Innovation and Economic Value: A Prospective Benefit-Cost Analysis of the Fab Bhutan Challenge*

*Milan Thomas***

Abstract

National governments and international donors fund challenge competitions to foster innovation, but there is little evidence on the economic return to such investments. This paper conducts an ex-ante benefit-cost analysis to project the economic return on the 2023 Fab Bhutan Challenge, which was part of FAB23 Bhutan (the 19th annual international Fab Lab Conference). For the Challenge benefits side of the analysis, studies covering five topics were drawn from: crop yield improvements from climate adaptation (for Challenge 1 in Sarpang), cost and time savings from improved water supply (for Challenge 2 in Pangbisa), livelihood savings from human-wildlife conflict prevention (Challenge 3 in Limbukha Chiwog), revenue generation from cultural exports (Challenge 4 in Thimphu), and economic returns from special needs education (Challenge 5 in Rinchending). For the Challenge costs side, budget data were collected and interviews with challenge participants were conducted. Conservative estimates that account for the probability of some challenge solutions ultimately being non-viable place the economic return to Bhutan between $5 and $12 per dollar invested. The paper concludes by discussing opportunities for scaling solutions from the structured innovation challenge based on the global evidence, and implications of the study for Bhutan's economic aspirations.

Keywords: agriculture, benefit-cost analysis, economics, human-wildlife conflict, innovation, labour productivity, special education needs, water supply

---

* This research was not supported by funding from any source. It is based on methodology developed in Kremer et al. (2021). It benefited from interviews with participants in the Fab Bhutan Challenge and discussions with staff of Druk Holding and Investments, notably Namgyal Tsheden Gyaltshen, Jigdrel Singay, and Nirpa Raj Dangal.
**Economist, Asian Development Bank, Bhutan. Email: mthomas@adb.org

Introduction

To foster solutions to some of the most intractable challenges facing Bhutan's economic development, the Fab Bhutan Challenge (FBC) was held in July 2023. It was part of FAB23 Bhutan - the 19th edition of the international Fab Lab Conference and Symposium. Designed and implemented by Fab City Foundation (FCF), and Druk Holding & Investments (DHI), FBC tasked five teams (constituted of members selected through a competitive selection process) with designing solutions to five difficult problems facing Bhutan: agricultural susceptibility to extreme weather and climate change, water supply inadequacy, human-wildlife conflict, textile production challenges, and inaccessibility of education for special needs students. The challenges were formulated by the five Fab Labs in consultation with their local communities, FCF and DHI. The teams designed their solutions to the challenges between July 16 and 21 at sites spread across Bhutan. The five challenges are explained in more detail in Sections 1.1-1.5, along with the proposed solutions.

FBC is part of a growing practice of using structured innovation challenges or competitions to produce solutions to societal and design issues. Governments, foundations, and private sector companies spend billions of dollars every year sponsoring research and development (R&D), challenges, funds, hackathons, and other mechanisms designed to produce innovation. But there is scarce evidence on whether such efforts pay off from a societal point of view.

While scientific discovery has intrinsic value, it is important to know whether innovation challenges pay off from an economic perspective, especially when public funds are used to finance them. Conducting benefit-cost analysis of innovation challenges can help ensure that funds are being spent effectively on issues that will generate sufficient societal benefit to cover innovation costs.

The true economic return of FBC will not be known for years. It can take innovations decades to develop into viable solutions and scale up. But given what we know today about the challenges and the proposed solutions, what are reasonable estimates for the economic return on the investment in FBC?

This paper answers that question based on a literature review and data collected from FBC participants. It projects a benefit-cost ratio – a measure of how much social benefit FBC is expected to generate per dollar invested – for FBC.

Even under conservative assumptions about the probability that each solution will be successful, the projected benefit-cost ratio is high ($5-12 per dollar spent), confirming that FBC tasked the teams with high-impact social challenges, and that the proposed solutions collectively are cost-effective.

1. Methodology

To project the economic return on Fab Bhutan Challenge, an approach to assessing the return on innovation investments developed by Kremer et al. (2021) is adapted. The authors start with the basic definition of benefit-cost ratio and social rate of return and tweak them to make them more appropriate for analysing innovation investments.

Similarly, adjustments are made to make the benefit-cost calculations more relevant for FBC. Each challenge can be thought of as an investment in a solution. Together, they form a portfolio of innovations that can be valued prospectively just like any investment portfolio.

Benefit-Cost Ratio of an investment in an innovation

A benefit-cost ratio indicates the return per dollar invested:

$$BCR_i = \frac{\sum_{t=0}^{T} \frac{N_{i,t} B_{i,t}}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_{i,t}}{(1+r)^t}}.$$

where N_{it} is the number of people reached by challenge solution i in year t, B_{it} is the estimated benefits per person reached (net of operation costs – the recurrent spending and capital investment that are required to make the solution viable) of challenge solution *i* in year *t*, and C_{it} is the innovation costs of challenge solution *i* in year *t*. Innovation costs are any investments that are formative to the development of a challenge solution (brainstorming, piloting, testing). *r* is the discount rate used to make monetary values from different time periods comparable. Year *T* is the final year for which challenge solutions are assumed to be functional. In the case of FBC, i = 1, 2, 3, 4, or 5 (for each of the challenges), and the prospective benefits are evaluated through 2033, so t = 0 corresponds to 2023 and T = 10 corresponds to 2033.

An investment is deemed socially beneficial if its benefit-cost ratio is greater than 1 (i.e., it returns at least one dollar per dollar spent).

Social Rate of Return of an investment in an innovation

Social Rate of Return (SROR) is an alternative measure of the performance of an investment or portfolio of investments. Mathematically, it is the rate SRORi that equalizes the two sides of the equation below, setting the value of discounted costs equal to the value of discount benefits:

$$\sum_{t=0}^{T} \frac{N_{i,t} B_{i,t}}{(1 + SROR_i)^t} = \sum_{t=0}^{T} \frac{C_{i,t}}{(1 + SROR_i)^t}.$$

An investment is deemed socially beneficially if its social rate of return is greater than some threshold. Often this is taken to be 10% for development projects (Millennium Challenge Corporation, 2017).

Extension to a portfolio of innovations

To calculate the return of FBC, the returns on the individual challenges must be summed and set against the innovation costs of not only the individual challenge solutions, but the FBC as a whole. This includes conference transportation costs, advertisement costs, and other expenses. They were borne by Druk Holding and Investments, Fab Foundation, and their sponsors in organizing and holding the conference, whereas the individual challenge solution costs (investment, maintenance, and operating costs) must be borne in the future by private or public funders as the solutions are scaled up.

Introduction of uncertainty

Kremer et al.'s application was ex-post. They assessed the economic return on an innovation portfolio ten years after the first funds were disbursed. In this case, the assessment is ex-ante. The economic return on investment is projected out ten years from today. Solutions have been developed but have not yet been applied, and their viability is uncertain. Scenarios with different probabilities of success are applied to give a range of benefit-cost ratios for Fab Bhutan Challenge in Section 2.

Valuing solution benefits

For each challenge, only economic productivity benefits are valued, while acknowledging that some of the most important benefits of the solutions (e.g., preservation of culture, protection of human and animal life, health improvements) cannot be valued. All five solutions aid workers in some way (by increasing their productive possibilities or saving time and effort) and are thus expected to improve their labour productivity. That is the primary benefit valued in this analysis (see Table 1 for an overview). The microdata of the 2022 Labor Force Survey (LFS) was used to calculate the size and status quo income of the occupational and geographic groups that would benefit from the solutions. All benefits were converted from ngultrum to United States Dollars ($, USD) using the prevailing exchange rate in July 2023 (82 ngultrum to one USD).

Valuing solution costs

Challenge participants were very uncertain about solution costs at the time the study was conducted. They were interviewed on investment, maintenance, and operating costs as comprehensively as possible, and a 27% overrun factor was priced in based on estimates of average R&D project cost overrun in Kumar and Thakkar (2017).

1.1 Challenge 1: Climate-adaptive agriculture with Technical Trainers Training and Resource Centre (TTTRC) Fab Lab in Sarpang, Sarpang Dzongkhag

Problem

Due to heavy monsoon rains, agricultural production comes to a halt in Sarpang between June and August. Unable to grow crops during those months, farmers instead purchase the vegetables that they grow during other times of the year (cabbage, cauliflower, potatoes, tomatoes, etc.) for consumption. Team 1 at the TTTRC Fab Lab was tasked with designing a solution that would extend the growing season through climate resilient infrastructure, tools, or practices.

Solution

Team 1 developed a solution that would enable chilies and tomatoes to be grown in Sarpang during the monsoon months. Their proposal was to install cool, covered structures for farmers (naturally air-conditioned greenhouses) with raised planter boxes for growing vegetables in a controlled setting when the monsoon rains are strong, and the climate is too humid. While this would likely not enable them to match their output during non-monsoon times, it would allow them to maintain some productivity during those months.

Benefits

Dekiling Gewog has 6,000 inhabitants, and 28% of the Dzongkhag's population is farmers according to the 2022 LFS[1]. Conservatively, it is assumed that half of those farmers stand to benefit from the proposed solution. By adding three additional months of agricultural productivity to the crop calendar, this solution raises the potential income of farmers.

[1] Author's calculation using LFS 2022 microdata.

That increased productivity is valued in the economic analysis as a 15% gain over the average farmer income for Sarpang district according to the 2022 LFS (17,000 ngultrum per month[2]). 15% is a reasonable expected gain because although the growing months will increase by 33% (three months), chilies and tomatoes are lower value than cash crops grown during other parts of the year.

In addition to this monetary benefit to farmers, there would be a national benefit through increased food security (which has been a government priority in recent five-year plans). This and additional benefits are not valued in the analysis.

Costs

The main cost associated with the solution is construction of the air-conditioned greenhouses and planter boxes. But as these will rely on recycled materials, the operating cost is estimated to be extremely low. More significant are the upfront investment costs. It is estimated that around 56,000 USD would be required in investment costs to train trainers and send them to Bhutan to instruct local craftspeople on building the structures. Since farmers would need to divert time away from their status quo economic activities during the monsoon season back to agriculture, the opportunity cost of their time must be accounted for. This is estimated based on secondary income reported in 2022 LFS.

Probability of success

Challenge participants were circumspect about their solution and acknowledged that more testing was needed to determine the viability of the solution. Based on this, the probability of solution success was estimated at 50%.

[2] Ibid.

1.2 Challenge 2: Water conservation with Druk Gyalpo's Institute (DGI) Fab Lab in Pangbisa, Paro Dzongkhag

Problem

In Pangbisa, there is excessive sedimentation and inefficient filtration at the water source, resulting in high water turbidity. Providing clean water for the community remains a challenge, and many rely on bottled water. There is also suspected high nonrevenue water loss.

Solution

Team 2 at the DGI Fab Lab proposed to address this critical issue through several complementary solutions. First, to address the water turbidity, multimedia filters were designed to remove the yellowish colour from local water. Second, an electronic monitoring system has been proposed to identify faulty areas in the water distribution system and reduce the workload of plumbers. Third, a rooftop water reclamation device was proposed. Fourth, an educational tool was designed to teach the local population about how to identify drinkable water and how to filter water appropriately.

Benefits

Roughly 1,500 individuals (assumed to be 300 households) in Pangbisa stand to benefit from the solutions. Access to clean water has several health and non-health benefits (Kremer et al. 2023). For this study, the focus is on the benefits associated with the second component of the solution, while noting that first, third, and fourth have high value as well. The electronic monitoring system would help reduce non-revenue water and save substantial labour by the plumbers. Before the system has been implemented, it is hard to know how much water is being wasted in Pangbisa. Water usage in Bhutan is 945 cubic meters per person per year (Tariq et al. 2021). Based on the global average non-revenue water is 30% and valuing water at 0.31 USD per cubic meter, this implies a value of roughly 90 USD in losses per person under the status quo. The saved labour of plumbers, who currently have to spend hours per day hiking to find faults and leaks in the distribution system, is also valued.

Other benefits from this solution include improved water consumption behaviour due to the educational tool. This will likely improve health of the local population, but the benefit is not valued.

Costs

The main costs identified for this solution are the digital water pressure/flow sensors. It is assumed that several will have to be purchased and installed at strategic locations in the water distribution system. The cost is roughly 10 USD per sensor, and it is assumed that 100 sensors would be placed. Other costs (of the filtration system and rainwater recovery) are very low, as they rely largely on available household items, and are not priced.

Probability of success

Challenge participants were confident in solution viability, since it relies on low-cost materials and proven technologies. The one threat identified was landslides and other climate-related issues. Based on this, the probability of solution success was estimated at 80%.

1.3 Challenge 3: Human-wildlife conflict in Limbukha Chiwog with Bio-Fab Lab College of Natural Resources (CNR), Punakha Dzongkhag

Problem

All over Bhutan, damage to crops is caused by conflict with local wildlife - wild boars, deer, and birds. Reducing those losses would greatly boost Bhutan's agriculture sector, which has stagnated for the past decade. Several traditional measures have been attempted over the years, including scarecrows, tree fencing, stone bunding, and fencing (chain link, electric, net). But none have taken hold as sustainable solutions due to prohibitive costs, inadequate maintenance, or ineffectiveness.

Solution

The Challenge 3 team at Bio-Fab Lab CNR proposed to prevent human-wildlife conflict in Punakha by improving the monitoring of existing electric fences in the area. In addition, complementary tactics would be used to support conflict prevention (laser scarecrows, remote sensing with support from Bio-Fab Lab CNR, and emission of predator sounds/smells).

Benefits

There are 1,000 inhabitants of Limbukha, 63% of whom are farmers, implying that up around 600 farmers could be assisted by the improved fencing. To value the benefits, this paper draws on Sapkota et al. (2014), who find that electric fencing in Nepal reduced livestock predation by 30-60% and crop losses by 78%. In Bhutan, it is estimated that about 30% of yield is lost to human-wildlife conflict (Wangchuk et al. 2023), which implies that the protection could increase yield by 23%. The gain in crop yield is valued against the average income for farmers in Punakha according to the 2022 LFS (16,000 ngultrum per month)[3]. Since some of the fencing is communal, it is assumed that all farmers would benefit from this solution.

There is also the averted loss of human and livestock life from human-wildlife conflict. This is an important benefit, but it is not valued in the economic analysis.

Costs

The cost of electric fencing is estimated at 600 USD per kilometre. Limbukha is a 33 square kilometre area, so it is assumed that around 48 kilometres of perimeter will have to be covered, placing the total cost at around 29,000 USD. It is

[3] Author's calculation using LFS 2022 microdata.

conservatively assumed that maintenance equivalent to 25% of installation must be done in five years. The complementary solutions are very inexpensive, using open-source software and designs, and are not priced.

Probability of success

Challenge participants were fairly confident in solution viability, since it uses proven technology and has been applied in other settings without major issues. Based on this, the probability of solution success was estimated at 70%.

1.4 Challenge 4: Cultural Preservation with the Jigme Namgyel Wangchuck (JNW) Super Fab Lab in Thimphu, Thimphu Thromde

Problem

Cultural exports have been identified as a potential area for growth for Bhutan (UNDP, 2022). But cost-effective production will require technological advancements in support of traditional methods. Bhutan has unique fabric designs, but they are not commonly exported. This is in part due to Bhutan's small population, but also due to the labour-intensive nature of textile production. Traditional techniques do not use technological supplements that would increase productivity. Wood is the main material used for weaving, and wood is prone to damage, not easily portable, and not readily available in Bhutan. More durable, efficient, standardized, and user-friendly weaving tools could revolutionize the industry. Modernizing practices could also contribute to cultural preservation by reversing the decline in numbers of people choosing weaving as a profession.

Solution

Team 4 at the JNW Super Fab Lab realized that a major constraint on weaver productivity is health issues caused by the manual labour. Specifically, standard chairs are not design for weaving and a more supportive prototype was developed that would reduce back issues for weavers. In addition, to preserve weaving as a cultural tradition, the team came up with a series of related solutions: a standardized loom blueprint to facilitate construction, a heritage website to maintain cultural memory of weaving, and kits to encourage children to take up weaving.

Benefits

Based on the 2017 Population and Housing Census and 2022 LFS, there are 2,800 weavers working in Thimphu Thromde. It is conservatively assumed that 20% of them would be served by this solution. The proposed solution would increase craftsperson productivity by an estimated 15%. This increase in productivity is valued against the base of the current productivity level, which is taken as the average income for craftspeople in Thimphu according to the 2022 LFS (13,000 ngultrum per month).

By making the production of textiles more lucrative, the proposed solution may also contribute to the preservation of traditional techniques in Bhutan. But this is impossible to put a monetary value on.

Costs

The chair developed by Team 4 (further prototyping will be done) is expected to cost around 30 USD. The complementary solutions were already developed during the Challenge week. Weavers in Thimphu report no secondary sources of income in LFS 2022, so no opportunity cost of weavers' time is included in the calculations.

Probability of success

Challenge participants were confident in solution viability, due to the progress already made and feedback from weavers. Based on this, the probability of solution success was estimated at 75%.

1.5 Challenge 5: Assistive Technology with Fab Lab College of Science and Technology (CST) in Phuentsholing, Chhukha Dzongkhag

Problem

The 12 Special Education Needs (SEN) schools spread throughout Bhutan lack inclusive infrastructure and assistive devices for children with special learning needs. Dozens of students living with disabilities attend two of such schools in Phuentsholing, Chhukha – Sonamgang Primary School in Phuentsholing and Phuentsholing Rigsar Higher Secondary school. Their access to education is impeded by lack of assistive devices and infrastructure. 5% of out of school children are unenrolled due to disabilities.

Solution

The Challenge 5 team developed eight prototype devices for assisted learning. These devices facilitate learning of students with various disabilities. Team 5 also developed a model for entrepreneurship and research partnerships among CST students and SEN students.

Benefits

An analysis by Lamichhane (2015) finds that the economic return to a year of schooling for persons with disabilities is 19-26%. This is much higher than the global average (10%). This figure is used to value the benefits of increased school attendance and completion by SEN students.

There are two sets of beneficiaries. One is special needs students who are already enrolled in school and whose experience as students will improve due to the solution. Their graduation rate is likely to increase as a result. The other set of beneficiaries are student who may be encouraged to attend school given the improved experience made possible by assistive devices. 5% of out-of-school children in Bhutan are unenrolled for reasons related to disabilities according to the 2022 Bhutan Living Standards Survey. That implies that 75 of the 1,500 school-aged children in Phuentsholing are both living with disabilities and out of school. It is assumed that 40% of them would be induced to enrol and finish high school due to the assistive technology.

For both types of beneficiaries, the benefit of the solution is valued as improved labour market earnings after graduation. Of course, there are non-monetary benefits such as personal dignity and pride that are more important but cannot be included in the economic analysis.

The benefits to the CST students and the community that benefits from their projects are also not valued. This analysis does not consider the outputs of student projects, which are impossible to know at this stage but likely to have high value.

Costs

The solution is partnership-based and relies on college students and SEN students working together during their education years, so there is no opportunity cost of their time. The assistive devices are made from recycled material. One major cost will be trained representatives at each of Bhutan's 12 SEN schools. They will be connected to the country's Fab Labs and oversee student partnerships. It is assumed that 12 teachers will have to be supported for every year through 2033, with a salary of approximately 4,000 USD. This is assumed to be inclusive of training costs.

Probability of success

Challenge participants were highly confident in solution viability, due to promising results from their week in Phuentsholing. Based on this, the probability of solution success was estimated at 90%.

1.6 Challenge-wide costs

In addition to the challenge-specific investment, maintenance, and operating costs discussed above, the benefit-cost calculation must account for the challenge-wide cost of FBC.

Bringing together the international participants and giving them the space and resources to design solutions was an essential part of the innovation process. FBC organizers estimated that a total of 125,000 USD (funded by Druk Holding and Investments and their sponsors) was spent to bring FBC together. This included transportation costs of challenge participants and the opportunity cost of participants time (valued conservatively at 20 USD per hour).

Table 1. *Summary of valued economic benefits and costs*

Challenge	**Primary beneficiaries**	**Valued economic benefit**	**Non-valued benefits**	**Main costs**	**Opportunity costs**
Monsoon vs. sprouts	Farmers in Sarpang	Longer growing season	Food security, income stability	Training of trainers, structure development	Secondary income of farmers
Aesthetics of water	Families in Pangbisa	Reduced non-revenue water loss, time savings for plumbers	Aesthetic value of clean water, health knowledge	Filtration devices, monitoring system	None
Interspecies peace	Farmers in Punakha	Increased crop yield	Human and animal lives saved	Monitoring system installation, fence maintenance	None
Textiles + Tech	Weavers in Thimphu	Improved weaver productivity	Improved health, cultural preservation	Chair prototyping, production costs	Secondary income of weavers
Aluminium waste	SEN students in Phuentsholing	Increased enrollment. graduation, and employment of SEN students	Student projects, dignity of students	Teacher salaries	None

2. Results

The discounted benefits of each challenge are set against the discounted costs of each challenge plus the upfront cost of bringing together FBC. The results of the benefit-cost analysis are shown in Table 2.

Table 2. *Benefit-cost ratio assuming each solution has 50% chance of viability*

Innovation	Real value (2023 USD)
Challenge 1	$299,560
Challenge 2	$403,794
Challenge 3	$621,719
Challenge 4	$393,841
Challenge 5	$251,606
Total Net Benefits	$1,970,520
Total Investment Costs	$239,179
BCR (through 2033)	**8.24**
SROR (through 2033)	**102%**

Table 2 shows the benefit-cost ratio under a moderate scenario, in which each solution has a 50% chance of being successful. Figure 1 shows alternative scenarios. Scenario 1 is based on challenge participants' subjective probabilities (each team was asked for their belief on the probability that their solution would be functional in Bhutan ten years from now). Scenario 3 is based on the finding in Kremer et al. (2021) that 33% of innovations in USAID's Development Innovation Ventures portfolio had reached market 10 years after investment. Scenarios 4 and 5 project the return if only one innovation out of the five take hold. Scenario 2 reflects the probabilities in Table 2 (each solution has a 50-50 chance of succeeding).

Even in a scenario under which only one low return solution is viable, FBC still pays for itself twice over, because the expected benefits from that one solution are large. At the other end of the spectrum, it is possible that all five solutions pan out. In that case, the benefit-cost ratio rises to $16 per dollar spent on FBC (not depicted in Figure 1).

While the challenge participants were optimistic, it is very unlikely that all five solutions will be operational in Bhutan a decade from now. But, as analyses of other innovation funds have shown (Kremer et al. 2021), a low success rate is common, with most innovations failing to ever reach market. In fact, it is to be expected. Innovation requires trial and error, and exploring uncharted territory. By design, innovation challenges address high-impact problems, so when a solution is successful, it often generates economic returns to cover not only its own costs, but the costs of failed solutions to other challenges.

In that sense, innovation challenges are like a diversified portfolio in which the funder is investing. Figure 1 confirms this for FBC. Under any reasonable scenario, the benefit-cost ratio of FBC exceeds 1 and the social rate of return far exceeds 10%.

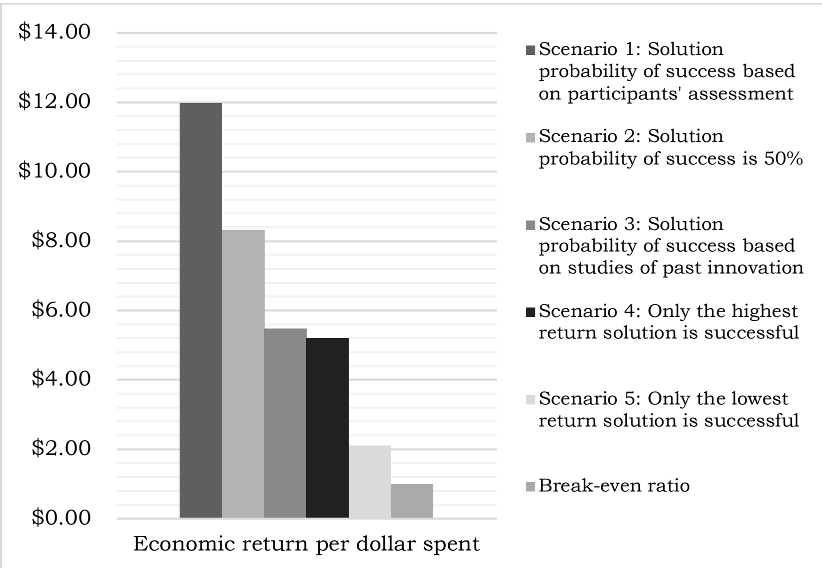

Figure 1. Benefit-cost ratio under different solution success scenarios

3. Discussion

3.1 Economic return on investment

The estimates in this analysis are highly conservative. They take a low number of expected beneficiaries (limited to the Challenge site, village, or district) and do not factor in that the innovation could spread to other regions of Bhutan facing the same problem. Team 1's solution could benefit not only farmers in Sarpang, but others in the subtropical region of the country. Weavers all over the country could benefit from Team 5's solution – not just those in Thimphu.

In addition, they each focus on one or two main benefits of the solution. In reality, there will be many other benefits, some of which are already foreseen but difficult to value. For example, the Challenge 2 solution is likely to generate health benefits by increasing awareness of water quality issues. Those health benefits were not valued in the economic analysis. The cultural exchange value of FBC as a whole (and potential increases in future tourism revenue) is also not accounted for.

For all of these reasons, the projected range of benefit-cost ratios can be interpreted as a lower bound on the benefit-cost ratio that is ultimately realized. That the projected economic return is large even using this conservative approach is a reflection of the high-impact challenges selected for FBC.

3.2 Scaling the challenge solutions

Just as there is little evidence on the economic return on innovation challenges, there is little evidence on which types of innovations are most likely to scale. In one of the only studies of this topic, Kremer et al. (2021) find through their analysis of United States Agency for International Development's portfolio that innovations were more likely to reach one million users if they had low unit costs, leveraged existing distribution platforms, and were grounded in research.

This has clear implications and increasing the probability of success of FBC solutions. All of the proposed solutions were developed in a cost-sensitive way, using open-source software and recycled and/or low-cost materials. This will make the solutions accessible and generate positive externalities in adoption.

Partnering with existing public platforms for delivering goods and services is also highly relevant to these challenge solutions. For instance, the solutions to Challenges 1 and 3 could be delivered through partnership with government extension services to make them more sustainable.

Finally, conducting impact evaluations of the solutions as they are piloted and scaled up in the field can ensure that the solutions deliver benefits in the long term. Evaluations provide user feedback on the performance of innovations. Acting on that feedback can then ensure that the solutions evolve as needed and become fixtures in the communities that they were designed to serve, rather than flashes in the pan.

3.3 Contributing to Bhutan's economic aspirations

To achieve its goal of becoming a high-income economy by 2034, Bhutan must grow at a double-digit rate every year for the next decade. In the past, most double-digit growth years in Bhutan were due to the commissioning of a new hydropower plant. The average growth rate declined from 9% in the 2000s to 6% in the 2010s (Figure 2).

Sustaining high growth will require revitalizing the agriculture sector (which has seen falling yields for the past decade), rejuvenating of the industrial sector (which has been sluggish since a strong manufacturing decade in the 2000s), propping up the services sector (which has struggled since the onset of the COVID-19 pandemic), and preparing Bhutan's young workforce for employment in the growing global digital economy. The FBC solutions touch all of these sectors, and there are many more pressing issues that can be investigated through future innovation initiatives.

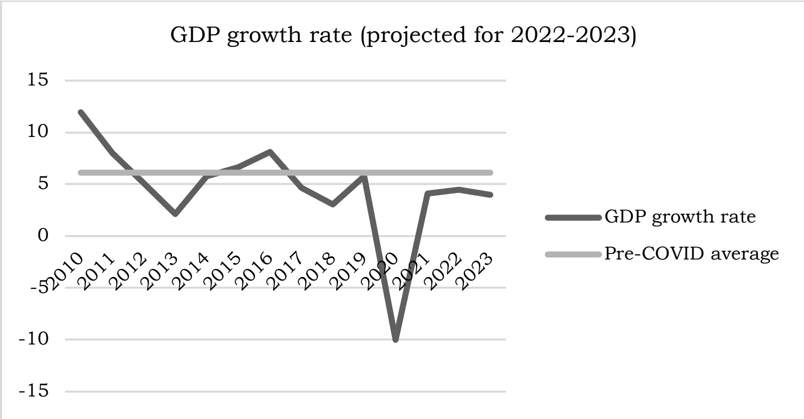

Figure 2. Bhutan's economic growth rate in the 2010s
Source: Asian Development Outlook (2023).

Bhutan's domestic market is limited and dispersed. With a falling total fertility rate and ongoing mass migration to Australia and other developed economies, Bhutan has a dwindling population. It also has more than half of its workforce still engaged in the low-productivity agricultural labour. Because of these challenging geographic and demographic circumstances, Bhutan's economic aspirations can only be achieved through productivity-enhancing investments that yield large economic returns – including tailored innovations like the kind of which were produced by Fab Bhutan Challenge.

Conclusion

The economic value of solutions from the Fab Bhutan Challenge cannot be known until many years down the line, after the challenge solutions have been implemented. But this prospective benefit-cost analysis based on literature review of impact studies, survey data on beneficiary populations, and interviews of challenge participant suggests that the economic return will be high, in the range of $5-12 per dollar invested. That projected benefit range only accounts for the value of improved worker productivity due to the solutions, and excludes other important benefits such as lives saved, health improvements, and cultural preservation. The high projected economic return suggests that innovation competitions can play a critical role in addressing socio-economic challenges unique to Bhutan, boosting labour productivity, and achieving Bhutan's economic growth aspirations for the coming decade.

References

Asian Development Bank (2023). *Asian Development Outlook*.

Kremer, M., Gallant, S., Rostapshova, O., & Thomas, M. (2021). Is development innovation a good investment? Which innovations scale? Evidence on social investing from USAID's Development Innovation Ventures.

Kremer, M., Luby, S. P., Maertens, R., Tan, B., & Więcek, W. (2023). Water Treatment and Child Mortality: A Meta-Analysis And Cost-effectiveness Analysis (No. w30835). National Bureau of Economic Research.

Kumar, S., & Thakkar, J. J. (2017). Schedule and cost overrun analysis for R&D projects using ANP and system dynamics. *International Journal of Quality & Reliability Management*, *34*(9), 1551-1567.

Lamichhane, K. (2015). *Disability, education and employment in developing countries*. Cambridge University Press.

Liemberger, R., & Wyatt, A. (2019). Quantifying the global non-revenue water problem. *Water Supply*, *19*(3), 831-837.

Millennium Challenge Corporation (MCC), 2017. Guidelines for Economic and Beneficiary Analysis.

NSB (2022). Bhutan Living Standards Survey 2022. National Statistics Bureau of Bhutan.

NSB (2022). Bhutan Labor Force Survey 2022. National Statistics Bureau of Bhutan.

NSB (2022). Bhutan Population and Housing Census 2017. National Statistics Bureau of Bhutan.

Sapkota, S., Aryal, A., Baral, S. R., Hayward, M. W., & Raubenheimer, D. (2014). Economic analysis of electric fencing for mitigating human-wildlife conflict in Nepal. *Journal of Resources and Ecology*, *5*(3), 237-243.

Tariq, M. A. U. R., Wangchuk, K., & Muttil, N. (2021). A critical review of water resources and their management in Bhutan. *Hydrology*, *8*(1), 31.

United Nations Development Programme (2022). Bhutan Workforce Futures: Stepping Stones to Industrial Strategic Propositions for the Agriculture, Creative, and Digital Sectors.

Wangchuk, S., Bond, J., Thwaites, R., & Finlayson, M. (2023). Exploring Human–Wildlife Conflict and Implications for Food Self-Sufficiency in Bhutan. *Sustainability*, *15*(5), 4175.