

WHAT IS HOLDING BACK ALBERTA'S PRECISION HEALTH INNOVATION AND COMMERCIALIZATION ECOSYSTEM?

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SUMMARY

Now, more than ever, governments and the public are recognizing the importance of health innovation. Precision health (PH) is the next frontier in medicine, enabling individually tailored ways to diagnose, treat and prevent disease in place of today's one-size-fits-all approach. Exploring new opportunities for economic growth is a priority in Alberta given the roller-coaster in recent years from reliance on hydrocarbon royalties coupled with resource-based economic divestment. PH offers Alberta the chance to diversify its economy by developing technology, attracting investment and creating a new health-care industry.

As discussed in greater detail in a policy communiqué released alongside this research paper, PH comes with tremendous benefits. Foremost among these benefits is the ability to narrow health disparities among population groups and support social services in times of crisis. Plus, an Alberta-grown PH sector will fuel economic growth, innovation and lasting prosperity. Opportunities are expanding as the global PH market is forecast to grow by 11.3 per cent annually, reaching \$141 billion in value by 2026.

With a unified health system and many clinical and research strengths, Alberta is well placed to make great strides in PH. Government and universities are already working on PH strategies. However, success is not assured.

The province is already dealing with severe fiscal constraints, especially in health care. This paper identifies several other policy issues, based on interviews with leaders in the public and private sectors. There are four main areas where Alberta

faces challenges: innovation networks; facilitating discovery; governance and decision-making; and risk and procurement.

Alberta's innovation networks are too fragmented, with too much competition and not enough collaboration. There is also a lack of supports and commercialization channels; entrepreneurs don't know where to turn or whom to talk to.

Motivating researchers to develop and commercialize products is an especially contentious problem. Projects range from those with high commercial potential to theoretical concepts providing the foundation for future discovery. The interviews for this paper revealed a powerful divide between academics, who want the freedom to research their interests, and government and funding agency participants, who want specific goals and health-care challenges to receive the bulk of the dollars.

Executing and co-ordinating a provincial PH strategy is another area where change is necessary. Governance is unclear and many participants are worried about the vagaries of politics affecting funding decisions. Research incentives are often misaligned or structured to produce impacts within one election cycle. This doesn't mean a single authority is required, since that likely would not align with existing structures in place. However, a central group charged with making high-level decisions about priorities might be a valuable resource.

Finally, there's procurement and the tolerance of risk. AHS as a single service provider is beneficial in that it cuts down on duplication and overspending. But the system is also rigid and risk-averse, so it's not the ideal customer for SMEs or early-stage ventures. PH is far from a mature industry, meaning results are not guaranteed. There's a need to expand the comfort zones of the powers that be, so they are more willing to bet on innovations. There's also a need to bring promising products to their attention. Health care is not a traditional market with individual consumers, and administrators remote from clinical practice may not grasp the value of new technologies.

This paper summarizes the findings of many interviews with decision-makers in health care, academia, government circles and the innovation sector. Much like PH, it presents solutions to specific problems confronting Albertans.

GLOSSARY OF RELEVANT CONCEPTS

Commercialization – *“The process of managing the transfer of research knowledge to the place where it becomes an application in the broad marketplace. The knowledge might be a research outcome or a skill; it might result in the development of a product, a technology, service or business, a community development program, or consulting activities” (Christian 2018).*

Demand-side Innovation Policies – *“All public measures to induce innovations and/or speed up diffusion of innovations through increasing the demand for innovations, defining new functional requirement for products and services or better articulating demand” (Edler and Georghiou 2007).*

Invention-oriented Policies – *“Policies with a narrower focus [than system or demand-side], in the sense that they concentrate on the R&D/invention phase and leave the possible exploitation and diffusion of the invention to the market (Edler 2017).”*

Innovation – *“A new or improved product or process (or combination thereof) that differs significantly from the unit’s previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)” (OECD Oslo Manual 2018).*

Innovation and Commercialization (I&C) Ecosystem – In the public policy context, this concept closely resembles national systems of innovation but can be at the provincial, regional or territorial level. *“A national system of innovation is the system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, protection, financing or regulation of new science and technology” (Niosi et al. 1993)*

Innovation Governance – Across the ecosystem, innovation governance describes the industry-wide structures of decision-making. *“A system of mechanisms to align goals, allocate resources and assign decision-making authority for innovation, across the company and with external parties” (Deschamps 2013).*

Precision Health (PH) – Providing individual, personalized health strategies through innovations that use individual characteristics ranging from social determinants of health to precision medicine to family medical history. *“The study of individuals and populations using a comprehensive approach and new technologies to improve health and to facilitate transformation of the health system” (Eagle and Dubyk 2019).*

Precision Medicine – Similar to precision health; however, it is limited to applications in medicine. *“A new era for diagnosing, treating and preventing disease that will move away from a ‘one size fits all’ strategy to a more individualized approach based on a patient’s genetic makeup. It offers an opportunity to dramatically improve the effectiveness of healthcare by pinpointing the right treatment at the right time in the right dose with reduced side-effects and maximum efficiency” (Health Canada 2016).*

Public Policy – “A set of interrelated decisions taken by a political actor or group of actors concerning the selection of goals and the means of achieving them within a specified situation where these decisions should, in principle, be within the power of those actors to achieve” (Jenkins 1978).

Social Determinants of Health – “The complex, integrated, and overlapping social structures and economic systems that are responsible for most health inequities. These social structures and economic systems include the social environment, physical environment, health services, and structural and societal factors. Social determinants of health are shaped by the distribution of money, power, and resources throughout local communities, nations, and the world” (World Health Organization 2008).

System-oriented Policies – “Focus on system-level features, such as the degree of interaction between different parts of the system; the extent to which some vital component of the system is in need of improvement; or the capabilities of the actors that take part” (Edler 2017).

I. INTRODUCTION

Health innovation is shifting toward precision health (PH), a new approach that synthesizes numerous sources of individualized patient information into policy and clinical decisions. Canadian jurisdictions must use mixed health innovation and commercialization (I&C) policies, or they will be left behind by intense global competition. In the event that Canada does not keep up with the global precision health technology market, public health systems and Canadians will become PH consumers instead of producers. Adopting PH technologies and fuelling the I&C sector across provinces would provide widespread benefits. On the other hand, expensive therapeutics and fiscal restraints mean large resource investments are not a feasible strategy to accelerate PH I&C.

The Canadian government has set lofty goals for this industry. “By 2025, Canada will double the size of the health and biosciences sector and become a top-three global hub by: leveraging and advancing innovative technologies; attracting and retaining capital, skills and talent; and ensuring a vibrant ecosystem that will unleash the full potential of the sector and lead to improved health outcomes” (ISED Canada 2018, 2). To meet these federal health innovation goals, the provinces (which deliver health services) must re-evaluate their policies and develop strategies to foster health innovation. Provinces, however, are facing health system spending constraints. Now, more than ever, economic shortfalls force innovative solutions to spending challenges that constrain health-care outcomes.

As a first step, provinces require analysis of the existing policy barriers and challenges within their PH I&C ecosystems. This study focuses on understanding these considerations in an Alberta context. Given the existing PH research capacity, expressed interest in this industry and health-care system fiscal pressures from cuts announced in Budget 2019, Alberta serves as a strong representative to discuss provincial PH I&C issues (Government of Alberta 2019). We conducted semi-structured interviews with leaders from key stakeholders within this sector to identify impediments to PH I&C ecosystem activity. Alongside this research paper, a policy communiqué was developed to describe what PH

and I&C ecosystems are, how health I&C ecosystems differ from other sectors and how PH changes the traditional concept of a health I&C ecosystem.

II. WHY PRECISION HEALTH?

Novel technologies, scientific discovery, advancements in data analytics and new methods of using non-health data are some of the driving factors for the growth of PH. Offering a more precise and tailored health strategy has countless benefits. PH solutions are another tool to implement upstream health intervention, reducing disparities among populations and improving overall health (Williams et al. 2008, s8-17). By predicting potential health concerns earlier, fewer patients require medical intervention, which is a more desirable option for decision-makers facing expanding health costs. Using more sources of information, such as social determinants of health information, provides an immense opportunity to improve health outcomes based on individualized data.¹

PH inherently requires interdisciplinary collaboration because it spans a number of sectors such as the Internet of Things (IoT), information and communication technologies (ICT), legal development, economic and business professionals, manufacturing and social work (Richter 2015). Initiatives in Switzerland, a leader in PH, focus on combining the strengths of these diverse fields to tackle health issues. Health 2030, for example, is a multidisciplinary endeavour that supports projects which combine these diverse backgrounds.²

Health-focused organizations are not the only beneficiaries of precise, individualized, interdisciplinary health innovations. Improving health outcomes should be a priority for economic development, for instance, because it creates a healthier population as a secondary benefit. The economic cost of poor health is comprised of both direct and indirect costs (Mayo Clinic 2008).³ Indirect costs are often overlooked because they do not appear on an expense sheet. In 2010 alone, poor mental health cost Canadians nearly \$50 billion, which is comprised of indirect and direct sources – \$30 billion and \$20 billion respectively (MHCC 2016). Considering mental health is only one of many potential poor health outcomes, the total economic cost of poor health is enormous. If PH is successful in improving health outcomes, it should be a priority for those outside the health-care system.

Precision health approaches may prove to be beneficial from the level of the individual through to population; however, they demand greater engagement from professionals, participants and the public due to the social implications of these technologies, such as access. Access in the future will depend on affordability. Since these technologies are often highly targeted, the number of available treatment options must also increase. Combined

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The Government of Canada defines social determinants of health as social factors that influence broader determinants of health including education, gender, culture, childhood experiences, physical environments, etc. (Government of Canada 2018).

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Health 2030 is a “multicentric and multidisciplinary initiative aimed at exploring and exploiting the potential in the fields of health and personalized medicine” (Health 2030 2018).

³

Direct costs are health expenditures borne by the provincial government spending on health, such as medical staff or outpatient fees and out-of-pocket expenses such as drugs, privately insured services and non-insured expenses. Indirect costs of poor health outcomes are non-expense forgone opportunities such as absenteeism, lost productivity, job turnover or disability payments.

with the fact that PH therapeutics can be extremely expensive (upward of \$500,000), PH may be unfeasible for the health system.⁴ Innovation poses a threat to the health-care system because it could increase costs, in a time where the mandate is to “bend the cost curve”.⁵ The “Paradox of Productivity, Technology and Innovation” describes this relationship: as productivity increases in the health sector there is a relative increase in the usage of overall health-care services by offering something new (Blomqvist and Busby 2017). The result is that the budget allocation toward innovation increases as innovations become increasingly personalized (Skinner 2013).⁶ This effect may drive up overall costs or require substitution from other areas of health spending.

III. WHY INCREASE PRECISION HEALTH INNOVATION AND COMMERCIALIZATION?

Beyond just the technologies themselves, the innovation and commercialization process creates social value; however, the expected benefits from an improved PH I&C ecosystem are diffuse across society. These widespread benefits imply the health-care system and its care providers are not the only beneficiaries of these policies. Development of this industry offers immense potential for social returns on public dollars by creating a healthy workforce, stimulating research investment, accelerating commercial outputs and contributing to diversification strategies across Alberta. The Canadian Advisory Panel on Healthcare Innovation (2015) described the link between health-care innovation and workforce modernization. Creating an interdisciplinary, innovative health sector spanning areas such as social services improves health-care workforce training and outcomes. This training improves the health-care system’s readiness for adoption, while simultaneously creating the workforce of tomorrow. Attracting high-skill talent, creating new professions, promoting interdisciplinary collaboration and modernizing the health-care workforce are spinoff effects of a PH I&C system.

Policies to diversify Alberta’s economy have gained increasing interest to reduce the reliance on natural resources (Government of Alberta 2013; Notley 2019). Provincial revenue streams have dried up from decreased tax revenue and royalties (from hydrocarbon-based resources), coupled with resource-based economic divestment. Exploring new opportunities for economic growth is a priority; innovation is an area needing improvement. The Conference Board of Canada (2018) benchmarked innovation factors in Canada and its provinces against 15 other nations.⁷ Alberta underperformed, scoring 19th of 26 international peers (“D”). Innovative industries such as PH are in high demand, creating opportunities to strengthen innovation factors and increase local revenues. The global PH market has exhibited rapid growth, already reaching \$43.59 billion in 2016 and forecasts

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The example provided is for a chimeric antigen receptor (CAR) T-cell therapy, an extremely promising cancer-fighting therapy. Source: Caffrey 2018.

5

“Bending the cost curve” refers to the process of slowing the rate of expenditure on health care (Dutton et al. 2015).

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Personalized health care can be a cost driver because the costs to administer the services or technologies are spread out over a fewer number of people. Think of this as a reverse economy of scale.

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How Canada Performs: Innovation – Provincial & International Benchmarking – May 2018.

expect sales growth of 11.3 per cent annually to over \$141 billion by 2026 (BIS Research 2017).⁸ Increased productivity in underdeveloped sectors is an example of a diversification policy that focuses on income concentration, not just employment.

Knowledge-based economic activity, such as PH I&C, provides supplementary benefits to resource-based economies. A balance of strong, twin-engine resource and knowledge industries results in increased resistance to economic hardship and reduced recession severity (Florida and Spencer 2015). Capitalizing on Alberta's existing health innovation strengths offers excellent opportunities for accelerated I&C through strategic investment. Widespread innovation in both technology and services, such as research and development (R&D) investment, leads to increased productivity and income diversification (Baumann and Kritikos 2016, 1263-74; Fazliglu et al. 2016, 439-60; Martin and NguyenThi 2015, 1105-30).

PH activities are often R&D-dependent. Many have noted the connection between R&D, economic output and knowledge spillover effects through concentrated centres for innovation.⁹ In most cases, the social rates of return to R&D significantly outweigh the private rates of return (Hall, Mairesse and Mohnen 2009, 1033).¹⁰ The market does not capture all the benefits of R&D, consequently resulting in lower than socially optimal quantities of investment and activity. Other countries made efforts to correct this shortfall by increasing government health I&C expenditures on R&D. Examples are France's Genomic Medicine 2025 and German Personalised Medicine Action Plan, which both commit to increasing public funding for precision-based R&D over the next decade (BMBF 2013; Lévy 2016, 2872). Unsurprisingly, these countries are quickly becoming leaders in the PH industry. Morton and McDonald (2015) postulate that "forced growth" in Alberta, through large-scale government expenditures, resulted in massive projects without the expertise to facilitate them. Therefore, diversification efforts should not only focus on the income concentration but also industries with the capacity to grow. Since the health I&C ecosystem has committed to PH, it is a strong candidate for investment.

IV. ALBERTA'S PRECISION HEALTH INNOVATION AND COMMERCIALIZATION ECOSYSTEM

Alberta has a unique advantage by using its health and administrative data, linked pan-provincially, for its population of more than four million within one health system, Alberta Health Services (AHS). Strengths in clinical research, advanced imaging and diagnostics, artificial intelligence, 'omics, analytics and bioinformatics, microbiome knowledge networks, precision public health and targeted therapeutics position Alberta to impact the global PH

⁸ This estimate is smaller than the actual industrial sales because the definition of PH used in the report does not include public health interventions and technologies.

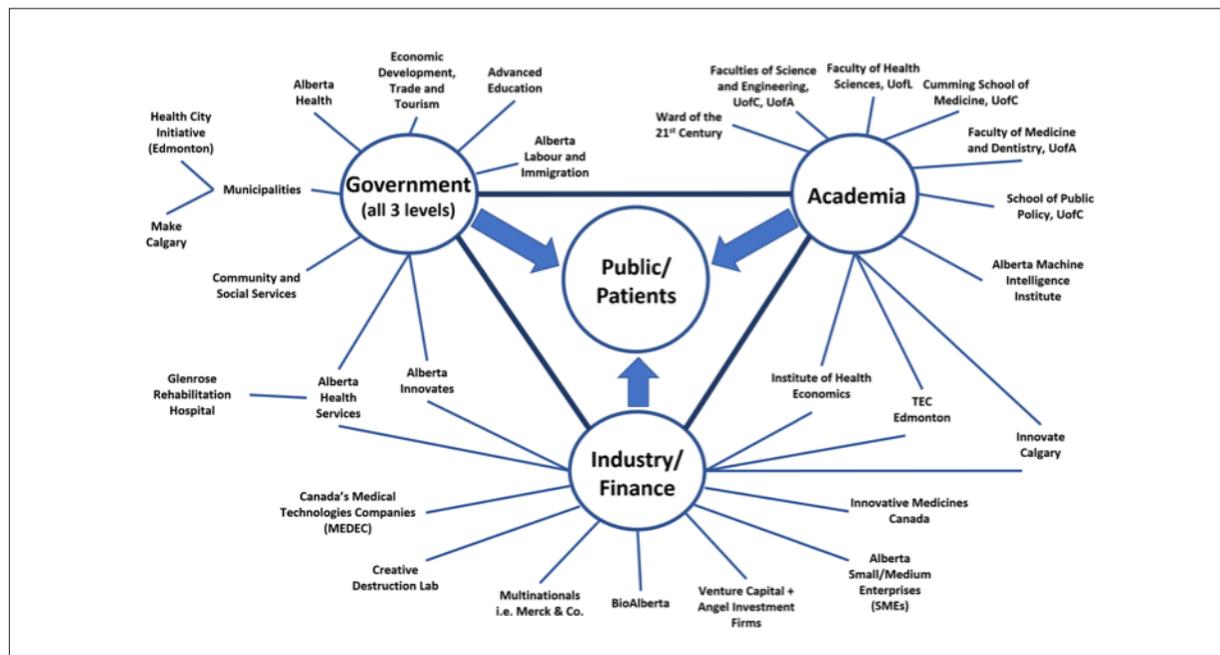
⁹ Knowledge spillovers are benefits that are incurred by anyone other than the R&D producer.

¹⁰ In Canada, estimates suggest the social rate of return to R&D exceeds the private rate of return by a factor of three or more in most industries (Bernstein 1996, 463-67).

industry (Alberta Academic Health Network, forthcoming).¹¹ PH strategies are currently underway through efforts from two government ministries, Alberta Health and Alberta Economic Development, Trade and Tourism; and research universities – the University of Alberta, University of Lethbridge and the University of Calgary.

Alberta’s PH I&C ecosystem is complex, involving government ministries, public agencies, health-care providers, research institutes, philanthropy and the private sector. Different ministries and public agencies in Alberta create and manage the policies that affect PH I&C. Many of the programs available in Alberta occur at provincial and national levels, but the civic level is also present. Appendix B highlights provincial and civic organizations with policies and programs pertaining to PH I&C. A companion policy communiqué explains the added complexity of a PH I&C ecosystem and the intended roles of such a system (Scott and Zwicker, forthcoming). Figure 1 visualizes some relevant stakeholders in Alberta based on categories from the quadruple helix model of innovation (academia, government, industry and the public). Intended to be illustrative rather than comprehensive, this figure highlights the ecosystem complexity. Other agencies exist across the various groups in different capacities. The public is at the centre because all the components of PH are designed to improve their outcomes.

FIGURE 1



¹¹ 'Omics – the study and integration of molecular biology fields ending in the suffix “omics”, including genomics (DNA), transcriptomics (RNA), proteomics (proteins) and metabolomics (metabolites). “The objective of omics sciences is to identify, characterize, and quantify all biological molecules involved in the structure, function, and dynamics of a cell, tissue or organism” (Vailati-Riboni et al. 2017, 1–7). Precision Public Health – Applying big data principles to individual-level data such as social determinants and more accurate methods for measuring disease, pathogens, exposures, behaviours and susceptibility to better assess population health and design targeted intervention for disease prevention (Khoury, Iademarco and Riley 2016, 398–401).

Health care in Alberta has major fiscal challenges ahead with an increasing percentage of the provincial budget used on health expenditures. In 2018-19, the Alberta government spent \$20.4 billion (41.1 per cent of revenue, 36.2 per cent of expense) toward health services alone.¹² Translating to \$7,552 per person, Alberta leads the nation in health-care spending per capita and is faced with a crisis as spending outpaces economic growth (CIHI 2018, 20). High spending does not translate to improved health and patient outcomes, as demonstrated when benchmarked against other provinces.

Health innovation is a key piece of Alberta's \$700-million-per-year life sciences industry. Three subsectors comprise 74 per cent of companies, medical technology and devices, health biotechnology and pharmaceuticals, and health information technology (Deloitte and BioAlberta 2017). Interest is strong in PH innovation specifically. Universities in Alberta have identified PH as a strategic priority in their schools of medicine and for the University of Alberta, the entire university. In 2017, the Alberta government announced its Alberta Research Innovation Framework (ARIF) – a roadmap for innovation indicators and targets by the provincially supported research and innovation organizations. Emerging technologies and two out of five priority areas for its 2030 innovation targets are important to PH (health, and fibre and bio-industrial). One of the goals ARIF identified for health innovation was for “Alberta to become a top 10 location for research, development and commercialization of health and wellness innovations in North America.”¹³

VI. INTERVIEW FINDINGS

Thematic analysis of the interview data uncovered four categories of PH I&C policy issues described as (1) innovation networks; (2) facilitating discovery; (3) governance and decision-making; and (4) risk and procurement. Table 1 summarizes these categories by grouping the discussion into sub-themes, describing the policy categories, illustrating examples of underlying policy issues and offering a recommendation for each category. This section of the paper unpacks these findings by presenting qualitative findings about each of the four major areas from the interviews.

¹² These proportions were calculated from the Government of Alberta 2019-2023 Fiscal Plan.

¹³ <https://www.alberta.ca/assets/documents/arif-report.pdf> page 9.

TABLE 1

Policy Category (Sub-themes)	Policy Issues Presented	Recommendation
<p>Innovation Networks</p> <ul style="list-style-type: none"> • Co-ordination & Collaboration • Navigation 		
<p><i>Description: Interpersonal and inter-organizational innovation activities such as joint organizational initiatives across the I&C ecosystem.</i></p>	<p>Balance of competition among the various organizations, co-ordination of transition points in I&C support and navigating innovation organizations</p>	<p>Incentive Greater Collaboration Among New and Existing Ecosystem Players</p>
<p>Facilitating Discovery</p> <ul style="list-style-type: none"> • Research Funding & Autonomy • Multidisciplinary Complexity 		
<p><i>Description: System design to motivate and provide opportunities for researchers to develop and commercialize products.</i></p>	<p>Conditions on research funding, market-pull vs. discovery-driven research, the promotion of multidisciplinary endeavours in PH and the variety of ecosystem players</p>	<p>Prioritize Innovation and Commercialization in Broader Provincial Strategy</p>
<p>Governance and Decision-Making</p> <ul style="list-style-type: none"> • Governance and Accountability • Misaligned Incentives 		
<p><i>Description: Determining who has the capacity to create, enact and enforce policies. Processes and data infrastructure necessary to capitalize on PH I&C.</i></p>	<p>Responsibility and mandate to make decisions, data management practices for cross-disciplinary activity, evaluation method protocols and health system economic monitoring</p>	<p>Establish a Provincial Governance Structure for the PH I&C Ecosystem</p>
<p>Risk and Procurement</p> <ul style="list-style-type: none"> • Procurement and Remuneration • Technology Assessment 		
<p><i>Description: Aligning incentives among ecosystem players and designing a system that promotes/rewards the intended activities.</i></p>	<p>Health system procurement and remuneration, organizational incentive gaps, insurance programs for innovation</p>	<p>Create Value-based Innovation Adoption Policies to Increase Transparency</p>

INNOVATION NETWORKS

Relationships within the PH I&C ecosystem were the first theme from the interviews. These relationships were not limited to one type but rather many different capacities ranging from personal professional networks to industry partnerships, academic centres and organizational supports. Many of the conversations centred on co-ordination and collaboration, which respondents described as sub-optimal across the ecosystem.¹⁴ “[PH I&C] functions are often disparate, fragmented and not necessarily as co-ordinated or collaborative as they could be.” Terminology such as fragmented, siloed and competitive

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Co-ordination and collaboration are two similar concepts that were often grouped together and used interchangeably. Co-ordination focuses on the concerting resources and efforts in an efficient manner, while collaboration involves activity that shares resources (monetary and otherwise).

was characteristic of nearly every description of these innovation networks. Contributing factors to the lack of collaboration varied among participants. The most common response driving ecosystem fragmentation was competition among organizations and cross-provincial rivalries. *“I think it’s a very fragmented, siloed ecosystem. So, there is very little learning from one enterprise to another.”* One participant attributed this competition to the misconception that I&C resources are a zero-sum game.¹⁵ Cross-provincial rivalries, driven by Edmonton and Calgary, were another contributor to this competitive environment. *“To me, one of the disadvantages in Alberta is having the degree of fragmentation we have. The two universities, the multiple silos.”*

One participant highlighted the importance of distinguishing co-ordination from control. *“These are not isolated activities. They need to be co-ordinated, not controlled, co-ordinated. That’s a key point. I don’t think research and innovation can be controlled.”* This participant suggested Alberta requires more efforts to co-ordinate PH resources, but was concerned about the level of interference. A contrasting opinion proposed that co-ordination is part of the problem. *“And should they [be co-ordinated]? The real problem we tend to have in Canada is that once we have invested in something it is very hard to admit it has failed.”* The remaining participants unanimously agreed that some level of co-ordination is required for maximizing innovation opportunities. Developing a governance model was discussed to co-ordinate activities for improved collaboration capacity, reduce duplication of supports, streamline transition points between organizations, clarify roles within the ecosystem and improve planning and foresight.

On a positive note, most participants felt co-ordination and collaboration are improving. *“[Alberta is] heading in a good direction on the collaboration, communication and co-ordination side of things. It’s on the right trajectory. You might be able to tweak some of the funding agreements to encourage people.”* They acknowledged that collaboration between organizations has increased throughout the past five years. When asked why there have been recent improvements, respondents attributed some of the credit to leadership across the various organizations in the ecosystem.¹⁶ Efforts by deans of the two medical schools in Alberta were offered as an example of improved collaboration. *“There are times in this province’s history where the two cities compete more like their sports teams than their educational institutes ... other times where they are much more collaborative. It is currently a more collaborative time and it’s an opportunity to get things done.”* Another contributing factor to the rise of collaborative activities was government funding programs, with stipulations to facilitate co-ordination and or collaboration. Some explained that increased collaboration has led to a better understanding of the roles within the ecosystem and strengthened connections for co-ordination among the various players.

Navigating the available supports and commercialization channels in the PH I&C ecosystem appeared as the last network issue. Interviewees explained that the pathway from innovation to commercialization is unclear. Mechanisms of governing transition

¹⁵ The perceived zero-sum game in this context was described as one ecosystem player’s project/financial support directly resulting in a lack of funding for another’s innovation activities.

¹⁶ These are from commitments to address collaboration and co-ordination across the major players in the ecosystem.

points for PH products and companies should be implemented because *“The navigation entry points are not as well spelled out as they should be.”* Despite efforts to increase accessibility, new entrepreneurs are still unclear where to go for I&C support.¹⁷ *“They’ve sought commercialization, they always say ‘I had no idea who to talk to. Didn’t know where to go. Didn’t know how to do it.’ It’s the same story over and over again. So, the researcher to entrepreneur leap is not easy for people to navigate.”* According to participants, the first point of contact within the ecosystem contributes to the success of a PH endeavour. The desired support structure, where entry points do not impact I&C success, has not been established. *“[The] philosophy collectively is no wrong window. Depending where a researcher or company is at [or] they need a particular support in the development cycle, they should be able to go to [any organization] to point them to the right people.”* Some felt these navigational issues could be resolved by investing in supports to guide entrepreneurs from concept to commercialization.¹⁸

FACILITATING DISCOVERY

Motivating researchers to develop and commercialize products was the second emergent theme. Responses under this theme discussed funding platforms for researchers in the PH I&C ecosystem, interdisciplinary requirements for innovation and discovery, as well as the complexity of the PH I&C ecosystem. While these were the overarching topics, there were nuances. As one interviewee pointed out, PH I&C funding is a spectrum, spanning from supporting projects with high commercial potential (immediate health-care system impacts) through to purely investigator-driven research. Despite these different funding mechanisms, most interviewees recognized the need for both types of research funding in the future.

The direction for future funding quickly became a divisive topic. Interviewees from academia argued that impactful innovation occurs from the ability to freely research their interests. *“Maybe it is because of my training I tend to believe in serendipity. I am not sure that we need more [market-pull]. We need space.”* They argued that market-driven research funding would not yield favourable expected outcomes. Instead, discovery-driven grassroots research would be more effective and innovative. To support this claim, this group explained that most of the PH inventions come from within universities. *“What I see here is very investigator-driven. You’ll have someone with a bright idea and they’ll bring other people together and then they’ll look for some angel investor funding and a way of taking them to form a company.”* They felt that by incentivizing researchers to work only on the problems outlined by funders, opportunities for PH I&C are missed.

Government and funding agency participants argued the most appropriate funding mechanism is a demand-pull innovation system, meaning specific goals or challenges for the health-care system should receive more focus and greater funding. *“This is what we are interested in focusing on from an innovation perspective. If you are working on these things in innovation you are more likely to have a partner in us and us funding or ‘playing’*

¹⁷

New entrepreneurs from academia or university hospitals were discussed in this context.

¹⁸

Similar navigational teams and processes in other countries were said to be effective at connecting entrepreneurs with appropriate supports.

with you than if you are just doing a technology push or some other piece.” The case these participants made is that meeting the health-care system’s immediate concerns is more important for public funding. When discussing future funding agreements, they felt the broader impact of research on the health-care system and potential commercial endeavours are major factors.

Facilitating discovery issues was not limited to research funding practices. Integrating a variety of health information from across this wide range of disciplines was another issue that interviewees offered. *“The majority of funding in [precision health] comes from government for scholarly endeavour. So, discover, publish, put it in the broader public context within the literature and have it built upon. I totally support that, but from my perspective there aren’t enough connection points between [innovators] and business acumen, as you move towards opportunities to be explored for commercial endeavours.”* These downstream human resource issues are concerning for many participants as they recognized PH I&C is dependent on multidisciplinary capacity. Some explained that true innovation often comes from outside the field and there is value in bringing in new partners and collaborations. *“You need people that are working on inventing the electric bulb when everybody is trying to produce a better way to produce gas light to your home ... I suppose that if we had the model that some people propose, most efforts will go into producing more, better gaslights.”* Issues with facilitating multidisciplinary collaboration and a lack of cross-organizational and cross-ministerial planning for PH are concerning to participants.

The co-ordination challenges mentioned above were described as negative consequences of the complexity of the PH I&C ecosystem; however, participants argued the benefits from diversity and multiple I&C channels outweighed these concerns.¹⁹ When asked for thoughts on the variety and complexity of the PH I&C ecosystem, participants unanimously felt it was a feature. A problem indicated in the interviews about Alberta’s PH space is that there is often a lack of representation from other disciplines. Health innovation leadership often involves the same people on each project. They argued that combining strengths from provincial assets in other fields (like oil and gas) could enable Alberta to increase the per-capita performance of medical research.

GOVERNANCE AND DECISION-MAKING

Mechanisms and authorities to carry out a PH I&C strategy were the third emergent theme. Respondents discussed governance, the centralization and concentration of decision-making, processes and data infrastructure necessary to capitalize on PH I&C and the involvement of evaluation in decision-making. The overarching finding is that decision-making structures are underdeveloped or are too fragmented within the health innovation context.

When asked about governance within PH I&C, many respondents were unable to define governance or identify the key players involved in governing. To many of these people, I&C activities are largely ungoverned. *“It’s not clear to me what the governance model is.*

¹⁹

The diversity of organizational support was described as a strength because the organizations have a different set of evaluation tools. Participants felt diversity in evaluation results in consistent evidence and information for system evaluators.

*I probably should know that, is it CAM? Who actually is it? Who's on the hook if precision health doesn't happen?"*²⁰ Contributors noted the upcoming PH strategy under the direction of the Committee on Academic Medicine (CAM) and the medical research focus of this strategy. Participants often noted governance is unclear because no entity has been tasked with the duty to develop policy in PH I&C. *"When it's everyone's job, it's no one's job."* They noted the lack of a mandated organization results in a lack of capacity to develop policies because no one is resourced to create such policies. Election-cycle influence on government was one of the key governance issues discussed in several interviews. The influence of the political sphere on government bureaucrats and government-funded organizations was a concern and a potential impediment to strategic long-term direction. Greater separation between activities from the government and PH I&C was suggested.

Generally, participants felt centralization would result in negative outcomes for I&C. Nearly all respondents agreed that a single supporting entity would fail to use the PH innovation and discovery across the province. *"You don't want to centralize everybody into one. It won't work. Because every organization has a different mandate, a different function and role within the system."* They explained that while organizations should share goals to maximize efficiency for I&C supports, there must be a diverse offering of supports for companies/entrepreneurs.²¹ One participant connected the variety of supports and the pursuit of serendipity because different PH companies can seek different supports. This participant argued that merging research council funding had not yielded success in other Canadian jurisdictions. However, some felt this view may be too simplistic, arguing the problem is identifying the types of roles that should be centralized. *"The issue that we have had in Alberta is not so much centralization versus decentralization. I think centralization is good if what the central group does is the big strategic, overall strategies. And what the local grassroots group does is implementation of that strategy."* According to this viewpoint, a central group would make high-level decisions (to identify the priorities) and the ecosystem players would find a role within that framework that meets their needs.

There was no consensus on the types of infrastructure investments necessary to enhance Alberta's PH I&C, except a focus on training and investment in data infrastructure. Many argued that training and human resources are necessary for broad implementation of PH I&C. Examples were training the frontline health-care workforce how to use and adopt new PH technologies, and training for technology developers/companies on implementation practices. All those who discussed infrastructure investment agreed Alberta's greatest strengths are data assets to serve as an innovation "sandbox".²² Participants felt it is not clear how activities like data access, maintenance or ownership operate across

²⁰ CAM = Committee on Academic Medicine. CAM is a group of key leaders in the health innovation ecosystem. Committee members are key officials from research institutes, public agencies for innovation, government deputy ministers from Health, Economic Development, Trade & Tourism, and Advanced Education, and other ecosystem players.

²¹ This statement was qualified by a need for better co-ordination to reduce duplication and administrative costs.

²² "Sandbox" was used to describe the provincial I&C activity where Alberta could serve as an area for companies to conduct proof of concept or clinical trials within the province.

organizations and ministries. Challenges identified in the data infrastructure are access combined with interoperability issues. Integration challenges remain a concern for numerous participants. Most respondents felt public data products are high quality, yet integrating private and public data poses a new challenge. New privacy concerns also arise as data usage becomes more commonplace.

Misaligned incentives contribute to sub-optimal health-care innovation and commercialization of PH technologies, participants pointed out. Examples of misaligned incentives were: political incentives to announce initiatives within a four-year (or less) impact time frame; reduced financial incentives from uncertainty in procurement; the reward structure in academia which creates and incentivizes research outputs such as papers more than impactful technology or commercial products; and an overall inability to reinvest benefits to the organizations that generate the savings. The governance structure to mitigate these concerns does not exist and participants felt these gaps in the ecosystem cause the misaligned incentives. Understanding each organization's contributions to try to both improve "*what can be done for Albertans and the other partner organizations*" remains an issue because of the underlying co-ordination issues.

RISK AND PROCUREMENT

This last section discusses the criteria to mitigate health-care system risk and procurement. Participants discussed the historical shift in the technology procurement process in Alberta from health regions to AHS. The old ways, characterized as "the wild west", were an uncoordinated system that resulted in overspending and duplication. They explained the shift from health regions to AHS in 2009 changed procurement to become more rigid and difficult to procure local technologies. The result is that AHS is often not the ideal customer for early-commercialization small/medium-size enterprises (SMEs).²³ "*Alberta is not a good first market in a lot of instances for small innovators. And that's just the reality of being AHS. You are better off in many instances to try a regional hospital whether in Toronto or Manitoba.*" Respondents felt the advantages of having a single organization like AHS (administrative efficiency, increased data capacity, etc.) outweigh innovation disruptions. These respondents felt the best course of action is to support strategies to sell to other markets.

Governing risk management was another policy issue raised. Participants indicated that the health-care system, as a single-payer system, is inherently risk-averse. PH technologies are risky, they explained, which causes issues within the procurement and adoption of technology. One example provided in the interviews was whether SMEs can cover their liabilities if harm occurs because of their innovation. A suggestion for this type of issue was solidifying policies for companies to have their liabilities covered if they meet/pass certain requirements or checkpoints. "*[Alberta has] one big system that's quite risk-averse and for a start up in Alberta to get their product taken on by Alberta Health Services they could go through a very significant scrutiny.*" Many felt that for the system to become truly innovative, risk tolerance should not be zero; novel discovery is generally outside of the comfort zone of traditional thinkers in the space.

²³

Some examples of the advantages described in the interviews are purchasing power, administrative efficiency, data linkage and continuity of care.

Most agree the issue of procurement and innovation remuneration are two of the most important policy challenges for Alberta's PH I&C ecosystem. *"Procurement is ... Well, that's where we have an issue. A company develop[s] something and it should be procured but [the] procurement people say there needs to be a champion in the system."* Two participants explained selling a private, for-profit technology to a single-payer health-care system creates an unavoidable challenge. Others offered potential solutions such as specific allocations of money for Alberta-developed technologies to enhance growth and incentivize entrepreneurship. Without clear paths to market, many feel innovations will be stagnant. Governance may also be required for the championing process of procurement that occurs within Alberta's health system.²⁴

Tied to the discussion about procurement, interviewees explained that AHS does not procure PH innovations and technologies without a health technology assessment. They went on to say adoption decisions are dependent on health economics and technology impact assessments warrant adoption in a risk-averse health-care system. *"To fund those projects [and] to get to those diffuse benefits is to make those benefits as concrete as possible."* Some participants felt monitoring and evaluation are tools in procurement to reward entrepreneurs for highly successful innovation. However, many described the capacity issues for this type of technology evaluation within AHS. Respondents indicated that PH rendered many traditional evaluation methods less useful.²⁵ They felt there was a requirement to invest in creating new evaluation methods. *"Precision health introduces some really interesting twists on the older ways of doing health economic assessment."* Despite these challenges, the consensus from these participants is the evaluation process adapts to changes adequately.²⁶

VII. DISCUSSION

INNOVATION NETWORKS

Innovation networks were the most widely discussed issue across the interviews. Collaboration of the various organizations, co-ordination of activity and programs, as well as navigating the PH ecosystem, emerged as three major issues for I&C. In their prospectus for PH in Alberta, Eagle and Dubyk (2019) identified a lack of strategic co-ordination between individual teams or projects as a challenge to successful outcomes. This finding was consistent with our research, as interviews supported the claim that there is a lack of co-ordinating efforts. Alberta is not alone in this issue. Canadian governments (federal and provincial) and other jurisdictions worldwide have faced this same policy co-ordination issue in their innovation policy platforms (Deschamps 2013; Laperche, Munier and Hamdouch 2008, 3-13; Ranga and Etzkowitz 2013, 237-62; Tamtik 2016, 417-27). This

²⁴ A champion is "a prospect who truly understands and loves your product, and is willing to fight for you and convince their boss to buy your product" (Hogan 2014).

²⁵ Respondents were also concerned that metrics for evaluating institutions were a potential concern because they do not promote collaboration.

²⁶ Participants explained the responsibility is often given to the Institute of Health Economics, O'Brien Institute of Public Health (U of C) health economists, or this is a responsibility handled by the innovation teams within AHS.

paper presents findings through the lens of PH, but these issues are also characteristic of the broader health I&C ecosystem. Establishing governance for I&C activity across the entire health innovation ecosystem would provide opportunities to improve many of the co-ordination and collaboration issues.

Governance is incredibly valuable in attaining long-term objectives. Human resources and decision-making structures are important in planning the policies and programs to meet the needs of the innovation system. Both the Deschamps innovation governance model (2013) and the triple helix model of innovation (2016) indicate I&C success depends on the ability of actors in an innovation ecosystem to combine a wide array of resources. Deschamps (2013) classifies co-ordination as a key responsibility for effective innovation governance. Alberta's reported co-ordination issues should be concerning for innovation activity outcomes. Evidence suggests that the lack of co-ordination and collaboration is an impediment to governance and public policy (Deloitte 2013; Rose-Ackerman 2017, 23–27; Shearer et al. 2012, 1200–11). Without high-functioning and well-defined policy networks, policy-makers are missing a key component to achieve their desired outcomes.

Interdependence in the PH I&C ecosystem warrants the study of multi-level governance among these ministries, organizations, research institutes, corporations and other actors. Multidisciplinary collaboration among ecosystem players is a key feature of PH I&C. The ecosystem map (Figure 1) underscores the diverse background of players and stakeholders. With such a diverse group of ecosystem players, the importance of governance is increased. Clarifying roles within the ecosystem would be beneficial to address the overlapping supports and services available for entrepreneurs and innovators. This mutual understanding could improve the scalability of companies through improved navigation of the ecosystem and organizational specialization to address specific I&C problems. An example to improving navigation across the ecosystem is creating a dedicated staff to probe academic labs for potential PH applications.

FACILITATING DISCOVERY

One of the more divisive topics was the level of research autonomy. Described as a spectrum from only solving the challenges in the current market (demand-pull) through to fully autonomous researchers, this issue is as much political as academic. Canada's Fundamental Science Review (ISED 2017) suggests a balance is needed to maximize social returns on research investments. This report indicated that investigator-led research operating grants are the highest priority to attain greater innovation, yet there are practical challenges requiring the research community's immediate attention. Nearly all participants agree innovation comes from the grassroots researcher's discovery. The academic community that we interviewed calls for more autonomy on the types of projects to receive funding, whereas government and funding agencies argue that efforts to solve the immediate problems should set the boundaries for research funding. The triple helix model of innovation adds to the complexity of this issue. Leydesdorff and Ivanova (2016) argue that demand-pull innovation activity is too linear and does not consider the chain of innovation (feedback loops). Innovation is a dependent variable caused by

a driving force from its predecessor. By this definition, Alberta needs a responsive and dynamic system whereby the directives from government and funding change in response to researcher discovery.

One of PH's greatest strengths is the diversity of backgrounds in the technologies, but so too is the diversity in potential partners to facilitate the I&C process. All the participants considered the variety of supporting organizations a positive influence on facilitating discovery. They felt this was a critical component for Alberta to have a successful PH I&C ecosystem. The random collision theory of innovation supports this assessment, indicating the best method of discovery is to facilitate multi-sector collaboration (Kaplan 2012). Since multi-sectoral collaboration is at the core of new, precise methodologies, these collisions are that much more important. It is worth noting that while variety is a strength, it also opens the opportunity for duplication, competitiveness and inefficiencies. By including PH I&C in pan-provincial strategies (such as an address from the premier's office), opportunities may arise for new partnerships and discovery without duplication.

DECISION-MAKING AUTHORITY AND INFRASTRUCTURE CAPACITY

No organization is tasked with developing policies, prioritizing needs for the ecosystem, or has received an accountability mandate to incorporate a PH paradigm. While CAM is creating a strategy for PH, the decision-making authorities are unclear.²⁷ The Alberta government recognizes the importance of these mandates: "Clear statements about roles and responsibilities that are reviewed and regularly accepted by the public agency and department are essential for good governance" (Government of Alberta 2018). Lessons from other jurisdictions with clearer decision-making authorities may be helpful. Swedish governance is vertically co-ordinated – government ministries set the agenda and create mandates for the responsible agencies, but the discretionary decision-making occurs outside government (OECD 2013). Most decision-making is conducted through vertical co-ordination between VINNOVA, the research councils, Tillväxtverket, semi-public foundations and the government.²⁸ By formalizing this type of co-ordination among decision-makers, PH I&C actors can better understand whom to ask for policy changes.

This research identified a lack of industry engagement from multinational SMEs in policy-making. The industry sector's expertise can assist policy-making frameworks for complex issues (Stigson 2009, 399–406). Innovative regions around the world are more commonly co-developing policies between the three pillars of innovation (government, academia and industry). France (Aviesan n.d.), New Zealand (Precision Driven Medicine Initiative 2016), and multinational governments like the European Union (European Alliance for Personalised Medicine 2018) have emphasized the importance of these relationships. Policy-makers working alongside industry partners will be a key feature of future health I&C policy.

²⁷ For a definition of CAM, please refer to footnote 20.

²⁸ VINNOVA is the innovation agency for Sweden. It manages many of the partnerships with neighbouring countries and the funding decisions (Vinnova 2019). Tillväxtverket is the economic development agency for Sweden. It manages the entrepreneurship and regional strategies for the government development programs (Tillväxtverket 2019).

PH requires integration from many data sources. Problems with multi-level governance between PH I&C ecosystem players were apparent through the interviews. Developing the capacity to address these various sources has been a primary focus for many countries. Switzerland's approach is centred on creating a personalized health network that is interoperable and interdisciplinary (Meier-Abt et al. 2018). Health systems across the globe are creating data linkages to improve public health and policy. Gilbert et al. (2018) highlight the U.K., the Nordic countries and notably, Manitoba, as key leaders in data linkage. Other Canadian provinces could follow the lead of these jurisdictions. Using data across ministries and sources is not a new concept in Alberta; successful projects in this province are already over 10 years old. PolicyWise for Children and Families – Child Youth Data Laboratory (CYDL) was launched in 2007 with the mandate to link data from five Alberta government ministries: Human Services, Education, Advanced Education, Health, and Justice and Solicitor General (Ridsdale 2016). This data linkage was a horizontal co-ordination of policy and data; however, government recently decided to de-link these data holdings and ended any analysis on this dataset for research or internal purposes. Interviewees for this paper raised concerns about horizontal governance and co-ordinating policies across the ecosystem. CYDL could be an indication of the ideal outputs from an integrated horizontal governance strategy; however, this initiative recently ended. Investment in data-driven projects like CYDL could be a way to facilitate PH I&C activity across ministries.

RISK AND PROCUREMENT

Health is more complicated than other sectors because consumers do not seek goods and services as they do in other markets. An example is the “market failure” that arises from asymmetry of information; consumers are not in a position to make personal choices about their health without professional assistance. The same holds true for the procurement process. When clinicians (champions within the system) demand technologies, the likelihood of adoption rises significantly. However, this championing process results in discrepancies in access and overall adaptability. Transparent mechanisms to determine value are needed. Other countries are trying to move toward transparent procurement policy. Sweden, Norway, Denmark and Finland aim to develop value-based procurement processes (Nordic Innovation 2017).²⁹ The capacity within Alberta for health economic evaluation and monitoring in the health system is a great strength for the implementation of this type of policy.

Costs to the health system are often the biggest determinant but should not be the deciding factor for public payers, governments and citizens. Understandably, new technology can cause sticker shock, but value-based economic evaluation of new technologies is the most important analysis for policy-makers. Costs are the inputs of the health-care system but they fail to capture the outputs that increase value for patients (Snowdon et al. 2012, 5-12). To improve PH I&C, there should be a social value assessment that encompasses many different factors and outputs. In the U.K., the *Public Services (Social Value) Act 2012* legislated the impact assessment of social, economic

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Value-based procurement is the purchasing of I&C products and technologies that exceed a minimum level of value based on the expected value for that technology or product. Price is not considered as the output variable; rather, it is included as one of the inputs into the expected value.

and environmental perspectives into one holistic assessment called the Social Value (Government of the United Kingdom 2017). A key role for policy-makers in this system is to set the parameters for the minimum societal value an innovation must provide. Integration that considers the winners and losers, cost-bearers and beneficiaries of each innovation ensures that societal benefits are maximized for the greatest number of people.

An environment scan of PH I&C organizations and policies in Alberta revealed many policies were invention-oriented. These policies and programs focus on the research, development and entrepreneurial training aspects of PH I&C and comprise a large group of those available. The result is an apparent shortage of policies that target the later stages of the continuum from research to market (commercialization phase), such as innovative procurement and lead market initiatives. This finding may explain why participants felt that scalability was one of the main concerns in the province. Edler and Fagerberg (2017) argue that for an innovation system to thrive, policies should target demand-side innovation stages. Last, there are other ways to create demand-sided policies. Two other examples are business-support improvements for selling abroad or across provincial borders and formalizing decision-making processes to improve certainty for I&C actors. Boon and Edler (2018) indicate there is agreement that demand-side policies are the most important to solving challenges in the innovation ecosystem. To implement an ecosystem approach, system-oriented policies geared toward the influence of creative destruction are required.

VIII. LIMITATIONS

A limitation of the study is the policy analysis' level of depth. The ability to provide recommendations is dependent on the scope of the question. In the case of this paper, the research questions and policy issues were high-level (quite broad). Consequently, the suite of instruments available for policy recommendations is quite high-level and broad. Further review of the essential policy and governance components in the PH ecosystem will increase the capacity to develop customizable policy solutions for Alberta. Building from this research, subsequent studies are required to identify policy instruments to tackle the themes presented.

The interview findings represent significant contributions but are the opinions of individuals, not their employing organizations. Therefore, the research findings are not official policy from organizations across the ecosystem; rather, they are barriers identified by key experts. Significant consultation is required in designing the specific policy instruments; however, we have summarized first steps that could address the issues presented in this paper.

IX. POLICY RECOMMENDATIONS

1. **Incentivize Greater Collaboration Among New and Existing Ecosystem Players.**

By increasing the frequency and integration of collaboration among PH I&C ecosystem players, policy-makers could create a system-oriented approach that rewards shared interests. An example policy would be multi-ministerial initiatives to create data-sharing platforms for interdisciplinary PH I&C.

2. **Establish a Provincial Governance Structure for the PH I&C Ecosystem.**

Formalizing governance mechanisms will increase the capacity to address PH I&C policy, such as co-ordination of resources, drafting industrial values/vision documents, integrating new partnerships and reducing duplication of projects across the ecosystem.

3. **Prioritize Innovation and Commercialization in Broader Provincial Strategy.**

By creating a mandate for PH I&C from citizens, political parties, health professionals and industry, an ecosystem can develop in Alberta. Opportunities for grassroots, interdisciplinary, collaborative research may arise while reducing duplication of strategies and investments in research and development.

4. **Create Value-based Innovation Adoption Policies to Increase Transparency.**

Specific policies to benchmark the minimum value that a PH innovation required for adoption would increase the certainty and confidence for entrepreneurs/companies. By leveraging existing provincial technology-evaluation programs, Alberta would mitigate some of the risk to the health system, while providing opportunities for commercial success.

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APPENDIX A – QUALITATIVE METHODOLOGY

QUALITATIVE INTERVIEWS FOR POLICY CHALLENGE IDENTIFICATION

The effectiveness of the PH I&C ecosystem was evaluated through qualitative semi-structured interviews. These interviews addressed policy challenges and barriers as a method of evaluating the effectiveness. Qualitative interviews were an appropriate method for this research because of the advantages semi-structured questions have in addressing our research questions. Semi-structured interview questions offer flexibility in the issue coverage, quick rapport building, opportunities for further explanations, follow-up questions to relevant comments and the ability to reorder questions in response to the answers provided (Smith and Osborne 2009). The average length of the interviews was 28.5 minutes and questions from five domains were asked throughout the interviews. Each of the interviews was conducted in-person and recorded for transcription.

Participants were asked questions from an interview script containing four pre-determined thematic areas: introduction and broader PH knowledge; aligned incentives and procurement; and organizational management. A literature review of innovation systems guided the topic selection. To uncover the individual perspectives, we designed open-ended questions. With the semi-structured format, we asked follow-up questions to responses pertaining to policy challenges. Reordering of questions occurred throughout the interviews. For instance, if questions from the “organizational management” section fit well with responses from the “PH knowledge” section, we asked questions pertaining to that response from other sections. At the end of the interviews, we offered an opportunity to discuss freely issues not covered in the interview.

PARTICIPANT SELECTION

The Triple Helix Model of Innovation guided the categorization of potential participants into three groups: academia, government and industry (Etzkowitz and Leydesdorff 2000, 109–23). Participant selection was completed through a mix of purposive and snowball sampling (Tongco 2007; Biernacki and Waldorf 1981, 141–63). Purposive sampling targeted senior officials from the PH I&C ecosystem, balanced across the three groups. Participants were selected based on their knowledge of PH, representability of the participant group and accessibility through professional networks. Snowball sampling enabled previous interviewees to recommend further participants with the expertise to discuss the topics. The benefits of this approach were the ability to reach a diverse set of technical individuals with a vested interest in the field, use of professional networks to schedule interviews and combined expertise of the PH ecosystem. Contact letters were sent to each of these participants, of whom 12 completed the interview. The University of Calgary Conjoint Faculties Research Ethics Board approved this research study (Ethics ID: REB18-0486).

INTERVIEW TRANSCRIPT ANALYTIC METHODS

Interviews were descriptively transcribed, meaning the entire interview conversation was transcribed as an exact account of the audio file. The transcribed documents were then imported into NVivo software, an organizational resource used to manage and catalogue qualitative data for further analysis (NVivo, 2018). Data analysis of the transcripts

was conducted through three stages of thematic analysis: primary reading and initial impressions; constructing thematic categories; and systematic coding data into thematic categories (Boyatzis 2008). The initial reading of the thematic analysis was completed at the latent level to identify patterns and general themes from the data. Subsequent categorical classification was required because different terminology was used by the various participants throughout the interviews to describe similar ideas (Maguire and Delahunt 2017, 3351-59).

NVivo software was used to code, classify and organize the findings. This process was used to develop the sub-themes from interview responses. Further details that encapsulate the nuanced differences between responses are reported throughout this section. A matrix was created to visualize individual respondent data to each of the emergent trends in the data. Emergent trends of interviewee data were then summarized in relation to both the participant population and their group (academia, industry or government).

APPENDIX B – DESCRIPTIONS OF STAKEHOLDERS

Table 3. Innovation Ecosystem players and their type of engagement/interest in precision health innovation and commercialization. A brief description of the organization’s stake has been provided.

Ecosystem Player	Stake in Precision Health	Link
Alberta Economic Development, Trade and Tourism	Economic applications of health technologies for activities such as job growth, investment and trade and business support. Supports many commercial applications and organizations	https://www.alberta.ca/economic-development-trade-and-tourism.aspx
Alberta Health	Improving health outcomes and generating value for health spending within the province. Allocates health funding and administers programs	https://www.alberta.ca/health.aspx
Advanced Education	Funds and supports post-secondary programs, approves programs of study. Aids in planning for future post-secondary training	https://www.alberta.ca/education.aspx
Community and Social Services	Administers social programs throughout the province and provides financial support to communities and families	https://www.alberta.ca/community-and-social-services.aspx
Alberta Labour and Immigration	Mandate to improve Alberta’s labour market, standards and workforce	https://www.alberta.ca/labour-and-immigration.aspx
Alberta Health Services (AHS)	Single health authority for Alberta. Sets and plans innovation goals and manages procurement into the health-care system	https://www.albertahealthservices.ca/about/about.aspx
AHS Strategic Clinical Networks	Developed networks with research and implementation capacity for specific aspects of health and procurement.	https://www.albertahealthservices.ca/scns/scn.aspx
University of Calgary, Cumming School of Medicine	One of the two major research institutes for PH within the province driving I&C projects in Alberta	https://cumming.ucalgary.ca/about/cumming-school-medicine
University of Calgary, School of Public Policy	Research entity focused on developing policy solutions to assist decision-makers	http://www.policyschool.ca/
University of Alberta Faculty of Medicine & Dentistry	One of the two major research institutes for PH within the province driving I&C projects in Alberta	https://www.ualberta.ca/medicine/
Alberta Machine Learning Institute	With partners, research labs and talent for developing machine-intelligence health applications	https://www.amii.ca/about-us/
Alberta Innovates	Largest research and innovation agency in Alberta to support innovation and research. Provides business support, funding and HR to other ecosystem players	https://albertainnovates.ca/about-us/
Institute of Health Economics	Independent design of decision analytics, health technology assessment, knowledge transfer and evidence-based health policy	https://www.ihe.ca/
Ward of the 21 st Century (W21C)	Research and innovation centre to test and develop health technologies	https://www.w21c.org/
TEC Edmonton	Health innovation accelerator and technology transfer agent for Edmonton and the University of Alberta	https://www.tecedmonton.com/about-us/
Innovate Calgary	Technology transfer and business incubator for the University of Calgary	https://www.innovatecalgary.com/about-us/
Glenrose Rehabilitation Hospital	Hospital focusing on developing precision solutions for recovery from illness and injury	https://www.albertahealthservices.ca/grh/grh.aspx
Health City Initiative	Economic development initiative to increase health innovation system capacity and access to capital	https://edmontonhealthcity.ca/about-health-city/

Make Calgary	Community-based, multidisciplinary research platform to tackle social and economic issues facing Calgarians	https://makecalgary.ca
Calgary Health Trust	Calgary-based charity to raise money for transformative health solutions in Alberta	https://www.calgaryhealthtrust.ca/about-us/
University Hospital Foundation	Support health research through philanthropic and lottery donations	https://www.universityhospitalfoundation.ab.ca/About
Alberta Cancer Foundation	Fundraising partner for CancerControl Alberta cancer centres	https://www.albertacancer.ca/about-us/
Alberta Children's Hospital Foundation	Support initiatives to improve child health, research and family-centred care	http://www.childrenshospital.ab.ca/site/PageNavigator/about/about
BioAlberta	Member-based organization promoting benefits and awareness for life sciences and companies in Alberta	https://www.bioalberta.com/about
Genome Alberta	Not-for-profit initiating, funding and managing genomic research in Alberta	http://www.genomealberta.ca/about-us/
Calgary Economic Development	Organization working with business, government and communities to attract business investment in Calgary	https://www.calgaryeconomicdevelopment.com/industries/focus-areas/life-sciences/
Merck & Co.	Multinational enterprise invested in Alberta with an innovation fund called Alberta Merck Innovation in Health Fund (AMI)	https://edmontonhealthcity.ca/the-alberta-merck-innovation/
AstraZeneca	Multinational enterprise interested in investing in Alberta for PH technologies	https://www.astrazeneca.com/
Johnson & Johnson	Multinational enterprise interested in investing in Alberta for PH technologies	http://www.jnjcanada.com/
Hoffmann La Roche	Multinational enterprise interested in investing in Alberta for PH technologies (2/3 of R&D in PH)	https://www.rochecanada.com/en/about-roche.html
Creative Destruction Lab	Mentoring and financing program for scalable science and health technologies	https://www.creativedestructionlab.com/locations/calgary/
Canada's Medical Technologies Companies (MEDEC)	National association for innovative medical technology industry to advocate, educate and liaise regulations	https://medtechcanada.org/page/AboutMedtechCanada
Innovative Medicines Canada	Organization representing members from Canada's innovative pharmaceutical industry	http://innovativemedicines.ca/about/

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