents of the Red River Valley receive ample warning of their recurring floods. This makes it possible for individuals to avoid death or injury through evacuation. With generous insurance and compensation for the damage to property, the prospect of hurricane or flood damage becomes acceptable for many individuals and firms. From a social viewpoint the locational decisions that result are very inefficient. It must unfortunately be accepted that this inefficiency would not occur in the absence of accurate forecasts and warnings. Reducing the quality of forecasts in order to offset this effect is clearly not an acceptable option. This means that inefficient locational decisions must be combated by preventing development in vulnerable areas.

VIII. Provision of Basic Scientific Information in Canada

Canada is the second largest country in the world. It therefore has a lot of geography, weather, water, resources and environmental concerns to keep track of! Thus the social benefit of SI is potentially high. At the same time we have a relatively small population, which means that the cost per capita of generating a certain quality of SI for the whole country can be very large.

Over the period since World War II as a whole, the Canadian economy has grown rapidly, in both absolute and per capita terms. The average growth rate of per capita GDP from 1950 to 2000 was 2.2%, and total GDP grew at an average rate of 3.9%.[26] For comparison, these growth rates stood at 2.3% and 3.5% respectively for the U.S. over the same period. Thus, Canada's capacity to support public services has grown at a strong rate. At the same time, however, there have been increasing concerns about the quality of SI provided publicly. There was a sharp reduction in spending on the Environment in the mid 1990's at all levels of government, with a strong impact in such areas as the met service. Over the period of "program review" from 1993 to 1998 there was a 50% reduction in capital spending on meteorological capital, for example, and a 42% reduction in MSC manpower.[27] Investment in much scientific infrastructure has been on a downward trend for the last 20 years or more. Better weather forecasts and warnings are being generated, thanks to technological and other improvements, but the information does not always get to the public effectively. Certainly, meteorologists and other scientists are very aware that with modern technology it would be possible to generate much more information and get it to the public more effectively.

Since the mid 1990's Canada's public finances have improved radically. The federal government has now been in surplus for seven years. Strong economic growth has led to rapidly rising public revenues and the purse strings have been greatly loosened for the high priority spending areas, most notably the health care system. Also, in the late 1990's the federal government adopted a focus on the knowledge based economy as the key to productivity growth and prosperity. Under that initiative it created the Canada Foundation for Innovation, the Canada Research Chairs program, and the Canadian Millenium Scholarship program. Funding for the NSERC and SSHRC granting councils was also substantially increased. These latter initiatives greatly increase resources for basic research and graduate education, which are both complementary with our systems for providing SI.

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[26] These figures are derived from the Penn World Table Version 6.1. They are based on real GDP for each country computed using a chain price index. See http://pwt.econ.upenn.edu/.

Recently we have seen government's increased resources being directed at environmental areas. For example, in March 2004 the federal government announced a $75 million modernization initiative for the MSC. Under this program operations will be concentrated in five storm prediction centres, two aviation weather service offices, and three national service offices. Money will also be spent on recruitment and training, introducing product service enhancements and innovation, and improving equipment.

While there has thus been some recent good news on SI funding in Canada, the main picture over the last 15 years is one of retrenchment. Large spending cuts in Canada contrast with increases in major comparator countries.[28] Even the recent funding increases are small compared to some assessments of the needs. In spite of this, there have been improvements in the quality of weather forecasts and warnings. All this creates a puzzle. Have cuts in Canada been too large, or are we blazing a trail towards rising productivity in SI production that other countries ought to follow?

About half of the mid-1990's cuts in the MSC were in capital spending. Such spending is needed to offset depreciation and upgrade our monitoring systems and other equipment. In the short-run cuts of this type can occur with comparatively little impact on output. This is probably a large part of the secret of how expenditure cuts could occur alongside improvements in forecasting. Another part of the story is that technological change was making it possible to shed some manpower while maintaining or improving services. (Over the period 1983-1996 the NWS in the U.S. reduced its manpower by about the same % as we did in Canada, and manpower was also reduced in Australia and Japan.) In the long-run, the failure to maintain equipment results in a decline in capabilities that will reduce output, or the quality of output. Thus the fact that services were maintained and improved during a period of restricted capital spending should not be taken to imply that a permanent reduction in such spending is tolerable or desirable.

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[27] Manpower fell by 930 persons and 56 MSC offices were closed. See AEP (1998).

[28] Jean et al. (1998) compares spending trends for national meteorological and hydrological services over the period 1983 – 1996. Over this period spending fell 23% in Canada but rose in the U.S., Australia, Japan and France by about 45%, 90%, 130% and 210% respectively (judging from the graph provided).

The large changes in expenditure, manpower, and capital spending in environmental areas in the last decade raise many questions. To what extent were the changes justified or at least excusable under the circumstances? What trends should we expect in the future? These are questions that we can hardly begin to answer here, but they are very interesting and we will hazard some conjectures.

There appear to be at least four major trends that need to be taken into account in attempting to understand or predict changes in SI expenditures, employment and investments at present. These are changes in:

i) the benefits from SI due to secular trends in climate, technology, population patterns, recreational activities and incomes,
ii) the cost of producing SI,
iii) tax burdens and budget surpluses,
iv) private insurance and public compensation for catastrophic losses.

Trends in the Benefits from SI

The frequency of severe weather is rising in Canada, as elsewhere; population is rising; more people are engaging in outdoor recreation and this is taking increasingly risky forms. Further, we are constantly acquiring "more stuff" that is vulnerable to severe weather and other natural or manmade disasters. While rising incomes, urbanization, and attention to preventing or reducing damages have resulted in some "hardening" of vulnerable assets and mitigation of possible damage, insurance sector statistics indicate that the expected damage per incident of extreme weather or disaster has been rising in Canada and other countries. This implies that the benefits from risk assessments, weather forecasts, storm warnings and the like have almost certainly been increasing and will continue to do so.

The impact of increases in property values, and the "softness" of the affected property, on disaster damage is highlighted by the large difference in damages caused by hurricanes in

Latin America vs. the U.S. The damage caused by Hurricane Andrew, which passed through Miami in 1992, cost in excess of $25 billion to repair - - far more than the estimated damage caused by any hurricane recorded in Latin America. The reason is that there is much more property that can be destroyed in the U.S. Structures in the U.S. are on average likely “harder” than those in Latin America, but this factor is not enough to offset the much greater value of the property at risk.

Changes in the cost of producing SI

There has been considerable technical progress in the production of SI. Ceteris paribus this would likely have reduced both the total and marginal costs of producing any given quantity of SI, leading to an increase in its optimal output. Whether or not *expenditure* on SI should have increased as a result depends on (i) how much MC is reduced, and (ii) the elasticity of the $\sum MB_i$ curve. For example, suppose that technical progress in itself reduced all costs by 50%. If the elasticity of the $\sum MB_i$ curve equalled 1, then the optimal quantity of SI would double, and expenditure would be constant. If, as seems more likely, the elasticity of $\sum MB_i$ is less than unity, optimal output of SI goes up but expenditure goes down.[29]

Over the last 20 - 25 years in Canada it has been observed that real expenditures on some forms of SI, for example MI, have declined. Theoretically, a *gradual* trend in this direction could be a rational response to technical progress in this area, and would not necessarily indicate declining output of SI. However, the very sharp expenditure reductions seen in the mid 1990’s appear hard to justify on this basis.

Other changes in the cost conditions for producing SI should also be considered. For example, the salaries of meteorologists and other scientists and technical workers in SI have increased. However, if these wages have gone up at the same rate as incomes generally, and if the benefits of SI are proportional to the general level of income, both

[29] Evidence provided by Lazo and Chstnut (2002) as well as the data given by Rollins and Shaykewich (2003) suggests that the elasticity of demand for weather forecasts equals about 0.3.

MC and $\sum MB_i$ will have been affected in the same proportion, and the optimal quantity of SI will not have changed.

While labor costs have risen, the IT revolution almost certainly means that the cost of capital inputs into SI production has declined. This should have reduced *MC* relative to $\sum MB_i$, leading to an increase in optimal SI. Substitution away from labor inputs toward capital inputs should also have occurred. In principle the employment effect of this substitution could be offset by the output effect. However, the wide evidence of downsizing in SI labor forces both in Canada and elsewhere suggests that the substitution effect has dominated for the labor input.[30] Note also that while real capital inputs must increase if SI output is being chosen optimally (since the substitution and output effects both raise optimal capital inputs), expenditure on capital inputs could fall. This will be the case if the substitution and/or output effects are sufficiently weak. Once again the elasticity of the $\sum MB_i$ curve comes into play in determining the output effect.

Summarizing, technical change and input cost changes in the production of SI in recent decades likely, in themselves, led to an increase in the optimal output of SI, a reduction in optimal labor inputs, an increase in optimal capital inputs, and ambiguous changes in optimal expenditures. Greater output of SI would likely mean that more informative datasets, better forecasts, and more informative reports would be made publicly available. These changes are not inconsistent, *qualitatively*, with broad trends observed in practice. It is hard to believe, however, that the very sharp decline in spending and manpower in the mid 1990's was caused by an equally sudden change in the optimal levels of these variables.

It should also be noted that other countries, as well as Canada, have been subject to the same technological forces. While major comparator countries have seen their SI labor forces decline over the last two decades, they have seen their *expenditures* increase. Either what Canada has been doing is appropriate and everyone else is wrong, or we are the odd country out. While we sometimes no doubt blaze a trail and do better than others, it is hard to escape the feeling in this case that we have been the ones getting it wrong. The serious fiscal crisis of the mid-1990's and the aggressive way in which it was dealt with, provide an alternative explanation of why our expenditures declined so much that is quite compelling.

Rising Tax Burdens and Tightening Budgets

The distortionary costs of taxation tend to increase with the square of tax rates. This means that the marginal cost of public funds, *MCPF*, is quite sensitive to the level of taxes. Today total government revenue relative to GDP in Canada is about 45% - - still not much lower than the peak of 46.6% reached in 1998. Forty years ago this bite was about 27% of GDP. This means that taxes today are almost double what they were in the 1950's and early 1960's. The *MCPF* has also no doubt increased considerably, making the net benefits of some formerly attractive services negative. Less dramatically, as we can see from the modified Samuelson Rule, $\sum MB_i = MCPF \times MC$, it will result in a reduction in the optimal quantity of public goods being produced. This could lead to a reduction in the optimal quality of datasets, forecasts, reports and so on.

While rising tax rates and an increasing *MCPF* in Canada could be used to partially rationalize the SI, and other, spending cuts of the 1990's, they are not equal to the job. The cuts were too fast and too sharp. It may be that in the high deficit days before 1996 expenditures on many public programs had gone beyond the point where marginal benefits equaled *MCPF* x *MC.* Getting the house back in order required general expenditure cuts in a crisis atmosphere. In that atmosphere the fact that cuts should be smaller in areas where social marginal benefit curves are likely less elastic, such as SI, may have been overlooked. Excessive cuts in SI may have been the result. With the improvement in public finances since 1996 the crisis atmosphere has been replaced by greater confidence and a more stable situation that one may hope will lead to a more

[30] Jean et al. (1998, p. 3) report that between 1983 and 1996 there was a 24% reduction in manpower in the MSC in Canada. Judging from their graph, there was a similar % reduction in the U.S. , and a fall of about

appropriate tuning of relative spending in different areas. We believe that tax rates, and the *MCPF*, will remain high for the foreseeable future, however. It seems unlikely that *rapid* increases in SI spending will be observed.

Changes in insurance and public compensation

In the summer of 2003 many homes were burned out or flooded in B.C. due to their location in areas of high wildfire or flood risk. Home owners are typically privately insured against wildfires, and receive public compensation for flood damage.[31] Arguably, there would have been fewer homes located in high risk areas, and less damage, if insurance and compensation coverage had been less complete.

Given that people are putting homes in riskier locations, and sometimes engaging in riskier activities (e.g. heli-skiing and other extreme forms of recreation), should government be providing better warning services to allow people to fine-tune their risk-taking and avoid loss of life and injury? As we discussed above, if the insurance and compensation schemes were unalterable, there is a possible second-best argument for giving lower quality warnings, in order to counter the incentive to locate homes or activities in high risk areas. We regard this argument as a curiosity, however, since the provisions of insurance policies and government compensation schemes are not unalterable. Canada has, for example, the most generous federal disaster compensation levels in the world, and at least one provincial government (Ontario) will compensate people for damages that they could have insured privately. Rather than reducing the quality of warnings, we believe the best approach is the straightforward one of reducing the excessive generosity of government compensation schemes.

It can, of course, be argued that better SI of the risk assessment variety is needed to help prevent people locating homes or activities in high risk areas. One of the consequences of cutbacks in recent years, for example, has been that flood risk maps are becoming out

15% in Australia and 5% in Japan. On the other hand, there was a 20% increase in France.

[31] Standard home insurance policies do not cover flood or storm surge risks in Canada.

of date in most provinces. But merely providing better information will not solve the problem if compensation schemes remain too generous. What is needed is a combination of good information and increased incentives for people to avoid unnecessary risks.

IX. Summary and Conclusion

The main points of the paper can be summarized as follows:

- There is a need for public provision of basic scientific information. This is due to market failures in SI. These market failures are caused by the non-rival nature of SI consumption, which makes SI a public good, reinforced by the consideration that some aspects of basic SI production are likely a natural monopoly and by the fact that consumption of much SI may have significant positive externalities.
- Most forms of scientific information (SI) are excludable public goods. Excludability makes it possible to charge a user fee, but this is inadvisable where collection/compliance costs are large or there are strong positive externalities from the consumption of SI. This provides justification for the free distribution of basic SI, including e.g. standard weather information and forecasts.
- "Value-added" SI should be produced in the public sector if this is cheaper than private sector production. If there are many users, a price equal to the marginal cost of dissemination only should be charged. If there is a single user or user group, the price should cover total cost.
- Changes in the public production of value-added SI should be signaled sufficiently well in advance to prevent losses or dislocation to private firms. Where public initiatives would compete with private activity, consultation and possibly joint efforts should take place.
- Trends in climate, population, asset values, and recreation patterns are steadily increasing the value of SI. These factors justify the provision of more basic SI by the public sector, e.g. in the form of more reliable and informative weather forecasts, disaster warnings, and the like.

- IT and other technological changes are making SI cheaper to produce. This allows increased productivity and greater SI output without large increases in expenditure.
- Tight public budgets are likely to continue and large increases in public SI expenditure are unlikely. With the private demand for SI increasing, this should lead to growth in the SI private sector. However, public agencies should also ask whether new services in which they have a cost advantage should be introduced with a user charge. If collection and compliance costs are small enough, and the services are of interest to subgroups rather than to the general public, this is an appropriate funding approach.
- Particularly in the earlier stages of production SI is capital intensive. Having high quality public SI therefore requires adequate spending on equipment and sensible planning to ensure stable growth in the SI capital stock.
- Improved information is not a panacea. Where people are well insured and also expect public compensation in the event of disaster, providing accurate information that allows them to evacuate before devastating storms or other disasters may encourage riskier patterns of residential and commercial development. Improvements in the provision of SI should be accompanied by reduced generosity of compensation schemes, in order to give appropriate incentives to individuals to avoid or reduce catastrophic losses. There should also be strict enforcement of development restrictions based on up-to-date risk assessments.

In conclusion, we would like to reiterate some of our thoughts about the demarcation between public and private sectors, a hot issue in recent policy debates. CMOS (2001) argued strongly that the U.S. approach of reserving the value-added field for the private sector should be adopted in Canada. But economic analysis does not support this approach. It points to a more pragmatic stance. The public sector should be required to implement rigorous accounting procedures, ensuring that it makes appropriate imputations for the cost of capital and business taxes faced by its private competitors. But when it can provide services more cheaply than the private sector, it should do so, as long as it does not make sudden moves or impose significant windfall losses on existing private firms. The demand for “clear guidelines” that would restrict public agencies to a narrow range of services should be rejected.

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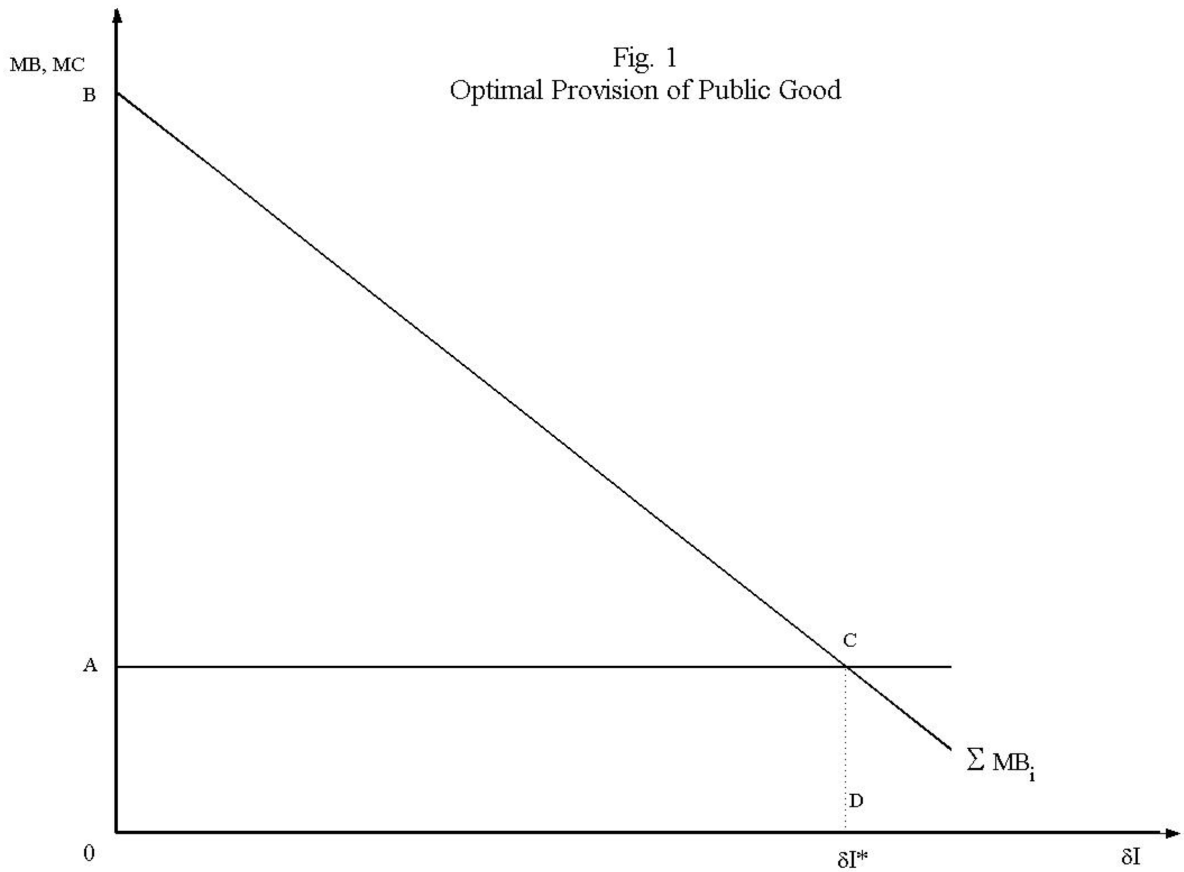
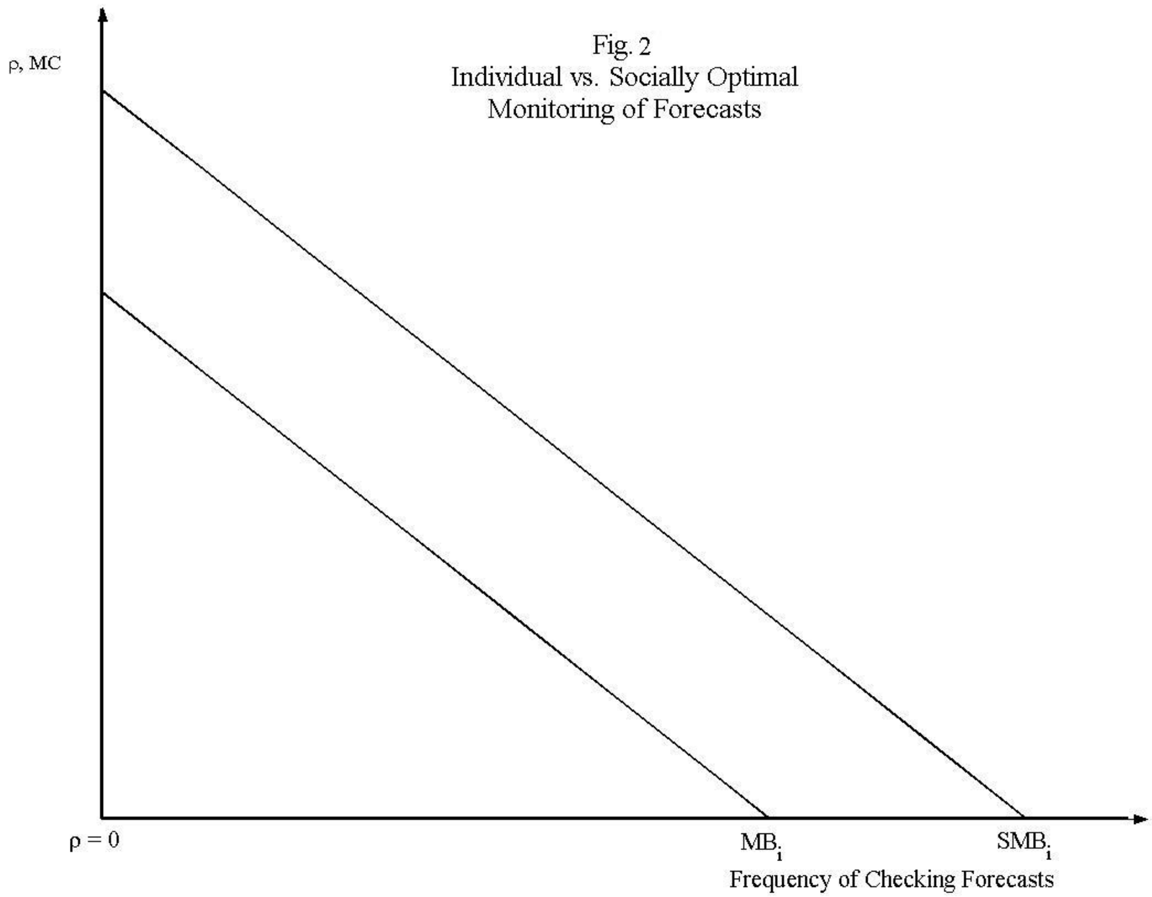


Fig. 1
Optimal Provision of Public Good


ρ, MC
Fig. 2
Individual vs. Socially Optimal
Monitoring of Forecasts
ρ = 0
MB_i
SMB_i
Frequency of Checking Forecasts