Economic Efficiency of Federal Provision of Scientific Information

and Support for Science Research in Canada[1]

James B. Davies and Al Slivinski
Department of Economics
University of Western Ontario
London, Canada

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Corresponding Author:
James Davies
Department of Economics
University of Western Ontario
London, Ontario N6A 5C2
Canada
jdavies@uwo.ca

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1. Introduction

Changes in the federal government's provision of scientific information and support for science research have both been controversial over the last eight years. Cuts to federal agencies and programs have reduced the provision of scientific information - - as in the 2012 terminations of the NRTEE, PEARL and ELA research programs[2] and the earlier cancellation of the long-form census.[3] There has also been a change of emphasis in extramural support towards applied and commercializable research, as well as cuts in the ranks of the government's own scientists and claims that they have been "muzzled"(Chung, 2013; Turner, 2013). On the other hand, important physical and socio/economic data have been made freely available online or through university libraries for quite some time, due for example to Statistics Canada's Data Liberation Initiative and parallel efforts by Natural Resources Canada (NRCan) and other Federal departments. In 2012 the government announced an "Action Plan for Open Government", which included the launch of an Open Data portal that claims to give free access to 244,000 public datasets (http://open.canada.ca/data/en/dataset). In addition, federal agencies and officers have made improvements in the data and research that is still being produced, for example by linking datasets, cooperating with U.S. agencies to bring new research aids to Canada, and taking advantage of new ways of organizing and disseminating data.[4]

While public officials and scientists are to be commended for these improvements, we believe that most Canadian physical and social scientists would agree that the amount of basic scientific information and support for pure research provided by the federal government have both been declining. In real terms, federal spending on science and technology fell 18% from 2010 to 2014, while the number of federal civil servants working in this area declined by 3,405 or 9% (Table 1 and Statistics Canada, 2014, table 8). Looking at international comparisons, from 2007 to 2013 government financed Gross Expenditure on Research and Development (GERD) fell from 0.61% of GDP to 0.57% in Canada while it stayed almost unchanged in the U.S., falling from 0.77% to 0.76%, and rose for the OECD as a whole from 0.63% to 0.67% (OECD, 2015a).[5] Although there is arguably easier access to the data that *is* still

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[2] The National Round Table on the Environment and Economy (NRTEE), the Polar Environment Atmospheric Research Laboratory (PEARL) in Eureka, Nunavut and the Experimental Lakes Area (ELA) in northwestern Ontario were all terminated either directly or indirectly as a result of the April 2012 federal budget. The NRTEE's role had been to conduct research on the environmental and economic effects of climate change. PEARL had engaged in a range of research, including study of changes in the ozone layer in the Arctic. It could no longer operate since it had received about three quarters of its funding from the Canadian Foundation for Climate and Atmospheric Science, which was terminated by the budget. Discontinuation of federal support for the ELA, which comprises about 20 lakes that have been the site of ongoing environmental research since the 1970s, meant the termination of several multi-year environmental experiments that were in progress. See CBC News (2012).

[3] See Dillon (2010), Green and Milligan (2010) and Veall (2010) in the symposium on cancellation of the long-form census in *Canadian Public Policy.*

[4] There are many examples of small but significant improvements along these lines. For example, income data in Statistics Canada surveys and the census is now obtained largely from income tax records, with the permission of respondents, which produces more accurate data than under self-reporting. A good example of cooperation with U.S. authorities is the 2011 agreement with FEMA to establish a standardized North American version of the U.S. system, HAZUS, for assessing natural disaster impacts (Nastev and Todorov, 2013).

[5] Comparing the most recent numbers (in this case, those for 2013) with 2007 rather than, say, 2010, is wise because 2007 was the last "normal" year before the global financial crisis. In the period during and after the crisis differences in the behaviour of the ratio of GERD to GDP across countries were significantly affected by differences in GDP changes. Note also that Canada relies more heavily on tax credits than on subsidies to support private-sector

generated in Canada, less data is being produced and there appears to be less access to the results of in-house government research. What is going on? Could this pattern of changes possibly make sense in public interest terms?

Here we identify four major trends in the provision of scientific information and support for research and ask whether they could possibly have a rationale in terms of economic efficiency. We ask this question because public provision of scientific information and support for research has long been justified on the grounds of market failure - - we cannot expect private markets to provide these goods.[6] Public provision is apparently motivated by a desire to offset that failure; that is, public provision has been specifically justified on the grounds of economic efficiency. It is therefore important to inquire whether there have been any changes in the efficiency rationale that could justify the trends we have seen in provision.

2. Trends

We can identify four principle trends in federal provision of basic scientific information and support for science research that have either started in, or continued during the last five to eight years.

Scientific Information

By scientific information we mean data and all other scientific information that is not a report of new research results. It may be physical or social. Thus we include, for example, meteorological and climate data, results of geological and topographical surveys, environmental data, social and economic data from household surveys, and census data. Scientific information also includes the results of applying that data in established ways to generate weather forecasts and warnings, geospatial maps, reports and warnings on air and water quality, aggregated socio/economic data, and the national accounts.

There have been two overarching trends in the provision of scientific information by the federal government and its agencies:

1. There has been a gradual move toward an open data approach. This is a longstanding trend that has continued in recent years. The sharing of satellite imagery began in the 1970s and Statistics Canada launched its Data Liberation Initiative in the early 1990s. Geospatial information followed with Geogratis and Geobase around the year 2000, and the amount of meteorological data provided by Environment Canada has been increasing for a long time. These programs all form part of the data now available through the government's Open Data Portal.

R&D than do most other OECD countries, so comparing the *level* of Government-financed GERD (which does not include tax credits) in Canada vs. other countries may potentially be misleading. Our concern, however, is with the change rather than the level.

[6] Former Clerk of the Privy Council Mel Cappe made this point to the Industry Committee of the House of Commons in August 2010 (CBC News, 2010) when he called for the restoration of the mandatory long-form census on the grounds that it was a public good. As we argue in this paper scientific information and science research are indeed public goods, and it has long been recognized in economics that efficient provision of such goods by markets alone is not guaranteed.

2. In the last five to eight years several important data-gathering programs or bodies have been terminated. PEARL, the ELA and the long-form census have already been mentioned but there are other examples, including programs in the Department of Fisheries and Oceans like the Habitat Management Program, and in Environment Canada - - for example, the Hazardous Materials Information Commission (Nelson, 2013 and Turner, 2013). There has been a sizable reduction in the portion of federal spending on science and technology that is devoted to data collection and information dissemination. These expenditures are the major items in the intramural "Related Scientific Activities" spending shown here in Table 1. Real spending in this area fell 15% from 2010 to 2014.

Support for Science Research

3. The fraction of federal science and technology spending devoted to research and development by the government's own scientists, that is "intramural research", fell sharply in the early 2000s and has remained lower since 2003, dropping from a range of 29 – 31% in the 1990s to one of 23 - -26%.[7] Spending on intramural research fell 14% in nominal terms from 2010 to 2014, and 20% in real terms[8], in line with the overall drop in federal science and technology spending, but in contrast to spending on research at colleges and universities, which has held steady in nominal terms. Over the long term the relative decline in spending on intramural research has been accompanied by a shift in resources towards extramural research, mainly at the universities. Research in the higher education sector increased its overall share of federal science and technology spending from 13 – 14% in the mid-1990s to 26 – 28% in the period since 2010. Spending on both intramural and university research has declined in recent years, with a 19% drop in real federal direct funding of research and development from 2010 to 2014.

4. In the last five to eight years there has been a change in emphasis in federal support for extramural research away from pure or basic research toward applied research, with an emphasis on commercialization. The intention to make this change was announced in Government of Canada (2007), and has been applied increasingly in intramural research, for example in the activities of the National Research Council (CBC News, 2013), as well as extramurally, via changes in the funding practices of CIHR, NSERC and SSHRCC. The 2011 federal budget enhanced special NSERC and CFI envelopes for applied research at community colleges and announced that 30 new chairs would be provided at the colleges through NSERC (http://nghoussoub.com/2011/03/25/is-canada%E2%80%99s-research-strategy-too-politicized/). The 2014 federal budget announced a ten-year, $1.5 billion program, the Canada First Research Excellence Fund, for spending provided through the three national granting agencies on postsecondary research in "areas that will create long-term economic advantages for Canada" (http://www.cfref-apogee.gc.ca/about-au_sujet/index-eng.aspx).

In addition to direct spending in support of science and technology the federal government provides a generous tax credit for Scientific Research and Experimental Development (SR & ED). It is

[7] Annual data on the level and composition of federal spending on science and technology was provided by Statistics Canada (2014) and earlier editions of that publication. It is also available for 2002 and later years through CANSIM An appendix is available from the authors that provides the key data for the years from 1991 to 2014. Table 1 of this commentary provides data on real federal spending on science and technology from that appendix.

[8] The spending decrease was reflected in a reduction of 1,541, or 9%, in the ranks of government personnel working on scientific research and development (Statistics Canada, 2014, table 8.)

projected that the SR & ED "tax expenditure" for 2014 will total $1.73b, which may be compared with the total of $6.79b spent in direct spending in support of research and development (Department of Finance Canada, 2014). In contrast to direct spending, which has fallen from $7.75b in 2010, the tax expenditure has increased from a 2010 value of $1.58b. Adding together the SR & ED tax expenditure and direct spending gives a total of $9.33b in 2010 and $8.52b in 2014. In real terms this is a decline of 16%. Hence, taking the SR & ED tax credit into account does not alter the picture of a substantial reduction in federal support for research and development in recent years.

3. A Rationale for Trends in Provision of Scientific Information?

Scientific information, like other information, is non-rival in use. One person or organization using the information does not prevent others from using it as well[9]. This means that it is a *public good* in the technical sense used in economics.[10] If it were also non-excludable, it would be a *pure public good*, and it would not be possible for the private market to provide it, due to free riding. In fact, complex scientific information is excludable - - as we saw, for example, when Statistics Canada charged users substantial fees for access to microdata files in the 1970s and 80s. If the data had been non-excludable it would not have been possible for Statistics Canada to collect those fees. Currently, Statistics Canada confines use of its most sensitive data to its Ottawa facilities or to Research Data Centres (RDCs) across the country with similarly high security. Even without such special measures it seems likely that the threat of losing access would prevent most users from breaching contracts to reproduce data and provide it to others without permission.[11]

While it is possible for private markets to provide excludable public goods, they will generally be under-provided from an efficiency viewpoint. This provides a rationale for public provision despite their excludability.[12] The first-best efficient outcome entails that any individual who values scientific information should have access to it, since there is no added cost in providing it to one more user once it is produced. That's the non-rivalry aspect of a public good. This implies that charging *any* fee for the information will not produce the first-best outcome, since a fee will prevent some who value the information from getting it. However, we do not live in a first-best world. There are many existing distortions, and under some circumstances it may be desirable to distort the use of a public good in order to counteract those existing distortions, or in order to allow them to be reduced, e.g. through tax cuts

[9] Note that this statement is equivalent to saying the marginal cost of allowing additional agents to use the public good is zero. In the case of information, this means that the marginal cost of dissemination is zero, a reasonable approximation in practice given modern information technology.

[10] We pursue the public goods rationale for public provision of scientific information, but it has been pointed out to us that an alternative rationale could be found in natural monopoly. If there are high fixed costs and low marginal costs of producing scientific information, then it may qualify as a natural monopoly, which may seem to provide an alternative justification for public provision or regulated private provision. However, the natural monopoly and public goods justifications for a public role are not mutually exclusive. And while they both point to the need for public provision or regulation, it is the non-rival nature of scientific information that drives its optimal provision and pricing analysis. Hence, we focus on the public goods aspect.

[11] The key point here is that the nature of scientific information makes it excludable: when produced by academics the typical choice is to not engage in exclusion, but that is a choice, and it could be otherwise.

[12] Another possibility would be for the public good to be provided through the private sector, but subsidized. For simplicity we ignore that possibility here.

made possible by charging a fee for use of the public good. In other words, we live in a *second-best* world, and how best to provide and price public goods has to be analyzed in that context.

Second-best analysis can be complex. However, there is a result that greatly simplifies matters. This is the Diamond-Mirrlees production efficiency theorem, which says that if taxes on final goods have been chosen optimally, under fairly general conditions one should not distort the method of production. So, for example, unless production inputs themselves create negative externalities, it does not make economic sense to tax them.[13] Now, basic scientific information such as that contained in a micro dataset is not consumed by individuals and households. It is rather an input into production by firms or other units that are themselves producing such outputs as scientific research and policy analysis. In other words, it is an "intermediate public good" (Sandmo, 1972) or "collective factor of production" (Feldstein, 1972). Therefore, the use of this data should not be distorted, which in the case of a public good means that a zero price should be charged, in the absence of externalities[14] This line of reasoning provides a strong rationale for the open data approach, which as noted above, has been embraced for some time by key federal data-producing agencies and which is now formally established under the Open Data initiative of the federal government. (The argument in a particular case would be strengthened if one could show that use of scientific information by producers had positive externalities, in which case a subsidy would be in order.) Thus, the first key development in the provision of scientific information can be justified as a move toward a more efficient outcome in a second-best world.

The second key development in the provision of basic scientific information has been the reduction in the quantity, and in some cases also the quality, of that information. For the sake of simplicity, for the moment we will think of this simply as a reduction in the supply of a public good. The question we ask is: under what conditions would it be necessary or advisable, from an efficiency viewpoint, to reduce the supply of such a good?

Consider a single public good, G, which has marginal benefits MB_i for users $i = 1, ..., n$, and is produced at marginal cost MC.[15] [16] Under the well-known rule due to Samuelson, (1954), the first-best level of provision of this good is the level G^* such that:

$$(1) \qquad \sum_{i=1}^{n} MB_i(G^*) = MC(G^*)$$

[13] See Boadway (2012) for exposition of the Diamond-Mirrlees result. Feldstein (1972) showed that it extends to the case where some, or indeed all, inputs are public goods.

[14] In theory, users of a pure public good can be charged "Lindahl prices" equal to their MB_i for its use, without causing a distortion (see e.g. Atkinson and Stiglitz, 1980). This result is generally considered to be of merely theoretical interest due to the difficulty of measuring individual MB_i s. One might think of viewing the Samuelson rule itself in the same light, but it may be easier to estimate the average MB_i than it is to estimate individual MB_i s, so that the Samuelson rule may remain useful even when Lindahl prices are not.

[15] Feldstein (1972) showed that the Samuelson rule continues to hold for an intermediate public good. In that case i is a firm and MB_i is its marginal profit from the provision of the public good.

[16] Note that the marginal cost in question here is the *MC* of *producing* the public good. In the case of information this means that it is the marginal cost of generating, rather than disseminating information. As mentioned earlier, given current information technology, the marginal cost of disseminating information is close to zero. In contrast, the marginal cost of generating the information will be positive and could be high, for example in areas where information gathering is still labour intensive.

In our second-best world this rule needs to be modified. The cost of a dollar of public funds is generally more than a dollar, since collecting additional revenue tends to worsen existing distortions and has an excess burden (Dahlby, 2008). This increases the deadweight cost of taxation. For each particular tax there is a marginal cost of public funds, or *MCPF*. For simplicity we assume that there is a single *MCPF* for federal funds at a moment in time. This is equivalent to assuming either that there is just one kind of tax or that the structure of taxes has been adjusted so that they all have the same *MCPF*, (which would be optimal). The modified Samuelson rule is then:

$$(2) \quad \sum_{i=1}^{n} MB_i(G^*) = MCPF \text{x} MC(G^*)$$

(see Boadway, 2012).

Under the modified Samuelson rule there can be three reasons for the efficient level of *G* to fall: (i) a drop in $\sum_{i=1}^{n} MB_i$, ii) an increase in *MC*, or iii) a rise in *MCPF*. Figure 1 illustrates the underlying logic by displaying the impact of an increase in $\sum_{i=1}^{n} MB_i$ on the efficient level of provision of G, increasing it from G` to G^+. In fact, we believe, all three of these factors have likely been moving in the opposite direction, so that, overall, the efficient level of G has been rising. The ongoing increase in the number of firms and other organizations that find scientific information useful, and the rising use of such information by existing firms, not to mention the rise in population and the size of the economy, would all be expected to increase the demand for G, that is to raise $\sum_{i=1}^{n} MB_i$, and thereby to increase the efficient level of G as in Figure 1. There could also be changes in tastes, technology, demography, the business or natural environment, or the relative price of substitute inputs that would affect this sum of benefits from G. Many such factors would increase the benefits - - the aging of the population, for example, presents challenges for the healthcare and other systems that increase related data, information and research needs. This all suggests that the sum of benefits from scientific information has been increasing in recent decades. However, we should ask whether there are any specific trends that could have been operating in the opposite direction.

It has sometimes been suggested that the rise of "big data" reduces the value of publicly provided information, and thus our sum of benefits. We stipulate that in fact big data tends to increase $\sum_{i=1}^{n} MB_i$s for at least two main reasons. One is that a considerable amount of data that is actually or potentially publicly generated *is* big data - - health data for entire populations and huge physical science datasets can now be readily assembled and analyzed for example. Governments around the world have shown considerable interest in these aspects.[17] A second reason is that big data and conventional scientific data are complements rather than substitutes in many cases, implying that an increase in the former increases the benefits from the latter. An interesting example is provided by the large datasets on voters

[17]The important role of big data in the public sector has been recognized in Canada in the federal government's Open Data initiative and in the Drummond report of 2012 in Ontario; in the U.S. in President Obama's Big Data Research and Development Initiative announced in 2012 (Executive Office of the President, 2015); by the European Commission in its Big Data Public Private Forum ("Big Data Public Private Forum", Cordis.europa.eu. 2012-09-01); and in Britain with the founding of the Alan Turing Institute ("Alan Turing Institute to be set up to research big data". BBC News. 19 March 2014.)

maintained by Canada's main political parties. The Globe and Mail (2015a) reports that the federal Liberal party combines information gathered by its canvassers with publicly available demographic data from the national census and other private sources to produce "analytics databoards – complex digital graphs and charts". No doubt similar techniques are widely used by non-political advertisers and marketers.[18]

Another possibility is that while the overall sum of benefits from scientific information has indeed been rising, more such information is provided today through the private sector than formerly, so that government does not need to generate as much G itself as it did in the past. This argument may be applicable in some cases. For example, more information may be provided today than in the past by "agri-business" and perhaps by large suppliers in the natural resource industries as well. And farmers and resource producers may be more sophisticated than in the past, so that they can track down the information they need without the help of public agencies. However, the information in question is still a public good, and there is good reason to believe that the market cannot provide the optimal quantity of that information by itself. Moreover, the underlying source of much information that is privately conveyed may often be public agencies or university-based research heavily supported by government. Thus public effort is still required in areas where the role of private suppliers of information has increased, and there remain sufficiently broad areas where private provision is still very small that we do not expect that the overall sum of benefits from government-provided scientific information has declined.

On the cost side, we contend that *MC* has likely been declining significantly for both the production and processing of most scientific data, due to the ongoing decline in the costs of computing and information handling. In addition, the labour intensity of data collection has been reduced in many cases, for example through the replacement of human observers by automated equipment on the physical side, and computer-assisted survey techniques on the socio-economic side, further reducing cost. This decline in the cost of producing scientific information has likely been reinforced by a significant drop in the *MCPF*.

The marginal cost of government revenue from a particular tax is proportional to the tax rate, both in theory (under some simplifying assumptions) and empirically (Dahlby, 2008). Here we are interested in the average *MCPF* over the bundle of taxes that the federal government would increase to collect more revenue if it was necessary to do so. It is hard to know what that bundle would be exactly, but we can get a reasonable idea of how the *MCPF* would change if we assume that revenues from all taxes would rise equi-proportionally. Then the average *MCPF* would rise or fall in proportion to overall revenue.

Total tax revenue of all levels of government together in Canada[19] stood at 30.3% of GDP in 1970, and rose to 35.3% in 1990 (OECD, 2015b)[20]. The ratio remained at 35-36% until 1999, when it

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[18] That the long-form census data was valuable to a large variety of organizations is apparent from the number who protested its termination and from the recommendation of the Industry Committee of the House of Commons that it should be reinstated (CBCNews, 2010). See also Globe and Mail, (2015b), for comments from a number of business and municipal leaders on this issue.

[19] We need to consider the tax rate across all levels of government since the *MCPF* for a federal tax increase depends on the total tax rate, taking into account all levels of government. Thus the *MCPF* for personal income tax, for example, depends on the sum of federal and provincial rates rather than the federal rate alone.

was 35.7%. Thereafter it declined, to 32.3% in 2007 and 30.6% in 2013. So, we could say that from 1999 to 2013 the overall average effective tax rate in Canada fell from 35.7% to 30.6%, which is a decline of 14%. If the *MCPF* in our modified Samuelson rule fell by a similar amount, which we have suggested above is reasonable to assume, that would have reinforced considerably the tendency for the optimal level of G to rise on grounds of rising $\sum_{i=1}^{n} MB_i$ and falling MC.

The arguments above imply that so long as scientific information is being provided efficiently as a public intermediate input to producers, there is no reason for its provision to have fallen over the last several years. However, it must be conceded that some scientific information is useful to and provided to *consumers*. Below we consider whether there are forces in play that would imply that this type of provision should have fallen.

Consumer demand for basic scientific information

We argued above that there is generally no efficiency rationale for charging a price for the use of a public good in production. However, scientific information has possible uses in consumption, also. Weather forecasts and warnings, for example, are important to many producers - - farmers, fishers, and operators of outdoor facilities spring readily to mind --but, these are also useful to consumers. Knowing how much it has snowed, or when it is likely to do so again, is useful information for planning one's skiing or snowmobiling outings, as well as in deciding when to leave for work or for the airport. Is there a possible argument for charging consumers for weather information or warnings, and could such an argument be extended into other areas? If there is, then the optimal provision of scientific information is determined differently than above, so we investigate that possibility here.

A long tradition of analysis of the provision of excludable public goods, stretching back to Boiteux(1952), and recently extended by Hellwig (2007), concludes that under reasonable assumptions, efficiency requires these goods to bear an "admission fee".[21] Hellwig shows that the optimal scheme implies that the fees charged for different public goods obey a version of the familiar inverse-elasticities rule from optimal commodity taxation.[22] That is, excludable public goods that are in relatively inelastic demand should bear higher fees than those that are in elastic demand. This is an interesting theoretical result that justifies charging user fees for access to public goods. However, there does not appear to be any research as yet that asks how the structure of actual user fees lines up in comparison with the inverse-elasticities rule. It must also be borne in mind that considerations of health and safety impacts, or of distributional impacts, could readily trump the argument for user fees. Hence, for example, one would

[20] These levels are considerably below those of total government revenue, which includes non-tax revenue. For comparison, in 1990 total revenue was 44.6% of GDP.

[21] Levying such a fee raises revenue and allows other fees and taxes to be reduced a little. Starting from zero, imposing a small fee has very little welfare cost; reducing a large existing fee or tax, in contrast, generally has a sizeable welfare benefit. Hence, there is a net benefit of charging at least a small fee for allowing consumers to use an excludable public good.

[22] The inverse-elasticities rule says that, absent externalities or distributional considerations, if goods have independent demands then it is efficient to tax them in inverse proportion to their demand elasticities. The intuition is that consumption of goods whose demand is relatively inelastic will be less affected by a tax, that is there will be less distortion of the pattern of consumption.

likely not want to put a price on weather forecasts and warnings. Further, many public goods may be used both by producers and consumers, with any classification of users being costly, so that the cost of trying to charge a fee for consumers but not for producers could exceed any benefits generated. However, in cases where these aspects do not apply, charging user fees for consumer access to excludable public goods is consistent with economic efficiency.

User fees are of course commonly observed in the provision of public services, particularly at lower levels of government. For example, constructing or modifying buildings, or transacting in property requires the payment of a range of fees, and the use of recreational facilities and in some cases of roads or bridges is subject to fees. At the federal level, travelers in Canada pay substantial fees for the use of airports. However, the main thrust in the pricing of access to scientific information has been the move toward an open data initiative, which reduces the price to zero.

There is a clear connection between prices and quantities. If fees for excludable public goods sold to consumers were to replace free provision, Hellwig shows that the optimal quantity of each public good to be provided would decline. Some consumers would not pay the fees and would not get the benefit of the public goods, resulting in a decline in the optimal output of the public good. Thus higher fees and lower provision go hand-in-hand. Yet what we are seeing is lower fees ("open data") along with lower provision. It is hard to see how efficiency considerations could dictate such a trend.

Thus, our conclusion that a reduction in the provision of scientific information doesn't have an efficiency rationale is not altered by expanding the analysis to include provision to individuals.

4. A Rationale for Federal Trends in Support for Science Research?

As detailed above, the major trends in federal support for science research are i) a long-term shift away from intramural research toward federal support for university and other extramural research, and a recent decline in all federal research spending in both nominal and real terms , and ii) a recent shift in funding emphasis away from pure research toward applied research and commercialization.

A gradual shift in the balance of intramural vs. university-based research is a trend that has been seen in the United States as well as in Canada.[23] It is likely that there is an underlying economic rationale for this trend. Most obviously, the relative cost of university research would have tended to decline due to increased post-graduate enrolment demand, which raised the supply of graduate students and post-docs available to serve as research assistants. Such a trend is benign but we would point out that sudden and sizable real reductions in intramural research capacity are clearly disruptive and wasteful, and may also reduce the ability of government scientists to provide timely and high quality information and advice when it is required by the government.

[23] The American Association for the Advancement of Science (2015) provides data on U.S. federal government research spending from 1953 to 2012. In 1953 intramural federal spending in the U.S. was 3.2 times the size of federal spending on university-based research. Over the years there was a gradual decline in this ratio, which had fallen to 0.38 by 2012.

As in the case of scientific information, economic analysis of the optimal level of science research based on efficiency considerations would also make use of the modified Samuelson rule (2). As we argued above, there has been a fairly large decrease in tax levels in Canada in recent years, suggesting a significant fall in the marginal cost of public funds, *MCPF*, which would argue for the government to provide more support for research rather than less. This makes it doubtful, in our opinion, that there is an economic rationale based on normal efficiency considerations for reducing federal support for scientific research. The arguments for maintaining or increasing research spending would be similar to those we have made above in the case of scientific information. However, there is a theoretical difference between the provision of scientific information and that of *pure* scientific research which needs to be considered.

Any scientific information that is produced by government or with public support in Canada is likely of value primarily to Canadians, which helps to make the argument for public provision of scientific information, as a public good, very strong. A similar claim could be made for much applied research. Pure research, on the other hand, is of interest to individuals and researchers around the world. That is of course reciprocally true for research done in other countries, so that one can put together an argument that it may be in the national self-interest of a relatively small country like Canada to 'free-ride' on the pure scientific research done in other countries. This argument for 'free-riding in the national interest' is, however, subject to at least two key objections. First, it assumes that there would be no 'retaliation' by other countries, via their own reductions in spending on pure research or by blocking Canada's access to their results. It seems that the risk of such retaliation is small, but that leaves the second problem. Besides being a public good in itself, producing pure research has a positive externality: it produces individuals trained to engage in and understand such research. Reductions in that activity in Canada imply fewer highly trained individuals, and a commensurate decrease in Canada's ability to understand and exploit the pure research done elsewhere. Thus, such a free-riding strategy would itself over time erode Canada's ability to continue it, and thus eliminate any benefits to free-riding.

So an overall reduction in government spending on pure research cannot be justified on normal efficiency grounds, and justifying it on the grounds of self-interested free-riding only holds up if one is willing to ignore the long-term impact of such a strategy. It is true, as we noted above, however, that the recent stark decrease in spending on intramural research has come at the end of a longer-term trend of shifting federal support towards research done in the higher education sector.

We can only speculate on the reasons for the shift from intramural to extramural research, but a straightforward extension of the Samuelson rule would say that in the presence of two technologies for producing a public good, each should be used up to the point where their marginal costs are the same. If the shift to extramural spending was prompted by a realization that this rule was not being adhered to, and so more spending should be allocated to lower-marginal-cost extramural research, a corollary of this shift would be that the total amount of research funded on efficiency grounds should also go up, rather than down. However, what we have seen in recent years is a large decrease in the overall amount spent on research and development, from $7.75b in 2010 to $6.79b in 2014, which is a drop of 19% in real terms.

We turn finally to the recent increased emphasis on funding applied, commercializable research. Note first of all that, given that overall federal research spending is declining, this trend magnifies the reduction in funding for pure research discussed above. Secondly, such applied research has the potential to produce benefits for firms, and to the extent that it generates commercializable (and patentable) innovations it seems impossible to rationalize this shift on efficiency grounds. Such applied research has a financial return which the patent system allows the innovator to capture; hence there is no efficiency rationale for government provision of the research. However, not all applied research leads to patentable innovations. Much government research in agriculture, for example, has been directed at identifying "best practices". One way to view such research is as helping groups of firms to overcome a collective action problem: it may be in no single firm's (or farmer's) financial interest to spend resources on solving a problem if that solution will ultimately also benefit most of their competitors. Government support for this sort of applied research and free access to the results can be justified on grounds of economic efficiency. This none the less leads one to ask what reasoning suggests that it has recently become appropriate for more of the shrinking government expenditures on research to be directed toward applied research.

The means for accomplishing this re-orientation of spending has been a proliferation of granting programs that require one or more private partners to put up real resources in order for the grantee to obtain 'matching' public funding for the project. It seems clear that the more will firms other than the partner firm (including its rivals) benefit from the results of the project, the fewer resources will the partner firm agree to provide. In other words, such partnering programs are likely to be most popular when they provide the least public benefit. We cannot see any argument that suggests an increase in this type of expenditure is efficiency-enhancing.

We conclude then that the shift in funding priorities from pure scientific research toward commercializable applied research exacerbates the overall reduction in funding of pure research that we argued above was inefficient, and cannot be itself rationalized on the basis of economic efficiency.

5. Conclusion

In this paper we identified four recent trends in federal government policy regarding the funding of research and the provision of scientific information, and then evaluated whether each of these trends could be rationalized by an appeal to economic efficiency. Our conclusions are the following.

i) The trend toward open and free access to scientific information has a rationalization based on economic efficiency, as the provision of an excludable public good in the face of a fall in the marginal cost of public funds, and a technology-driven fall in the marginal cost of providing such information.

ii) The trend toward producing and gathering less scientific information does not have any economic efficiency rationale that we can devise. This is true even if we take into account analyses which conclude that the provision of such information to consumers (but not firms) might justifiably be priced above zero.

iii) The sharp reduction in real federal spending on scientific research and development in the last five years, which has been particularly marked in the case of intramural spending, has no efficiency justification. A justification of this trend as self-interested free-riding on other countries' R&D is possible only if one ignores the long-term cost of such a strategy.

iv) The shift in emphasis in government support for extramural research away from basic research toward applied research that has private sector partners and is commercializable first of all magnifies the impact of the overall reduction in support for non-commercializable research, which we argue has no efficiency rationale. Further, the means by which this shift is encouraged are likely to result in the projects that get the most support from private partners being those that have the narrowest overall benefits. We do not see a valid economic efficiency argument for this shift taking place.

The traditional economic rationale for public provision of scientific information and support for science research is that these are public goods. There is a clear justification for public provision of such goods on the grounds that they cannot be efficiently provided purely via private markets. It is therefore important to ask whether the strong trends seen in the provision of scientific information and support for science research by our federal government are justified by economic efficiency considerations. The failure to find such a justification here for most of the policy trends suggests that they are not conducive to the long-term health of the Canadian economy.

References

American Association for the Advancement of Science (2015), "Historical Trends in Federal R&D", http://www.aaas.org/page/historical-trends-federal-rd

Atkinson, A, and J. Stiglitz (1980), *Lectures on Public Economics*, London and Toronto: McGraw-Hill.

Boadway, Robin, 2012, *From Optimal Tax Theory to Tax Policy*, MIT Press: Cambridge, Mass.

Boiteux, M., 1956, "Sur la gestion des monopoles publics astreints à l'équilibre budgétaire", *Econometrica* 24, 22–40

CBC News, 2010, "Committee want long-form census reinstated", Aug. 27. http://www.cbc.ca/news/politics/committee-wants-long-form-census-reinstated-1.939792

CBC News, 2012, "High Arctic Research Station Forced to Close", Feb. 28. http://www.cbc.ca/news/technology/high-arctic-research-station-forced-to-close-1.1171728 retrieved Jun 1, 2015.

CBC News, 2013, "National Research Council move shifts feds' science role", May 7. http://www.cbc.ca/news/politics/national-research-council-move-shifts-feds-science-role-1.1323958

Chung, Emily, 2013, "Muzzling of Federal Scientists Widespread, Survey Suggests", CBC News, Oct. 21. http://www.cbc.ca/news/technology/muzzling-of-federal-scientists-widespread-survey-suggests-1.2128859 retrieved June 2, 2015.

Dahlby, Bev, 2008, *The Marginal Cost of Public Funds*, Cambridge: Cambridge University Press.

Department of Finance Canada, 2014, "Tax Expenditures and Evaluations 2014", Government of Canada, http://www.fin.gc.ca/taxexp-depfisc/2014/taxexp14-eng.asp

Dillon, Lisa, 2010, "The Value of the Long Form Canadian Census for Long Term National and International Research", *Canadian Public Policy* 36(3): 389-393.

Executive Office of the President, 2015, "Big Data Across the Federal Government", White House. https://www.whitehouse.gov/sites/default/files/microsites/ostp/big_data_fact_sheet_final_1.pdf retrieved June 7, 2015.

Feldstein, Martin S., 1972, "The Pricing of Public Intermediate Goods", *Journal of Public Economics* 1 (1): 45-72.

Globe and Mail, 2015a, "Old-school campaigning goes high-tech", June 2, p. A5.

Globe and Mail, 2015b, "Scrapping of long-form census causing long-term issues for business", February 6 (online edition)

Government of Canada, 2007, *Mobilizing Science and Technology to Canada's Advantage*, Ottawa: Public Works and Government Services.

Green, David A. and Kevin Milligan, 2010, "The Importance of the Long Form Census to Canada", *Canadian Public Policy* 36(3): 383-388.

Hellwig, Martin F. 2007, "The Provision and Pricing of Excludable Public Goods: Ramsey-Boiteux Pricing versus Bundling", *Journal of Public Economics* 91: 511‑540

Nastev, Miroslav, and Nikolay Todorov, 2013, "HAZUS: A standardized methodology for flood risk assessment in Canada", *Canadian Water Resources Journal* 38 (3): 223–231.

Nelson, Joyce, 2013, "The Harper Government's War on Science: Many scientific programs terminated, many scientists fired", Canadian Centre for Policy Alternatives.

OECD (2015a), "Main Science and Technology Indicators", OECDiLibrary, http://www.oecd-ilibrary.org/science-and-technology/data/oecd-science-technology-and-r-d-statistics/main-science-and-technology-indicators_data-00182-en?isPartOf=/content/datacollection/strd-data-en

OECD (2015b), "Revenue Statistics – Comparative Tables", OECD.Stat, https://stats.oecd.org/Index.aspx?DataSetCode=REV

Samuelson, Paul 1954, "The Pure Theory of Public Expenditure", *Review of Economics and Statistics*, 36: 387-89.

Sandmo, Agnar 1972, "Optimality Rules for the Provision of Collective Factors of Production", *Journal of Public Economics* 1: 149-57.

Statistics Canada, 2014, *Federal Scientific Activities 2014-2015*, catalogue no. 88-204-X, Ottawa: Statistics Canada.

Turner, Chris, 2013, The War on Science, Muzzled Scientists and Willful Blindness in Stephen Harper's Canada, Vancouver: Greystone Books.

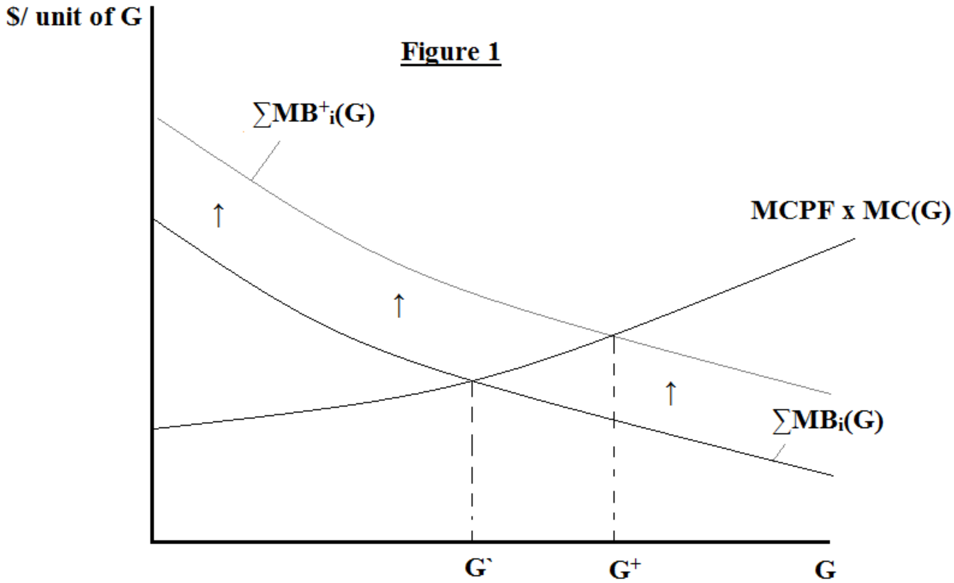
Veall, Michael R., 2010, "2B or Not 2B? What Should Have Happened with the Canadian Long Form Census? What Should Happen Now?", *Canadian Public Policy* 36(3): 395-399.

Table 1 Real Federal Science and Technology Spending 1991-2014 (2007 dollars)

Years	Total	Related Scientific Activities*		Research and Development		
		Total	Intramural	Total	Intramural	Higher Education
1991-94	7,995	3,174	2,326	4,821	2,347	1,107
1995-99	7,410	2,880	2,208	4,531	2,263	1,058
2000-04	9,352	3,596	2,755	5,756	2,436	1,983
2005-09	10,347	3,792	2,815	6,555	2,577	2,628
2010	11,508	4,089	2,923	7,419	2,880	2,857
2011	10,561	4,045	2,923	6,515	2,455	2,728
2012	10,197	3,770	2,737	6,428	2,333	2,821
2013	10,065	3,611	2,660	6,454	2,465	2,608
2014	9,397	3,389	2,493	6,007	2,303	2,572

*Related Scientific Activities includes Data Collection, Information Services , Special Services and Studies, and some smaller spending categories. See Statistics Canada, *Federal Scientific Activities 2014/2015*, Publication No. 88-204X.

Source: Nominal spending for 2002-2014 is from CANSIM table 358-0144; for earlier years it is from Statistics Canada, *Federal Scientific Activities*, Publication No. 88-204X, 2000 and 2005 editions. Amounts converted to 2007 dolars using the GDP implicit price index from CANSIM table 380-0102.



$/ unit of G
Figure 1
∑MB⁺ᵢ(G)
MCPF x MC(G)
∑MBᵢ(G)
G`
G⁺
G