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The economic potential of high-value biotechnology (biotech) start-ups within Zimbabwe

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Abstract
This article encourages Zimbabwean research institutes and universities to place heavy emphasis on biotechnology research and development (R&D) work that leads to novel products and processes that can generate high economic value for society at large. The novel output can also bring financial windfalls when commercialised effectively. The R&D interventions and subsequent output could be in nutrition supplements that mitigate certain health ailments; in innovative feeds that boost productivity, bio-fertilisers that meet growing customer preferences as well as processes that reduce costs thereby boosting enterprise profitability. Universities with biotechnology degree courses and that also conduct biotechnology research within Zimbabwe are shared and compared. Africa and global success stories are also given so they soundly act in buttressing the author's call of generating income, job creation and fiscal injections through upscaled R&D commercialisation. The link with sectoral and overall development; resultant job creation, enterprise creation, injection into fiscus and overall economic development as impact parameters are covered by the article.

Keywords: High value biotech start-ups, novelty, research commercialisation, x-factor dimensions, globally high impact projects

Introduction
Biotechnology can be regarded as the multidisciplinary field that harnesses biological processes, organisms, or systems to develop products and technologies for various commercial applications. The applications can save life, raise productivity and generate viable businesses that feed into economies at large. The discipline integrates principles from biology, chemistry, genetics, microbiology, and engineering to drive innovation in areas such as healthcare, agriculture, environmental science, and industry. High-Value Biotechnology start-ups then become commercial entities generating substantial income from innovations that often lead to products or services in demand by varying clientele. These emerging companies exploit the x-factors of skill, technology and novelty in generating the much-needed output. Expert drivers under such emerging enterprises often study existing patents, utility models, industrial designs as well as trade-marks and exploit gaps to further exploit economic and business interests. Such strategies in development are now being catalysed by the rising influence and application of artificial intelligence (AI). The International Service for the Acquisition of Agri-Biotech Applications (ISAAA), in its year 2017 edition, published those benefits accruing to the commercialisation of biotechnology. Value generated amounted to USD186 billion cumulatively for the twenty-year preceding period and USD18.2 billion in the single year of 2016. ISAAA revealed that years 1996-2016 top gainers from biotech commercialization were: USA (USD80.3 billion), Argentina (USD23.7 billion), India (USD21.1 billion), Brazil (USD19.8 billion), China (USD19.6 billion), Canada (USD8 billion), others combined (USD13.6 billion). These multi-billion dollars gains indicate potential benefits that may come to Zimbabwe should we take biotechnology commercialization more seriously. The benefits accrue to economies through: Jobs; New businesses; New product lines; Increased productivity; Timely access to affordable agro-raw materials; Solutions to ailments; Mitigation of opportunity care costs (time, treatment, care costs); Know-how, which can be licensed globally; Access to technology for use under own terms and the Export potential.

In Zimbabwe, where can biotech start-ups emerge from?
Within Zimbabwe, high value biotech start-ups are expected to emerge from the following:

- Research and Development (R&D)- output from R&D can generate start-ups of great value; this can be from: Scientific and Industrial Research and Development Centre (SIRDC)'s Biotechnology Research Institute (BRI) and Food and Biomedical Technology Institute (FBTI); National Biotechnology Authority of Zimbabwe (NBAZ)'s Research Division; African Institute of Biomedical Science and Technology (AiBST); Kutsaga Research; Pig Industry Board (PIB); International Maize and Wheat Improvement Centre (CIMMYT) and Department of Research, Innovation and Specialist Services (DRI&SS)
- Academia or universities offering degrees in the discipline which include: University of Zimbabwe (UZ), Harare Institute of Technology (HIT), Chinhoyi University of Technology (CUT), National University of Science and Technology (NUST) and Bindura University of Science Education (BUSE)
- Inspiration through professional networks such as Zimbabwe Plant Breeders Association (ZPBA) and Zimbabwe Seed Association (ZSA)
- Diaspora expertise
- Innovative industrial players in Seed (Seedco, Innov Afri Genetics, ZTS Seeds, Agricultural and Rural Development Development Authority (ARDA) Seeds); Dairy (Kefaloes, Dairibord Zimbabwe Limited-DZL); Pharmaceuticals; Stock feeds; Livestock breeders
- Retired biotechnology experts

What remains is developing the right strategy and executing it guided by bankable business plans; sound joint ventures and the rising role of public-private partnerships (PPPs). Financial resource injections remain integral.

Key applications include
A brief application inventory is shared below
Healthcare and Medicine

- **Drug Development:** Biotechnology is used to create biopharmaceuticals, including monoclonal antibodies, vaccines, and gene therapies to treat diseases.
- **Diagnostics:** Advanced technologies like polymerase chain reaction (PCR) and next-generation sequencing allow for rapid and accurate disease diagnosis.
- **Personalized Medicine:** Tailoring medical treatments based on an individual's genetic makeup enhances treatment efficacy.

Agricultural Biotechnology

- **Genetically Modified Organisms (GMOs):** Crops engineered for improved yield, pest resistance, and climate resilience.
- Genome edited products in Health, Low fertiliser needs, Higher yields
- **Bio-pesticides and Bio-fertilizers:** Sustainable practices that reduce dependence on chemical fertilizers and pesticides.
- **Plant Breeding:** Techniques like Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) gene editing are revolutionizing crop improvement through precise genetic modifications.

Industrial Biotechnology

- **Bioprocessing:** Using microorganisms to produce enzymes, biofuels, and biodegradable plastics, contributing to more sustainable industrial practices.
- **Bio-refineries:** Facilities that convert biomass into renewable fuels, chemicals, and materials.

Environmental Biotechnology

- **Bioremediation:** Using living organisms to clean up contaminated environments, such as oil spills or heavy metal pollution.
- **Waste Treatment:** Biological processes to treat wastewater and reduce environmental impact.

Bioinformatics
The application of computer technology to manage biological data, essential for analysing genomes and proteomes, and facilitating biological research.

Education
Biotechnology education is designed to provide students with a thorough understanding of both the science and applications of biotechnology. Key stages in biotechnology education are:

- **High School Education:** Students typically take biology/biology in co-science, chemistry, and mathematics as part of their curriculum. Advanced courses like AP Biology or AP Chemistry provide a stronger foundation for future studies
- **Extracurricular Activities:** Participation in science clubs, fairs, or biotechnology-related internships can enhance interest and provide practical experience.
- **Undergraduate Degree:** A bachelor's degree in biotechnology, biology, biochemistry, molecular biology, or a related field is the first formal step. Programs often cover fundamental topics such as genetics, microbiology, bioinformatics, and biochemistry.
- **Laboratory Skills:** Hands-on laboratory courses are crucial, focusing on techniques such as PCR, DNA sequencing, cell culture, and chromatography.
- **Internships and Research:** Gaining practical experience through internships or undergraduate research projects allows students to apply their knowledge and build their resumes.
- **Graduate Education:** Many students pursue a Master's in Biotechnology or a related field. This stage often involves advanced coursework, research, and specialization in areas like genomics, pharmaceutical biotechnology, or agricultural biotechnology.
- **Research Projects:** Graduate studies typically include extensive research components, culminating in a thesis or dissertation that contributes to the field of biotechnology.
- Doctoral Degree (Ph.D.) For those interested in research or academic careers, pursuing a Ph.D. in biotechnology, molecular biology, or a specialized area is common. This involves original research, publication in scientific journals, and the defence of a doctoral dissertation.
- **Postdoctoral Research:** Following a Ph.D., many graduates undertake postdoctoral research to deepen their expertise and broaden their research capabilities.

- **Continuing Education and Professional Development**
  - **Certifications:** Professionals may pursue certifications in specific areas of biotechnology or related fields to enhance their qualifications.
  - **Workshops and Seminars:** Participating in workshops, seminars, and conferences to stay updated on the latest advancements and regulatory changes in biotechnology.
  - **Networking:** Joining professional organizations like the Biotechnology Innovation Organization (BIO) and participating in industry events to build connections.
- **Industry Experience**
  - **Employment:** Graduates can work in diverse fields, including pharmaceuticals, agriculture, environmental science, and academia. Many job positions require ongoing training and skill development.
  - **Specialization:** As biotechnology is an evolving field, continuous learning and specialization are essential for staying relevant and competitive in the job market.

Link with Development Economics

The development economics discipline focuses on the economic, social, and institutional factors that affect development in low- and middle-income countries. It pursues the understanding of how to improve living standards, reduce poverty, and enhance overall economic growth. Key Areas include: Poverty Alleviation: Strategies to increase income, provide access to education, and improve health; Sustainability: Ensuring that economic growth is environmentally sustainable and socially inclusive as well as Policy and Governance: Examining how government policies and institutions can promote or hinder development. Discipline Interconnections manifest in:

- **Agricultural Development:** Biotechnology can enhance food security by developing crops that are more nutritious or resilient to climate change. This can have a profound impact on rural economies and subsistence farmers.
- **Healthcare and Economic Productivity:** Improved health outcomes through biotechnology can lead to a more productive workforce. Reducing disease prevalence can lower healthcare costs and improve quality of life, thereby contributing to economic growth.
- **Job Creation:** The biotechnology sector can generate jobs in research, manufacturing, and services, contributing to economic development, particularly in regions that focus on biotechnology as a strategic industry.
- **Innovation and Technology Transfer:** Developing countries can benefit from partnerships with biotech firms and institutions in developed countries. Technology transfer initiatives can help local economies harness biotechnological advancements.
- Ethical and Equity Issues: The implementation of biotechnological solutions must consider ethical implications, including access to technology and potential inequalities between nations or within societies.

Table 1: Where is biotechnology creating impacts to economies?

Zimbabwe	Africa	Global
SIRDC BRI (agriculture and health biotech research and development) Kutsaga Research Station: playing a crucial role in biotech solutions (tobacco, horticulture crops) Biotechnology Engineering Research and Development (BERD) African Institute of Biomedical Science and Technology (AiBST): specializes in biomedical sciences and technology HATZ (Health and Agricultural Technologies): innovative health and agricultural solutions Farm Biogas: sustainable agricultural practices, utilizing biogas technology to improve waste management and energy generation on farms. Ceres Consulting: Works within the agricultural sector, providing services and products that leverage biotechnological advancements to enhance crop yield and health. BIOTECH Institute	21st Century Technologies (Nigeria): biopharmaceuticals, specializing in the development and manufacture of drugs for various diseases. Worms for Change (South Africa): uses biotechnology to manage organic waste through vermiculture and worm farming, turning waste into valuable products like organic fertilizer. Biovac (South Africa): biopharmaceutical company that focuses on the manufacturing of biological products, including vaccines African BioTechnology and Natural Resources (ABN) (Kenya): research and commercial application of biotechnology to improve food security and resource management in agricultural sectors. LifeBank (Nigeria): uses biotechnological methods to store and manage blood products, providing critical health solutions across Nigeria. Kokonut (Ghana): utilizing the coconut plant for various products, including biofuels and cosmetics, leveraging biotechnology for sustainable resource use. MediMush (South Africa): medicinal mushrooms, this start up leverages biotech to develop health supplements with potential benefits for immunity and general wellness. YAPILI (Kenya): A digital health platform that connects entrepreneurs with investors and stakeholders in the biotech field. Sana Health (South Africa): focuses on plant-based medicines and natural products, developing treatments derived from South African indigenous flora. Ginkgo BioWorks (Global but with initiatives in Africa): bioengineering to develop custom microbes for various applications, including agriculture and sustainability projects in Africa.	North America: Ginkgo Bioworks(USA): Organism design and synthetic biology; Uses genetic engineering to design custom microbes for various applications, including pharmaceuticals and agriculture. Moderna (USA): mRNA technology; Gained prominence for its COVID-19 vaccine, but also works on therapies for other infectious diseases, cancer, and rare diseases. CRISPR Therapeutics (USA): Gene editing technologies; Develops transformative gene-based medicines for serious diseases using CRISPR/Cas9 technology. Europe: BioNTech (Germany) Immunotherapy and cancer vaccines; Known for its mRNA-based COVID-19 vaccine developed in partnership with Pfizer; it also develops cancer therapies. Sana Biotechnology** (USA): Cell and gene therapies; Aims to create, manufacture, and deliver engineered cells as a new therapeutic modality for various diseases. Asia: Zymeworks (Canada): Therapeutic proteins and antibody-drug conjugates; Develops biologics for cancer treatment, with a range of candidates in various stages of clinical trials. BeiGene (China): Cancer therapies; molecularly targeted and immuno-oncology drug development. Known for its innovative approaches to cancer treatment. Insilico Medicine (Hong Kong); AI-driven drug discovery; Utilizes artificial intelligence to discover and develop new drugs, particularly in aging and age-related diseases. South America: Biominas Brasil (Brazil) Innovation in biopharmaceuticals; A platform that supports biotech start-ups in Brazil, facilitating connections between research and market applications. Oceania: Cynata Therapeutics (Australia); Stem cell technology.

Source: Author synthesis (2025)

The model for Zimbabwe

The main ingredients into the model which maximises gains from exploiting biotechnology within Zimbabwe include: Generation of novelty; Scope of Inclusivity (from R&D roots to industry and beyond); Collaboration (product, facility, expertise); Resourcing (Exposure, Consumables, Mentorship); Socio-cultural dimension (soft skills); Business Plans (technical, finance, markets); Funding and Policy support to sustain the start-ups.

Challenges and Considerations for Zimbabwe

For Zimbabwe to fully exploit benefits accruing from biotechnology, the following matters require attention:

- **Investment and Infrastructure:** The funding, laboratories, equipment and timely access to needed consumables are key. Zimbabwe, like many developing countries, lacks the necessary infrastructure and investment to fully leverage biotechnological advancements.
- **Regulatory Frameworks:** Whilst strides are being made to work on regulatory gaps, effective regulation is still needed to ensure safety and public trust in biotechnology. These must be adapted within the context of rising significance of artificial intelligence (AI).
- **Public Perception and Acceptance:** Concerns about GMOs and other biotechnological innovations can lead to resistance from local communities, which is often driven by a lack of understanding or misinformation. This dimension must be addressed through demystifying biotechnology.
- **Ethical Concerns:** Issues around genetic modification, cloning, and biosecurity must be addressed responsibly.
- **Regulation:** Biotech products often require stringent regulatory approval to ensure safety and efficacy.
- **Public Perception:** Misinformation and scepticism among the public can challenge the adoption of biotechnological advancements.

Ingredients for success

Arthur Humphrey (1996) [1] pointed out that "many hurdles" must be overcame for biotechnology to be fully exploited and these include regulatory approval for the processes, products, premises and expertise; prohibitive costs and gaps in knowledge base on the development, design and validations within the discipline. Michael Stephen, Kayode Sheriffden (2024) [8] called for collaboration in risk mitigation covering: Intellectual Property (IP) theft, resource gaps, regulatory compliance and also for opportunities exploitation, that is, accelerating development timelines as well as market access. Ferguson SM, Kamundiya US (2020) [4] advised on the upfront importance of facilitating agreements namely: secrecy and non-disclosure (NDAs), Material transfer agreements (MTAs), commercialisation special purpose vehicles (SPVs); Licensing to start-ups - either exclusive or nonexclusive; Royalties and terms. Expert advice is key on these matters.

Conclusion

Overall, biotechnology holds immense potential to tackle global challenges in health, food security, and environmental sustainability, but it requires careful consideration of ethical and regulatory frameworks to ensure responsible advancements. Each stage of biotechnology education builds on the previous one, combining theoretical knowledge with practical skills. This structured pathway equips students to meet the demands of a rapidly evolving field, contributing to innovations that can address global challenges in health, agriculture, and environmental sustainability. Biotechnology and development economics are two interrelated fields that can significantly impact each other. The integration of biotechnology into development economics offers significant potential to address pressing global challenges, such as food security, health, and environmental sustainability. Policymakers and stakeholders must work collaboratively to harness these innovations while ensuring that ethical considerations and equitable access are prioritized to maximize the benefits for all sectors of society. Jointly biotechnology and development economics so that interconnections remains live gong forward.

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