# Moving Beyond Commercialization: Strategies to Maximize the Economic and Social Impact of Genomics Research

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### Editor's Preface

Launched in 2009, *GPS: Where Genomics, Public Policy and Society Meet* is a series hosted by Genome Canada to facilitate a dialogue between federal policymakers and researchers exploring issues at the interface of genomics and its ethical, environmental, economic, legal and social aspects (or GE$^3$LS).

Overarching themes for the series and specific topics are selected on the basis of their importance and timeliness, as well as the "ripeness" of the underlying scholarship. Accordingly, the first series focused on "Genetic Information," whereas in year two, attention shifted to "Translational Genomics."

At the core of these exchanges is the development of policy briefs that explore options to balance the promotion of science and technology while respecting the many other considerations that affect the cultural, social or economic well-being of our society.

Co-authors of the briefs are leaders in their field and are commissioned by Genome Canada to synthesize and translate current academic scholarship and policy documentation into a range of policy options. The briefs also benefit from valuable input provided by invited commentators and a group of expert participants and other stakeholders convened at half-day events in Ottawa.

Briefs are not intended to reflect the authors' personal views, nor those of Genome Canada. Rather than advocating a unique recommendation, briefs attempt to establish a broader evidence base that can inform various policy-making needs at a time when emerging genomic technologies across the life sciences stand to have a profound impact on Canada.

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## *Executive Summary*

With the emergence of the federal government budget surplus in the mid-1990s, the government increased its investment in academic genomics research with the introduction of new policies, agencies, and programs. Despite increased funding, the expectation of an economic return on investment, as measured by traditional metrics such as patents, licenses and spin-offs, has not materialized. In the attempt to improve Canada's performance, granting programs now increasingly include assessment criteria related to achieving both economic and social impact from the supported research. Furthermore, a majority of stakeholders now recognize the need to move beyond traditional technology transfer activities of patenting, licensing, and spin-offs. New modes of achieving the desired economic and social impacts worth considering include knowledge translation, entrepreneurship, and industry and community collaborations. Looking at recent European experiences, the concept of valorization presents a broader framework that encompasses economic and social benefits that arise from research and are realized through multiple pathways that go beyond traditional technology transfer. This GPS policy brief traces the Canadian history of commercialization programs and policy development over the past two decades and presents strategies for a new framework based on valorization to guide future policy development in genomics research. The scope of this policy brief, along with several illustrative examples, centres largely on life sciences and health genomics in particular. Where warranted, we will engage in more encompassing analyses about research in general and discuss other important life sciences sectors in Canada, including plant genomics and agricultural biotechnology. The best way to move forward "beyond commercialization" in genomics research will likely require addressing the problem globally since the structure, programs, resources, and talent required to promote changes across the channels of valorization entail much more than genomics research alone to justify the policy changes and resource (re-)allocation.



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Angus graduated from UBC with a B.Sc. in Computer Science in 1983. In 1988, he joined the UILO where he has held various positions relating to industry sponsored research and technology transfer. He has played critical roles in the creation of many Canadian technology transfer and commercialization initiatives including: Westlink Technology Commercialization Internship Program; B.C. Advantage Funds (VCC) Ltd.; Flintbox™; Aggregate Therapeutics and the IP Toolkit; The Centre for Drug Research and Development; and the Canada California Strategic Innovation Partnership – IP Protocol.

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## I. The Context

The concept of university research has substantially changed in the last thirty years and continues to evolve at a rapid pace [1]. Long perceived as knowledge creators, universities are now also viewed as wealth creators [2, 3] and innovation-producing hubs [4]. Novel, more entrepreneurial ways of conceptualizing the production of scientific knowledge have been introduced, including "mode 2" [5] and "triple helix" [6]. These concepts seek to explain innovation, the development of new technology and knowledge transfer applications, and how in turn these have relationally, temporally, and spatially evolved.

While Canada has increased its research funding for post-secondary educational institutions [7], it has simultaneously demanded from them more tangible results [8, 9]. Echoing its American neighbour, the Canadian government has promoted the commercialization (Box 1) of university research to boost university financing and improve technology transfer (Box 1) [10]. This trend is particularly visible in the area of genomics research, where the federal and provincial governments have become increasingly anxious to see the return on their substantial investments [11-13].

**Box 1**

**Key Definitions**

*Commercialization*

The process of extracting economic value from new products, processes, and knowledge through the use of IP rights, licensing agreements, and the creation of spin-off companies [14].

*Technology transfer*

Moving advances in knowledge and technology into the commercial stream, where they can be put to work for the public good [15].

*Valorization*

A broad concept encompassing all channels (Figure 1) that contribute to ensuring that the outcomes of scientific knowledge add value beyond the scientific domain [16]. It is a "process of realization" of relevant added value products (e.g. novel systems or devices derived from genome-based technologies) in a given domain for broad, societal benefit [17]. The importance of both economic and social values should be recognized [18]. Valorization is broader than commercialization, which is motivated primarily by profit [19-21].

There are certainly examples of successful life sciences technology transfers. For instance, through the support of Genome Canada, the Ontario Genomics Institute and others, the University of Toronto's spin-off company DVS Sciences is now successfully marketing – with sales in the tens of millions – the CyTOF™ mass spectrometry machine that is capable of simultaneous quantitative determination of up to 100 biomarkers in individual cells. Nevertheless, the technology transfer-through-commercialization framework has garnered criticism for its perceived one-dimensional, linear model of innovation [22-24], and for neglecting to account for the social value of innovation [25, 26]. Commercialization of university research

remains differentially successful and largely concentrated in just a handful of universities [27].

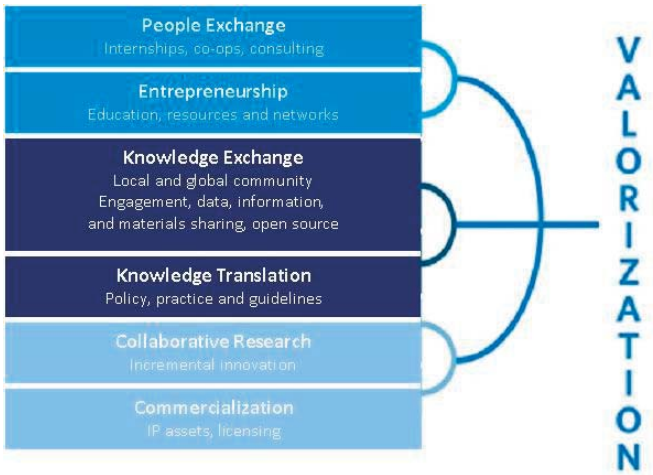
Recent Canadian research has found that there has been only a modest number of invention disclosures, little generation of valuable intellectual property (IP), and almost no revenue generation [12, 28]. A 2008 OECD report found that there was no correlation between intellectual property ownership and better technology transfer [29]. The most recent Canadian survey results from data collected by the Association of University Technology Managers (fiscal year 2010) reveal a total of 1,732 invention disclosures (a 9.2% decrease from 2009), 928 new patent applications, and 50 new start-up companies formed. However, the number of start-ups already in existence that became non-operational increased from 4 to 21 from FY 2009 to FY 2010 [30]. Canada is not alone. This "valley of death" between bench and boardroom is a global phenomenon and similar data have also been reported in other countries that have adopted research commercialization strategies, including the United States (U.S.) [24, 31-33]. The reasons for questionable success, therefore, do not appear to be related to legislation (e.g. the Bayh-Dole Act in the U.S.) or lack thereof (e.g. Canada's emphasis on policies). Further, despite the noted time-lag between research and successful commercialization in the life sciences sector, metrics collected for more than 25 years demonstrate that commercialization has led to limited positive outcomes [34, 35].

In the health biotechnology sector, the poor record in commercialization is often associated with regulatory approval and financing issues which arise after a successful transfer of intellectual property from academia to industry. Despite the exponential growth in global R&D funding in the life sciences, the number of U.S. Food and Drug Administration drug approvals has declined from an average of 36 per year between 1994 and 2004 to an average of 21 per year since 2005 [36]. This counter-performance is choking off investment in the industry, particularly for "innovation funds", which conduct early stage development (pre-clinical, phase I & II) work. Given that the majority of Canadian biotechnology companies engage in such innovation fund work, the industry has now reached a point of virtual collapse. Similarly, there is a weakness of new venture financing in Canada at both the angel and later stages [28, 37, 38]. In the venture capital sector, there has been a 10-year internal rate of return of negative 5% for the asset class. As a result, investors such as pension funds have left the market, leading many to conclude that it will take significant changes to draw them back [39]. Canadian performance in the commercialization of life sciences R&D may be viewed as on par with most other countries, but given underwhelming global outcomes, it begs the question: has Canada, and the world, been following a flawed model?

In Canada, biotechnology research commercialization has been identified by some as an impediment to open academic collaboration [40, 41]. There is growing evidence that commercialization may be associated with data withholding and delayed publication [12, 42, 43]. This aligns with studies in the U.S. which demonstrate that commercialization has altered Mertonian academic norms [44] regarding open and disinterested scientific exchange [45-47]. Additionally, genomic patenting issues (such as patent thickets, diagnostic patents, and parasite patenting) and the recent proliferation of material transfer agreements (MTAs) are seen as impeding research and university-industry collaboration [14, 48-50].

The global biotechnology sector is now living in a new reality, especially in the poor economic climate that is afflicting many European and North American countries. In Canada, since the technology/dot-com bubble collapse of 2001, overall business expenditure on R&D has remained flat after taking inflation into account [28]. Support for biotechnology entrepreneurialism has greatly diminished [51]. Within the university setting, dissatisfaction with the commercialization framework has recently led practitioners, scholars, and policy experts in Canada and abroad to promote the adoption of a richer and more comprehensive translational framework for academic research [16, 52-54]. This framework goes beyond narrow proprietary approaches to promote the use of multiple complementary activity channels to maximize the impact of university research (Figure 1). Illustrations of the influence of this new trend of research valorization (Box 1) can be found in recent guidelines and programmatic support from several Canadian funding organizations (e.g. Genome Canada's Policy on Data Release and Resource Sharing, the NSERC Engage Grants Program, and the CIHR Knowledge Translation programs) and in the renewed interest in identifying or creating adequate metrics to measure return on investments in research and to assess research transfer activities [12, 55]. Yet, research valorization remains a nascent, complex strategy that is thus far not fully understood, endorsed, and consistently applied by policymakers and institutions across Canada, as this policy brief will explain.

**Figure 1. Main channels for valorization**



## II. The Issues

Stakeholders have recently discussed the need to move beyond a narrow commercialization framework [15, 55]. Valorization should not be seen as a radical change but rather the confirmation and standardization of a natural transition that Canadian universities and the public and private sectors have been witnessing in the past several years. Indeed, several emerging examples of innovative research valorization can be found in Canada. These include the Canadian Cancer Research Alliance's (CCRA) inventory of cancer research and its research strategy [56] and Québec's AmorChem Financial, which uses a venture capital approach to invest in start-up life sciences projects and lets them mature instead of launching spin-offs too early. Another example is the Québec Consortium for Drug Discovery (CQDM), a non-profit organization which funds research projects carried out in partnership between public sector institutions (e.g. universities and hospitals) and private sector biotechnology organizations so as to enable pre-competitive tools for drug development. Despite these emerging examples of potential successes, significant barriers remain to adopting a broader Canadian innovation strategy based on research valorization. These obstacles, although not insurmountable, would have to be addressed early on for a successful transition process.

*Terminology*: The meanings of various concepts and strategies proposed to maximize university research output (e.g. technology transfer, commercialization, university-industry collaborations, industry co-ops and internships, knowledge mobilization, knowledge sharing, entrepreneurship) are increasingly conflated by policymakers and academics. For example, there has been a growing tendency to describe commercialization and technology transfer more broadly to also account for the social value of innovation [26]. Given the current state, some might question the benefit for Canada to import the European concept of "valorization", which may not be as appealing as the more familiar terms of "entrepreneurship" or "commercialization". However, commercialization in North America is often associated with pre-conceived notions, such as a focus on patenting and licensing; it could be difficult, therefore, for policymakers to successfully promote a broad vision of commercialization to Canadian stakeholders. Interestingly, the term "valorization" has been used in science and innovation strategies in Québec for a decade [57, 58]. While perhaps simple to fix in theory, settling on a proper definition of "valorization" and incorporating its use into the lexicon of science and innovation strategies may be difficult in practice. Awareness campaigns among various stakeholders may be an important first step in the process of distilling a broadly accepted and holistic definition of valorization.

*Ideological resistance*: A framework based on the valorization of university research will require the convergence of multiple views. Commercialization, industry-sponsored research, and technology transfer have historically faced significant resistance from many university researchers [59-61]. Innovation strategies based on these concepts are perceived by a broad category of researchers as unduly restrictive of academic research freedom and post-secondary education, as well as negatively impacting basic research and research integrity [26, 41, 62, 63]. It has therefore been challenging for these researchers to embrace the commercialization agenda. In turn, the low priority given to commercialization by researchers has likely contributed to the poor implementation of innovation strategies into practice [2].[1] If a Canadian strategy based on valorization is inadequately promoted within academia, it could encounter similar ideological resistance, especially if it is perceived as yet another source of administrative pressure. Therefore, to ensure that the valorization agenda is not sidetracked by misperceptions and cultural differences, it will be imperative to align academic-industry incentive structures with valorization goals [64] and present an inclusive, coherent, and clear strategy that will unite all stakeholders.

*Lack of empirical data*: Despite its current popularity in European innovation policies and universities, much is still unknown about valorization, such as to what extent knowledge is actually brought to market, how long this process takes, and which factors exert a negative or positive influence on the rapidity of the process [65]. So far, researchers have focused on invention disclosures, patent applications, patents granted, licenses, and spin-off firms as modes of knowledge mobilization [2]. Yet, other valorization streams that could be more significant but more difficult to quantify (e.g. publication, networking, teaching, student placement, consulting, and collaboration) have yet to be explored [15]. Moreover, in the field of genomics, some valorization channels (such as open source/open sharing) have simply been introduced too recently to yield meaningful data [14, 67]. Thus, it is presently difficult to assess how effective research valorization has been or will be in the future.

*Absence of coordinated national strategy*: A combination of factors inherent to Canadian society hampers the level of collaboration required to successfully implement a national strategy. Canada is a confederation where social and education policies are generally associated with the provincial domain, and economic policies with the federal. The coupling of a decentralized pluralist political system with a thinly distributed population and variegated life science clusters has led provinces to regionalize science, technology and innovation policymaking [68, 69]. Consequently, science and innovation policies are mismatching and territorially fragmented and there is an absence of a systematic value creation chain [70]. Indeed, there is extensive provincial variation in the degree to which research and innovation occur [1]. While most provinces have prioritized investments in the biomedical sciences, competitive and disjointed niches have been carved out (e.g. health genomics and the discovery of cancer treatments in Ontario, pharmaceutical research and personalized medicine in Québec) to encourage research commercialization and university-industry collaborations. While provincial

[1] A related issue to this is that stakeholders often take a myopic view of technology transfer based on their own perspective. For example, venture capitalists may think that technology transfer offices should focus on creating investable spin-offs, while politicians may focus on new job creation but ignore process improvements that lead to increased productivity and job retention [66].

variation in policies has benefited the research outputs in universities, it has also been a source of policy duplication, inconsistency, and roadblock to the adoption of a collaborative national strategy [69].

*Lack of a critical mass:* The scope of research in a particular area and the volume of a particular type of knowledge asset at a given university are often insufficient for it to be worth experimenting with a particular valorization channel [69, 71]. Researchers that lack university support and a high volume of knowledge assets could have less success in valorization outputs [72]. Canadian academic institutions and researchers will therefore need to develop strategic alliances to get the critical mass and resources needed to improve economies of scale and experiment with different valorization channels to achieve optimal research impact [26, 73]. Several examples illustrate how universities have attempted to collaborate to aggregate knowledge assets to achieve critical mass, both from a bottom-up and a top-down approach, though these efforts have failed more often than they have been successful for a variety of complex reasons (e.g. under-capitalization, lack of buy-in, etc). First, the bottom-up oriented West Coast Licensing Partnership (WCLP) brought together research institutions along the West coast of Canada and the U.S. to make the research tools it developed globally accessible and assist in the development of inter-institutional collaborations and development of new norms of practice and behaviour [74]. Another bottom-up attempt at achieving critical mass, Aggregate Therapeutics, was a biotechnology company created by the Canadian Stem Cell Network (in operation from 2005 to 2010) that held the exclusive rights to commercialize stem cell technologies of Canadian scientists at major universities and hospital research institutes [75]. The top-down approach is exemplified by the CECR (Centres of Excellence for Commercialization and Research) program, initiated by the federal government in 2007 to commercialize technologies within a set domain (e.g. scientific and regional) [76].

## III. Policy Background

Canada has implemented a series of strategies in the recent past to promote commercialization of academic research. But, lack of coordination between those strategies and the short term nature of financial commitments has made it difficult to achieve consistency and harmonization across the country. In Canada, science, technology, and innovation policies are subsumed under the larger rubric of economic policy. They are largely shaped by the federal government through organizations, studies, reports, and strategic frameworks and commitments [77, 78]. Only since the adoption of the 1983 National Biotechnology Strategy, following the advent of new recombinant DNA techniques, did the federal government use nation-wide policy guidance and funding control over major research councils to promote biotechnology as a strategic technology and research commercialization as a national priority [79-81]. Keen to implement the National Biotechnology Strategy, the government thereafter embarked on a build-up phase to promote biotechnology research and eliminate barriers to the creation of a national research and development model [10, 82].

In the past decade, the federal government launched strategies and recommendations that promoted commercialization ideals (i.e. technology transfer and a more competitive Canadian economy through science and technology). The Prime Minister's "Expert Panel on the Commercialization of University Research" recommended in 1999 that universities retain ownership of inventions resulting from publicly funded research, and "be held accountable for maximizing returns to Canada," noting that "the proposed IP policy framework will inspire a transformational shift in culture within Canadian universities, as happened in the United States with the passage of the Bayh–Dole Act in 1980" [83]. A new Canadian Biotechnology Strategy was introduced in 1998 [79], which focused on further facilitating the commercialization of biotechnology research [82], and supporting new mandates for federal funding agencies and research granting councils (e.g. Genome Canada and CIHR). From this point forward, many grant programs required the inclusion of a commercialization strategy and/or an assessment of economic and social benefits to Canada in grant applications [10]. Yet, these programs were often misaligned with provincial strategies or abandoned for new policies after a few years, such as the Intellectual Property Management (IPM) Program that was launched in 2001 and cancelled in 2009 [84]. Federal regulatory agencies have expended time and resources examining and reviewing the regulatory system for the biotechnology and life sciences sectors, yet they have encountered difficulty converting recommendations and strategies into action [85]. This policy activity has not led to recognizable, successful, or tangible outcomes [12, 28].

Industry Canada has reaffirmed its commitment to align the programs and activities of existing federal organizations to increase research commercialization outcomes, and to work with the provinces and territories in this regard [86-88]. As part of this strategy, the Science, Technology and Innovation Council (STIC) was created in 2007 to provide the federal government advice on science and technology issues, a commercialization focus in four sectors (later expanded to encompass 13 sub-sectors), and "State of the Nation" reports in 2008 and 2010 that measured Canada's science and technology performance against international standards of excellence. Finally, the six-member expert panel Review of Federal Support to R&D reported in October 2011 on federal government support programs for innovation and provided recommendations on maximizing the effect of federal programs that contribute to innovation and create economic opportunities for business. Among the most relevant of its recommendations were to 1) create an Industrial Research and Innovation Council (IRIC) with a clear business innovation mandate (including the delivery of business-facing innovation programs, development of a business innovation talent strategy, and other duties over time), and 2) enhance

the impact of programs through consolidation and improved whole-of-government evaluation [89].

University administrators have generally supported the commercialization agenda of the federal government and in 2002, universities adopted the Framework of Agreed Principles on Federally Funded University Research. Under this Framework, the Association of Universities and Colleges of Canada (AUCC) stated that upon the federal government doubling its support for R&D, universities would triple their commercialization outcomes by 2010 [90]. This objective was not met [30].

In recent years, the Canadian granting councils and Genome Canada have actively developed policies and programs to promote research commercialization, narrowly or more broadly defined. In 2011, CIHR created a "Knowledge to Action" grant through its Knowledge Translation Branch that seeks to "increase the uptake and application of new knowledge by supporting partnerships between researchers and knowledge-users to bridge the knowledge to action gap, and in so doing, increase the understanding of knowledge application through the process" [91]. Genome Canada has also actively promoted genomics entrepreneurship through some of its recent grants. For example, the Entrepreneurship Education in Genomics (EEG) Program supports initiatives to educate the Canadian genomics research community on how to create and capture value from their research and translate discoveries into marketable applications, products, technologies, systems, and processes [92].

Virtually all provinces have adopted policies promoting the commercialization of genomic research and are providing programmatic support to complement what is offered by federal agencies, but as discussed in Section II, their coordination with federal policies greatly differs [1, 10]. In sum, commercialization of publicly funded genomics research is supported by the federal and provincial governments and universities, while largely operating outside a strict, coherent legislative framework. The question then becomes how best to maximize or "satisfice" [93] the economic and social impact of genomics research, acknowledging the inherent challenges of innovation. Conceivably, Canada can maintain the status quo, but there is a detrimental cost to doing nothing (even if this is virtually impossible to quantify). As documented above, the current commercialization system is slow, under-performing, under-resourced, and convoluted by a bewildering array of standards. As outlined below, we think a toolbox approach that makes use of the multiple channels available in the valorization model,while allowing some room for context specificities, is the most effective way forward.

## IV. Policy Options

There is a growing consensus that the narrow commercialization approach to maximizing the impact of research is inadequate [2, 15]. Canada's innovation framework is currently in transition. New valorization channels (e.g. knowledge exchange, entrepreneurship, collaborative research, and open source) are unevenly introduced at the regional level. These approaches are often segregated – rather than included – within a coherent, holistic framework. This lack of coordination contributes to inefficiency and inconsistency in our efforts to convert genomics and other research into social and economic benefits for Canadians [78].

We offer the following policy options. We wish to note that these options are not necessarily mutually exclusive and can be used complementarily:

### Option 1 - Unite stakeholders behind a common, broader innovation strategy

Policymakers at the federal, provincial, and institutional levels should collaborate more closely. They should agree upon a long-term, committed, single strategy that sends a clear message to academic researchers. This new strategy could be promoted through complementary, coordinated application of the usual policy levers, e.g. resource allocation, regulations, policies, programs, and tax breaks. In this context, the federal government and its leading organizations (e.g. Department of Industry, Health Canada, Genome Canada) could leverage its central position and comparative financial stability to play a quarterbacking coordination role and cooperate with the provinces to create a much needed synergistic effect.

To achieve this innovation strategy, a survey conducted by researchers or the government of the genomics research community (researchers, funders, techology transfer offices, etc.) may be a vital tool to assess Canadian innovation competencies and gaps. R&D funds may then be channelled appropriately to avoid duplication and encourage consolidation and complimentarity. Some organizations, such as the Canadian Cancer Research Alliance, are already moving towards this type of informed approach to innovation funding. As well, intramural federal R&D and regulatory expertise could complement early stage university research to add value, especially in areas where knowledge of regulatory affairs is lacking, such as biomaterials formulation and prototyping.

At the same time, coordination and collaboration around a common strategy can still accommodate local contexts and avoid a one-size-fits-all approach or "one unique best practice model" driven by narrowly defined performance indicators [94]. By implementing the strategy via processes that reflect location or university-specific strengths (e.g. agriculture biotechnology), limitations (e.g. provincial budget deficits), or other pertinent factors (e.g. geographic isolation), an equitable synergistic effect can be achieved that promotes a common goal – a holistic innovation framework – within a diverse Canadian research landscape. Indeed, many industry groups in Canada – such as those in agricultural-biotechnology (e.g. Canola Council of Canada) – are neither fully public nor private, but rather middle-ground and community-driven.

The proposed new strategy could take the form of research valorization as introduced earlier in this brief (option 1A), or it could

also consist of substantial reforms to broaden the current commercialization framework to achieve a similar holistic innovation framework (option 1B). A drawback of these options, however, is that it is challenging to create and implement a consistent national innovation strategy since the provinces are primarily responsible for universities.

### Option 2 - Promote open information sharing to foster harmonization

At the university level, much remains to be done to improve harmonization of and open access to the various tools (template agreements, primers, decision tree models) and commercialization/valorization policies [14]. The size, funding sources, research specialization, research infrastructure, and interests of universities can vary considerably. Given these differences, facilitating improved dialogue and communication of information both across and within institutions is needed to avoid perpetuating some of the issues associated with commercialization, such as lack of critical mass, inconsistent approaches, and duplication. Canadian universities have much to gain by working towards integration of common goals and developing symbiotic relationships with one another, strategically aggregating strengths and resources [78].

At a minimum (option 2A), universities should collaborate on the development of a national online repository of research valorization. This open access online repository would contain archived copies of valorization policies, information papers, IP policies, template agreements, authorship policies, etc. from academic institutions across Canada. Open, standardized, user-friendly access to this material will promote transparency and encourage the imitation of successful models, leading to greater harmonization of practices. Research hospitals and federal provincial labs could also contribute to the repository. Ideally, funding for the creation and maintenance of this infrastructure could be shared between a variety of sources (e.g. governments, industry, universities, etc.). A catalogue of knowledge, perhaps under the rubric of a national strategy for information sharing in various fields (e.g. patient data and genomics data), would facilitate more open sharing of knowledge of broadly applicable technologies such as algorithms for biomarker identification.

Going further (option 2B), universities sharing similar research interests could join forces and create organizations to coordinate their valorization activities. In addition to providing the community with a resource such as the one described above, university associations could pool resources and aggregate innovative products and expertise in order to achieve the critical mass necessary to experiment with new valorization channels and pilot projects. Moreover, such university associations could share data and research on the performance of new valorization streams to provide the research community and policymakers with the necessary evidence to improve evaluation metrics in the future. These associations will need to coordinate their activities to achieve complementary synergy with the valuable output of the Centres of Excellence for Commercialization and Research (CECRs). They will also need to work hand-in-hand with other Canadian associations involved in the standardization of institutional innovation practices (e.g. ACCT Canada).

### Option 3 - Reshape the mandate of technology transfer offices

Technology transfer offices (TTOs), industry liaison offices (ILOs), and their equivalent (hereinafter, TTOs) have a strategic role to play in the promotion and implementation of a new valorization strategy or a similar broad commercialization approach. The results of a recent survey of a subset of the roughly 400 technology transfer professionals in Canadian universities [95] demonstrates that professionals are torn between narrow economic visions of technology transfer manifesting themselves in growing pressures to generate revenues, a more holistic view of the process, and concerns about the social dimension and benefits of innovation [12]. It should be noted that the names of some TTOs are already changing, e.g. University of Calgary (Innovate Calgary), University of Toronto (Innovations and Partnership Office), and Simon Fraser University (Innovation Office), in order to reflect a new appreciation for a broader range of activities beyond the traditional field of technology transfer.

Looking at the current mandate of TTOs and the potential future role they could play within the valorization process, the following two options should be considered. First, (option 3A), institutions could broaden the mandate of TTOs to reflect a more holistic vision of valorization. Under this broader mandate, TTOs would be treated as more than an ancillary service and all valorization channels (e.g. open source, partnership, open publishing, etc.) introduced earlier in this policy brief would then formally fall within the institution's purview. TTOs would shift focus to view valorization as an investment more than a source of revenue, which could reign in the tendency to overvalue technologies and demand up-front payments on licenses. Additionally, TTOs can work with researchers to provide measurable deliverables and determine projects with great potential for joint economic and social impact. TTOs can also work towards identifying valuable niches for Canada so that they can leverage these assets with other countries that have similar interests. A drawback of this broadened mandate is that it would likely entail the expansion of resources (e.g. staffing and facilities) within the TTO, and universities alone may not have the necessary financial resources to afford such significant restructuring.

Second (option 3B), assuming institutional will and financial capacity, universities could support valorization at the institutional level while creating specific offices to handle each of the different channels of the valorization process. In this case, special attention should be given to ensure that all channels are represented within an institution and that resources are distributed appropriately between offices to avoid favouring traditional channels over newer ones. The new valorization office(s) and university associations (as suggested above) could both have a role to play in educating researchers on the merits of the valorization framework and in helping them to integrate it into their research.

## V. Practical Application and Considerations

If one envisions the adoption of a valorization-based strategy, the following practical issues will need to be considered to ensure proper implementation and optimal results. Many of these issues share a common theme of working collaboratively with many players in the innovation ecosystem. Given the sheer number and complexity of variables, this section simply introduces the main issues.

The first important steps to adopting a valorization strategy will likely be a joint mutual commitment from the universities and the federal and provincial governments, ideally with the inclusion of viewpoints and possible concerns from community stakeholders and researchers. Researchers may benefit from entrepreneurial skills and training, education awareness, and business model development around valorization [96]. At the same time, to ensure a better return on investment success rate, a valorization-based strategy could benefit from a "market pull" (i.e. needs) approach, in addition to a traditional technology push model. This approach, which is centred on determining the needs of users and is well reflected in agricultural genomics and in forestry [97-99], will help ensure a better balance of appropriate knowledge flows between commercial, and technological perspectives. We therefore see a need for both technology push policies such as R&D tax credits, education and training, and market pull policies such as intellectual property protection, technology mandates, and regulatory standards [100].

The private sector also has a vital role to play in the research valorization process, particularly in the current economic environment where government funding has peaked and governments are now looking to downsize their funding role in many sectors. While research on the performance effects of university–industry collaboration are only now starting to appear (and mainly in Europe) [101-103], findings show a strong positive impact of value chain complementarities between the two sectors. Greater collaboration and networking between private sector organizations and between private and public actors is highly desirable and could lead to the development of new financial programs, partnerships, and policy initiatives. If consulted, organizations with significant expertise such as BIOTECanada, the National Angel Capital Organization, and the Canadian Association of Business Incubation can greatly contribute to the valorization framework.

Access to early pools of capital remains a top priority for emerging biotechnology firms. There are important fiscal options to consider. For example, allowing biotechnology and life sciences investors to use flow-through shares, as in the natural resources and renewable energy sectors, may be an option worth exploring as a means to facilitate valorization of genomics research [104]. Another fiscal option would be to create an investment tax credit for those investing in eligible start-up and early-stage companies, including spin-offs. The National Angel Capital Organization has proposed an Innovation and Productivity Tax Credit (IPTC), which would entitle individuals investing in eligible companies to a specific tax credit allotment. Upon making their investments, investors would apply for a 30% refundable tax credit that would be funded equally by the federal government and participating provinces [105].

As discussed in Section IV, there are many policy levers that can be pulled to promote research valorization. Research policies of funding bodies such as Genome Canada and CIHR, if used in a strategic and coordinated fashion, are excellent tools to promote a valorization-based framework. Different channels of valorization can be addressed through an integrated set of research policies (on publications, data-sharing, intellectual property, reporting, etc.). To avoid sending conflicting messages to university researchers, special attention should be given to the internal coherence of these funding policies (e.g. a policy on intellectual property should be well-adjusted to those on open access and data sharing). Funding policies should also be harmonized with the research policies of academic institutions [106].

The development of more elaborate evaluation tools as proxies to assess and reward valorization performance should be viewed as an integral part of a successful framework. However, these proxies must not be viewed as the ultimate goal, which should remain the maximization or satisficing of net social and economic benefits [107]. Metrics will need to be adjusted to reflect a more realistic, longer cycle from funding to research output (in contrast to increasingly typical short-term funding of two-to-five year cycles) and the holistic, non-linear and heterogeneous nature of university innovation [107]. They should, as much as possible, be harmonized across institutions, funders, and governments to make them useful for as wide an audience as possible. Moreover, we should expect some possible early-stage disappointments with these new metrics; they would be the natural by-product of political cycles and Schumpeterian "creative destruction", which is a healthy component of an innovation ecosystem. There is still much research needed to identify and fine-tune all suitable valorization metrics that accurately measure performance and minimize value-laden and university-dependent variables. However, we urgently need to move beyond narrow quantitative assessment models and experiment with a broader, richer framework if this is to be accomplished.

Governments, funding bodies, and academic institutions are encouraged to make full use of the vast potential of information technology (IT) to promote valorization across all sectors. The internet repository for academic institutions discussed in Section IV is one good illustration. Another example is Flintbox™ (http://www.flintbox.com), an online platform that handles the marketing and licensing of research outcomes, such as software, biomaterial, and digital works. End users can access multiple networks of research in a common format through a single account. Researchers can manage both the content and licensing process; because Flintbox™ tracks access and licensing activity of each research project posted, demand for technology can be identified, relationships can be fostered, and early-stage research can grow into products with valorization potential [11]. By greatly facilitating collaboration, exchange, and access, IT has a significant role to play in the valorization process.

## VI. Future Research Questions

The focus of this policy brief has centred mainly on the valorization of genomics research, yet genomics is a broad and complex discipline. Different genomics (and related omics) fields will likely require different research questions. For example, grape and wine genomics [108] is quite different from human proteomics and metabolomics research. There thus remains many unexplored avenues for future research. Additional data and expertise on the different channels of valorization will need to be obtained through research and experiment. Appropriate heuristics (e.g. scientific methodologies) between technological, commercial, and organizational perspectives should be developed in order to reduce uncertainties in the valorization model [109]. Economic analyses, refined to the context of academic genomics research, will also be needed to provide its insights on how valorization may increase the rate of return on investment beyond the narrow commercialization context. Research should be undertaken to explore how Canadian prosperity, social benefits, and revenue for IP owners can be more appropriately balanced. The power of open innovation to resolve the translation problem that genomics research currently faces [110] certainly warrants full attention. Given the present context of research globalization, it would also be important to keep track of how valorization and other similar innovation frameworks are evolving abroad.

The transition from a narrow to a richer, wider innovation framework has created much confusion among stakeholders. Given the need for clarity and synergy across the board, it seems inappropriate to advocate for a "genomic specific" innovation framework. Nevertheless, it would be useful to undertake additional research on how best to personalize valorization to optimally promote the different fields of academic research, including engineering, physics, marine biology, and plant genomics and its various derivatives (e.g. genetically modified organisms in the agriculture biotechnology sector). Finally, special attention should be given to the roles of various, heterogeneous stakeholders (including the public) in the valorization process [111] and to the means of improving the communication channels between these stakeholders.

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