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A rural bioeconomic strategy to redefine primary production systems within the Australian innovation system: Productivity, management, and impact of climate change. In: McHenry, M.P., Kulshreshtha, S.N. and Lac, S., (eds.) **Agriculture Management for Climate Change.** Nova Science Publishers, pp. 55-70.

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Chapter

**A RURAL BIOECONOMIC STRATEGY TO REDEFINE
PRIMARY PRODUCTION SYSTEMS WITHIN THE
AUSTRALIAN INNOVATION SYSTEM: PRODUCTIVITY,
MANAGEMENT, AND IMPACT OF CLIMATE CHANGE**

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ABSTRACT

This chapter explores components of a rural research, development, and extension strategy that amalgamates the primary industries with a larger class of broad-spectrum biological science and technological capability in Australia. Innovative enabling biotechnologies are likely to continue to alter approaches to tackling regionally-specific problems that link non-biological and biological resource use and production efficiency, including climate change. Such linkages will require a diverse scientific capability derived from research fields of science and technology currently external to conventional primary industry capabilities. However, capturing potential benefits of transformational technologies requires a progressive approach to investments in higher education, business, and government. This chapter asserts three crucial non-exclusive investment drivers are receiving insufficient consideration in the rural research, development, and extension in what is termed the “rural bioeconomy”: human collaborative knowledge; sustainable production capability, and; cross sectoral transformational science and policy. Discussed are some policy and institutional options to assist convergence of these three non-exclusive drivers to enhance collaborative capabilities in a rural context.

Keywords: Bioeconomy, rural, primary industry, research, collaboration, science, policy.

INTRODUCTION

One-third (7.7 million) of the Australian population live in rural and regional areas of the nation. The rural sector manages around 60% of Australia’s 7.6 million km² of lands, and 10.2 million km² in the exclusive economic zone relevant for fisheries. The sector accounts for around 17% of national employment, and the farm dependent economy represents around 12% of gross domestic product (GDP) (RRDC, 2011). Whilst the rural sector is vital to the nation, the long-held

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differentiation between the rural sector and other sectors requires redressing to acknowledge the reality of a complex cross-sectoral space, particularly in the higher education sector, which heavily influences research, development, and extension (RD&E) outcomes. The bioeconomy concept invokes the consideration of the important roles of fundamental science and education in these complex biologically-dependent cross-sectoral issues, such as climate change, food security, energy and water security, improving health outcomes, long-term production security, development objectives, etc. Refocussing of the bioeconomic potential into the “rural” requires interdisciplinary thinking, and active collaborative science, education, and technology to meet the accelerating challenges and expectations of production systems dependent on rural biological systems directly or indirectly (OECD, 2006; PMSEIC, 2010a; RRDC, 2011).

Using a bioeconomic framework (explored in detail in the OECD literature) places the rural sector within a larger and more inclusive context to be more engaging to policymakers and other sectors, such as health, minerals and energy, information and communications, climate change, etc. This paper specifically endeavours to refocus and internationalise the national rural RD&E capability for enhanced productivity and greater return on investment. In particular, the extension of rural and primary industry RD&E through the value chain requires collaboration between numerous existing industries, and will blur the interface of primary production and other industrial production systems (ACIL Tasman, 2008; PMSEIC, 2010a; RRDC, 2011). Whilst, the term “bioeconomy” is often interpreted slightly differently within the existing literature, the most cited OECD interpretation is:

“...the aggregate set of economic operations in a society that use the latent value incumbent in biological products and processes to capture new growth and welfare benefits for citizens and nations. These benefits are manifest in product markets through productivity gains (agriculture, health), enhancement effects (health, nutrition) and substitution effects (environmental and industrial uses as well as energy); additional benefits derive from more eco-efficient and sustainable use of natural resources to provide goods and services to an ever growing global population” (OECD, 2006, p. 3).

A “rural” bioeconomic perspective refocusses both private and public rural sector research investments towards convergence between primary production and industrial biotechnology, within environmental and social objectives of long-term, profitable, and sustainable systems. While the biosciences and biotechnology are required to advance and inform the bioeconomy, these elements are not an end in themselves¹ (OECD, 2006), and are simply are enabling capabilities and technologies (Cutler and Company Pty Ltd, 2008; Arundel and Sawaya, 2009; RRDC, 2011). As an enabling technology, biotechnology may bring marginal rural production systems into the mainstream of new economies in fuels, materials, and industrial primary feedstock. This provides a new opportunity to maintain or increase productivity growth, achieve environmental objectives, and diversity from traditional food/feed systems (Glover et al., 2008; PMSEIC, 2010b). However, biotechnology development itself requires active cross-pollination between disparate research disciplines often outside of the traditional biological science sphere, (including health, minerals and energy, information and communication sectors) to derive greater scopes, scales, and the socio-economic benefits from RD&E investment (Arundel and Sawaya, 2009; PMSEIC, 2010a). It is the assumption of the requirement of greater cross-collaboration on which this paper suggests an education policy and institutional refocus is necessary to enhance collaborative sectoral convergence that fosters the national science and technology capability for a greater return on rural RD&E investment. The author wishes to point out the differences between Australian higher education, government, and business investment, especially the significant business expenditure which is often relatively “low key”. As Australia is not unique in the attempt to attract additional private investment, a renewed focus for increased RD&E return on investment

¹ The use of the term biotechnology in this work does not simply refer to non-conventional breeding genetic modification as is generally assumed, but to numerous processes that generate useful products using biological inputs at some stage in the production chain.

through collaborative efficiency and less duplication to generate knowledge is critical to make the most of available capability (Cutler and Company Pty Ltd, 2008; PMSEIC, 2010a; RRDC, 2011).

The extensive collaborative opportunities, and continual nationally policy evolution in relation to international RD&E cooperation, may be sufficient to maintain an effective capability for enhancing and deploying new knowledge for development goals, particularly in the agricultural sector (UNFCCC, 2008). However, the relatively minimal historical Australian RD&E expenditures in recent years for even fundamental agricultural collaborative partnerships overseas may be indicative of the historical lack of a collaborative focus in RD&E policy. Table 1 shows the 2008-09 expenditures from the Australian Government on agricultural research centres, predominantly located in transitional economies. The majority of the total RD&E expenditure includes the Australian Centre for International Agricultural Research (ACIAR), which forms part of the Australian Government's international development and aid assistance programme. In 2008-09, ACIAR received only \$52.333 million from the Commonwealth Government directly, with an additional \$16.006 million, primarily through AusAID and the Department of Agriculture, Fisheries, and Forestry (DAFF). Of the \$68.416 million of ACIAR expenditures in 2008-09, only \$9.362 million was spent through the Consultative Group on International Agricultural Research's (CGIAR²) fundamental agricultural research centres, and only a further 1.2 million to non-CGIAR research centres (ACIAR, 2009).

Table 1. Previous Australian Government expenditure on CGIAR centres (ACIAR, 2009).

CGIAR Centres Funded by ACIAR 2008-09	Country	Total AUD\$
Bioversity International	Italy	338,132
International Center for Tropical Agriculture	Columbia	375,266
Center for International Forestry Research	Indonesia	669,099
International Maize and Wheat Improvement Center	Mexico	1,866,102
International Potato Center	Peru	601,902
International Center for Agricultural Research in Dry Areas	Syria	422,061
World Agroforestry Centre	Kenya	250,000
International Crops Research Institute for the Semi-Arid Tropics	India	1,026,944
International Food Policy Research Institute	USA	871,138
International Livestock Research Institute	Kenya	475,760
International Rice Research Institute	Philippines	953,490
International Water Management Institute	Sri Lanka	676,081
WorldFish Center	Malaysia	1,016,377
Total		9,204,558

Whilst this is projected to increase (ACIAR, 2009; CGIAR, 2011), the approximately \$10.5 million expenditure on core agriculture, forestry, and aquaculture collaborations are only almost only 1% of the total 2008-09 agricultural, fisheries, and forestry rural subsector expenditure. While noting that the above RD&E expenditures and the stated mechanisms/institutions are by no means the only channel for RD&E capability and knowledge development and transfer, the relatively small figures do not confer the primary importance of basic food production security in rural areas, especially in our neighbouring countries. Australia's current deficiency in international RD&E collaboration was specifically targeted in recommendation 6.5 on p73 of the 2008 Cutler Report, stating "...build concentrations of excellence, encourage collaboration and achieve better dissemination of knowledge, introduce additional funding support for university and other research institutions to partner with each other and with other research organisations (national and international)" (Cutler and Company Pty Ltd, 2008). This funding deficit and the growing opportunity was recognised by the previous Australian Government committing an additional

² CGIAR is a partnership of 64 donor country members focussed on fostering international agricultural RD&E.

AUD\$33 million over four years to establish the Australian International Food Security Centre, to be lead by ACIAR using a rural development focus. These rural-based RD&E policies, funding, and institutions are hoped will be sustained to continue making inroads to increased primary and rural-related productivity for all partners' concern.

In terms of looking at productivity gains from the Australian RD&E expenditure from simply a national utilitarian perspective, the lack of international RD&E collaboration related to the rural sector overlooks the significant benefits of collaborating with countries in the Asia-Pacific and African regions with favourable currency exchange rates. In addition to relative purchasing power, Australia may choose to take advantage of the commonly lower labour costs, even for world-class scientists and engineers in many collaborating Asia-Pacific and African countries. Collaboration such as this can pass on lower RD&E costs to Australia while generating greater RD&E capability in collaborating nations without requiring researchers to relocate to Australia. Compared to other OECD countries, Australian RD&E costs are lower by approximately one-third, which includes wages of university graduates and experienced personnel. Labour costs are roughly half of total RD&E expenses in OECD countries (ACIL Tasman, 2008). Therefore, the ability for Australia to attract investment capital from other industrialised nations, and access the often lower RD&E labour costs in other Asia-Pacific regional collaborations is a competitive advantage. A fundamental challenge related to international collaboration involves retaining the highly mobile RD&E labour base in countries with a lower domestic remuneration levels than major industrialised countries, which includes the lower wage Australian researchers (Birch, 2006; OECD, 2006). As the vast majority of both public and private biotechnology RD&E is undertaken in the USA (Arundel and Sawaya, 2009), many nations may see their investment in human capacity simply leave to engage the USA RD&E labour market. Thus, RD&E administrative bodies, including the higher education sector, will likely need to look for non-monetary incentives to compete with the global RD&E talent market. One option may be the reduction in administrative burden increasingly associated with research fields. Australian research time dedicated to short-term research grant applications and maintenance requirements are known to be high. A nation-wide move to longer-term and flexible contracts may be areas to improve Australia's ability to attract and retain researchers and their increasingly important personal collaborative networks (ACIL Tasman, 2008).

BIOECONOMIC DRIVER : HUMAN COLLABORATIVE KNOWLEDGE

Drivers of the rural bioeconomy are fundamentally human economic issues related to productivity of a given area of land: i.e., increasing wealth, growth in productivity, population change, escalation of human concern about climate change and the environment, etc. (Arundel and Sawaya, 2009). Therefore, it is fundamental to explore the various human elements in the RD&E supply and demand chain within the rural innovation system. Education institutions, governments, and private non-profit institutes continue to play an important role in fostering the human and social elements of biotechnology sector (Hilgartner, 2007; Arundel et al., 2009). Large integrated multi-disciplinary teams are becoming increasingly necessary to tackle scientific questions regarding plant interactions within the environment and regional primary production systems (Glover et al., 2008). The increasingly interdisciplinary nature of bioscience will thus require a diverse scientific workforce, including chemists, physicists, computer scientists, mathematicians, engineers, etc. (Arundel and Sawaya, 2009). Enabling interdisciplinary and cross-jurisdictional RD&E projects, through early career research fellowships and programmes will engage Australia internationally with the growing global technologically complex interdisciplinary focus (Cutler and Company Pty Ltd, 2008; PMSEIC, 2010a; RRDC, 2011). Whilst the supply of basic research/science skills and "human inputs" has gained much attention in recent decades, this work explores the less prominent, but just as essential, collaborations between people "downstream" from the primary research knowledge generators. Such people (including primary producers) more

often extend such knowledge to produce, process, and also consume the products/services, and thus hold essential knowledge required to be “fed back” into research.

As more than three billion of the world’s workforce are involved in producing food for the total human population, rural primary industries play a disproportionately large role in the lives of people and environments, especially in non-industrialised economies (UNFCCC, 2008; Arundel et al., 2009). A major driver of the bioeconomic focus is the parallel increase in global population and per capita income in non-industrialised economies, alongside the pursuit of environmentally sound regional production systems (Arundel and Sawaya, 2009; RRDC, 2011). Despite this driver from non-industrialised regions, there has been little focus to date from the biotechnology sector on increasing food production, nutrition, or farm incomes in non-industrial production systems (Herdt, 2006). Both the technological and human issues are often very different in rural areas in industrialised economies, where depopulation is an overriding issue. In addition to social disconnection, service rationalisation, declining knowledge-base, seasonal skill shortages, and an increasing proportion of absentee landowners in agricultural regions, make environmental and climate change monitoring considerations more difficult. However, regardless of development status, people who live in rural areas have a unique and detailed knowledge of their lands and environment over time, and must be enabled to play a central role in their management towards sustaining the natural environment which supports productivity. Unfortunately, at present the complex multi-functional lives, skills, and knowledge (often informal) of people in rural regions do not generally feature in RD&E policy documentation, implementation, and capacity building (Jordan et al., 2007; RRDC, 2011).

External to capacity and efficiencies in the production chain, additional human components in the rural bioeconomy are likely to become increasingly challenging, especially in relation to the food sector RD&E (OECD, 2006; ACIL Tasman, 2008). One example is when some biotechnologies raise public concern while others remain unopposed. Consumer concerns will continue to shape some GMO commercialisation activities, which may shift public and private investment towards non-transgenic biotechnologies (Commonwealth Government of Australia, 2003; Arundel et al., 2009), or public investment towards traits that more directly benefit the public or environment. Interestingly, in contrast to public perception, recent institutional and field GMO crop trial data suggest such a move from herbicide research on tolerance and pest resistance towards a greater focus on value-added quality traits and environmentally beneficial plant stress tolerance (Arundel et al., 2009). Therefore, biotechnology research will continue to be a unique field where public perception is crucial to the future prospects of the sector (Commonwealth Government of Australia, 2003), and active and informed science communication to producers and consumers will become increasingly necessary, akin to what we have seen with atmospheric scientists and the climate change “debate”. In terms of public acceptance of some biotechnologies, history has shown that pioneering scientists have not anticipated public opposition particularly well, and were often simply focussed on potential benefits of the technology, such as increased food production, improved health treatments, and generating greater industry profits (Herdt, 2006). It may be argued that biological scientists may be morally and professionally obligated to raise the level of public debate to enable discrimination between various types of biotechnologies and their respective ethical implications for safety, development equity, food security, climate change, and environmental protection elements (Hilgartner, 2007). Indeed, scientists skilled in the biosciences may be increasingly required to disclose experience, risks, and benefits to policymakers and the public who may directly or indirectly sponsor them.

BIOECONOMIC DRIVER : SUSTAINABLE PRODUCTION CAPABILITY

Between 1974-75 and 2007-08, the Australian Agriculture, Fisheries and forestry sector achieved 2.8% average annual productivity growth, double that of the national average (RRDC, 2011). In spite of this, arable land and freshwater sustainable resource limit implications for the

agricultural RD&E investment will be a major challenge to meeting growing demands for food, feed, fuel, and fibre, while reducing environmental impacts and meeting climate change obligations (OECD, 2006; Fedoroff et al., 2010; McHenry, 2009a,b; 2011a,b; 2012a,c,d; 2013a; RRDC, 2011; McHenry and Anwar McHenry, 2013). While a bioeconomy based on primary industry biomass promises an avenue toward a more “green” and a geographically diverse and secure economy (Jordan et al., 2007), biotechnology-based production will require risk analyses and standards development to maintain production within environmental capacities (Arundel and Sawaya, 2009; RRDC, 2011). For example, ecological harm from transgenic crops remains a concern, but any risk assessment must distinguish between the probability and the hazard elements to estimate risk (Herdt, 2006; OECD, 2006). Therefore, it is essential to cultivate a sufficient public-sector research and education capability to utilise bioscientific knowledge and techniques to independently develop standards, safety testing, and assess private business assertions (OECD, 2006; Fedoroff et al., 2010).

Australia invests less in biotechnology as an absolute, and as a proportion of total expenditures than many OECD countries, and even less than many of its major agricultural competitors (ACIL Tasman, 2008). Nevertheless, this work argues that the quantum of investment is only one component of integrating knowledge and applications across sectoral value-added chains which can attain efficiencies in rural economies of scale and scope (Arundel and Sawaya, 2009). Another option is structural change to production systems, and a bioeconomic focus may involve (and even necessitate) sweeping changes in development and production across disparate regions (Arundel and Sawaya, 2009; Gibbs et al., 2009). In recent times there has been an active focus towards structural adjustments to technology-transfer and dissemination of RD&E of sustainable practices, technologies, and capacity-building investments (OECD, 2006; UNFCCC, 2008). However, national and business interests have been less concerned with structural adjustment and environmental benefits, and often remain focussed on RD&E innovative behaviour to generate short-to-medium term economic development and financial returns, respectively (Smith, 2005; Gibbs et al., 2009). In contrast, the development of biotechnological knowledge requires an intensive RD&E focus (Arundel and Sawaya, 2009), with both short-term applications and long-term innovation components (Glover et al., 2008). In addition to current RD&E, a greater focus on the extension of existing knowledge, exploration of applications of our current biological and genetic inheritance, and the development of new ecologically sound practices requires integration local and technical knowledge, capacity building, and infrastructure investment. All of these occur outside of traditional RD&E activities. This “inclusionary view” towards innovation will be particularly important in developments concerning unconventional land-uses and new species, particularly in arid and saline terrestrial environments (Fedoroff et al., 2010). These new frontiers of production will require unprecedented innovation in research, engineering, monitoring, regulation, and cross-communication, with a particular focus on the social and ecological integrity of these newly complex production landscapes (OECD, 2006; Fedoroff et al., 2010; RRDC, 2011; McHenry, 2012a,b,c; 2013b; McHenry and Anwar McHenry, 2013). This all points towards an unprecedented integration of knowledge from a range of traditionally distinct sectors and fields. For example, as world energy demand continues to rise dramatically, the successful navigation of the various available bioenergy development paths already encompasses elements of energy supply diversity, national security, air pollution and health, rural and technical development, climate change, biodiversity and deforestation, improved strain selection, tax incentives and subsidies, fresh water quality and supply, distributed infrastructure, resource limitations, and so on (OECD, 2006; Hilgartner, 2007; McHenry, 2009b,d; 2010; 2011b; 2012a,c; 2013a; PMSEIC, 2010b; Borines et al., 2011; McHenry et al., 2012). These domains clearly do not fall squarely within current scientific disciplines and educational structures. Nonetheless, as in the past, science and technology RD&E will routinely be expected to find solutions that minimise negative consequences and deliver yield and profit gains, all with less inputs (Arundel et al., 2009).

In terms of the relative potential of areas within a bioeconomy, it is not uncommon to hear persuasive extraordinary claims about the future for biotechnology in particular, despite the

epistemic challenges of foreseeing future challenges and developments (Hilgartner, 2007). Within often sensationalised claims, there is a practically limitless potential biotechnological research projects that could be developed to increase rural productivity in the food, feed, fuels, industrial feedstock, forestry, animal and insect husbandry, cropping, fine chemicals, pharmaceuticals, and even health industries spheres (Arundel and Sawaya, 2009; Arundel et al., 2009). Recent biotechnology developments relevant to the human health sector includes biopharmaceutical, cell tissue engineering, gene therapy, small molecule therapeutics, diagnostics, DNA sequencing, functional food nutraceutical, medical device, and pharmacogenetic developments (Arundel et al., 2009), each with the potential to improve disease prevention, treatment, and cure. While much of this biotechnological potential is far in the future, the number of biopharmaceuticals expected to enter the market before 2015 is remarkable (Arundel et al., 2009). However, at present primary industry biotechnology predominantly consists of plant and animal breeding and diagnostics in the agricultural sector, with some veterinary medicine applications (Commonwealth Government of Australia, 2003; Arundel et al., 2009). Thus, there is a growing capability to expand into new areas downstream from production for environmental protection, waste management, and biomaterial conversion, to name but a few (Commonwealth Government of Australia, 2003).

The bioeconomy literature often discusses the scope for integration of bioindustrial processing into existing agricultural production systems towards higher-value production, including biofuels, plastics, industrial chemicals, etc. (Arundel and Sawaya, 2009). However, the development of bioindustries within a rural context will likely require additional supporting technologies and financial mechanisms than simply traditional biosciences or biotechnology, and to compete with existing products will likely require additional supporting technology capability from information and communications, enhanced computational power, and nanotechnologies (OECD, 2006; Arundel and Sawaya, 2009). However, in the short-term, instead of a direct competition with existing products, it may be more likely that cross-pollinating supporting technology and bioindustrial production follow a development path in non-biological industrial production. The returns on investment for top-down policies that aim to foster totally new bioindustries will likely be dwarfed by largely “unplanned” innovation, and a focus on developing supporting technologies and collaborative capabilities may generate more returns.

In the agricultural and fishery primary industry sectors, biotechnology is currently facilitating a reduction of environmental impacts and greenhouse gas emissions by improving production efficiency, often using crop varietal improvements with cleaner processing management (Arundel and Sawaya, 2009; Fedoroff et al., 2010). Examples include reduced chemical and fuel inputs, less soil tillage, improved bioremediation, genetic fingerprinting to prevent fish stock mismanagement, and greenhouse gas mitigation (Arundel and Sawaya, 2009). Mitigation of enteric fermentation methane, manure methane and nitrous oxide, pasture carbon release, water-related methane, biosequestration, and land conversion emissions are fundamental challenges for biological RD&E at the regional scale. As agricultural emissions are fundamentally subject to biological and environmental variability, a transition to full greenhouse gas emission accounting practices will be expensive and complex in the short-term without significant capacity building in the biological sciences (UNFCCC, 2008; McHenry, 2009c). However, a “biological science-only” approach will likely be insufficient, as barriers to agricultural mitigation also include the availability of regional investment capital, slow technological development and uptake, and the lack of robust opportunities to break from traditional practices. Ensuring maximum efficiency of agricultural mitigation investments will require a systemic approach that takes into account several co-benefits and trade-offs to optimise regionally appropriate policy, and also the extension of knowledge suitable to production systems (OECD, 2006; UNFCCC, 2008).

In terms of making shorter-term, practical collaborations for integrating rural and regional primary industry research with industrial biotechnology, there are opportunities in linking of biorefining and bioprocessing infrastructure providers, seed firms, and growers to produce optimised plant varieties for bioprocessing requirements and improved marketability of final product (OECD, 2006; Arundel and Sawaya, 2009; PMSEIC, 2010b). Also, specific consideration is required in regions specialising in animal husbandry, as livestock accounts for between 40-50%

of the value of agricultural production in OECD countries. Breeding programmes, health diagnostics, and therapeutics are the major focus of animal biotechnological innovation, and enjoy a large international market (Arundel et al., 2009), and the new and complex interplay between emerging international corporate interests and traditional livestock breeders requires attention (Birch, 2006; Gibbs et al., 2009). However, Australia will need to strategically approach this complex interface to maximise benefits, and efficiently foster existing areas of strength to develop a capability that is synergistic with national competitive advantages and the Australian population and economy.

BIOECONOMIC DRIVER : CROSS-SECTORAL SCIENCE & POLICY

Goal oriented policy and leadership from governments, scientists, and innovative businesses will be required to both harness and guide biological science capabilities to sustain primary production, health, and bioindustrial development (OECD, 2006; Arundel and Sawaya, 2009; RRDC, 2011). In addition to government and publically funded higher education capability, three general criteria need to be addressed to attract private investment over time: technical feasibility, financial viability, and community acceptability. Thus, primary producers, industry, scientists, and governments will need to collectively identify technological and policy options that are most promising over the long-term (OECD, 2006; Glover et al., 2008). Whilst private technical and financial requirements are often well known by the private proponents themselves, demonstrating the return on investment for public expenditures is often followed by demands for the creation of indicators by policymakers. To measure resultant outputs, impacts, reduction of barriers and bottlenecks to production, or any other change resulting from investment require quantification (OECD, 2002; RRDC, 2011). Such empirical analyses will involve a combination of statistical surveys, private data, and new innovative statistical techniques akin to those used to measure impacts of the information and communication technology investment (OECD, 2006; Hilgartner, 2007; RRDC, 2011). The ability of institutions to develop suitable economic indicators and metrics for comparative analysis across countries and over time may enable a politically-tangible quantification of the bioeconomy to better engage the public and heighten the importance of the required science and innovation investment (OECD, 2006; Hilgartner, 2007). However, their development should include private, commonwealth, state, and local institutions, alongside international investors (Jordan et al., 2007; PMSEIC, 2010b).

International collaboration will be essential for small nations to develop RD&E efficiencies through sufficient scale, and rural Australia must maximise the inflow of new international technology, techniques, products, and services by public investment leverage in science and innovation to foster technical capacity for domestic adaptation (Smith, 2005; ACIL Tasman, 2008). In a similar manner to avoid the unnecessary division of the bioeconomy RD&E into traditional sectors such as health, energy, primary industries, etc. (OECD, 2006), multifunctional agricultural and rural landscapes require a focus on appropriate evaluation of scaled and managed enterprises and production systems across traditional sectors (Jordan et al., 2007; PMSEIC, 2010b). Fostering multifunctional agricultural production land use for working landscapes can deliver food, biomass, employment, security, innovation, and various other environmental products and services (Jordan et al., 2007). Such an approach may lessen the competing objectives of environmental, social, and economic elements while optimising biomass production and input use while avoiding negative outcomes such as productive land retirement (OECD, 2006; Jordan et al., 2007; McHenry, 2012c). These optimisations will require significant policy planning, investment, regulatory advancement, market reform, management, innovation, and of course active and legitimate consultation.

Regional innovation systems exhibit interdependence on applied and basic research infrastructure, and both small and large businesses are necessary for the multidisciplinary perspective that facilitates new economies (OECD, 2006; Arundel and Sawaya, 2009; Cooke,

2009; RRDC, 2011). Several primary industry biotechnological businesses are exploiting discoveries made outside primary production to maintain productivity (Arundel and Sawaya, 2009), and a unique relationship within the bioeconomy between very large and small businesses is necessary to sustain economies of scale, bring products to market, cover regulatory costs, and keep up with the fast pace of technological development (OECD, 2006; Arundel and Sawaya, 2009). Bioeconomic development can follow a number of development pathways, including collaborative models that share knowledge and costs, or integrator models that create and maintain markets (Arundel and Sawaya, 2009). While the cost of Australian production and distribution of final biotechnological goods and services is similar to other industrialised nations, the national primary industry biotechnology market is small in terms of demand, value adding, and employment (ACIL Tasman, 2008). Existing capabilities can be leveraged by policies which increase public and private research investment, encouraging public-private partnerships, creating markets for sustainable biotechnology products, or collaborative networks (Smith, 2005; OECD, 2006; Arundel and Sawaya, 2009). Akin to entrepreneurial networks which underpinned the emergence of industrial districts, the so-called “green cluster” concept relates to the convergence of diverse industries, such as information and communication technology, biotechnology, and clean energy technology (OECD, 2006; Cooke, 2009). The concept is a platform based development focused on horizontal technological convergence (rather than the traditional sectoral, and vertical approach favoured by industrial economic theory and governments) which enables regional development paths more attune with historically successful development (OECD, 2006; Cooke, 2009). Nonetheless, clustering approaches still require prioritisation of RD&E, funding, and structural encouragement (Birch, 2006; Glover et al., 2008; RRDC, 2011).

Quite apart from RD&E scale, rural RD&E economies of scope are facilitated by investment in fundamental science, tools, techniques, and processes. Examples are bioinformatics, genome sequencing, RNA interference, metabolic pathway engineering, DNA synthesis, and synthetic biology (OECD, 2006; Arundel and Sawaya, 2009). These tools, techniques, and processes enable multiple applications (which are often unplanned) and may result in positive development spillovers. Such fundamental tools and techniques are known as platform technologies (Arundel and Sawaya, 2009), and each have multi-layered subcategories of knowledge useful to multiply the value of investment to obtain increased scale and scope. For instance, bioinformatic subcategories such as phenomics, metabolomics, proteomics, and genomics are platform technologies that increase agricultural RD&E productivity by orders of magnitude relative to conventional agronomic methods (Herdt, 2006; OECD, 2006). However, the complexity of the bioinformatic challenge within particular physical environments, terminological, and human capacity constraints is daunting in terms of development, cross-communication, and analysis (Herdt, 2006).

In terms of the biotechnology sector, regardless of advancements, priorities, and development paths, the ability of private firms to recover expenditures from the entire production chain from research to marketing will strongly influence the bioeconomy and areas where it is concentrated (OECD, 2006; Arundel and Sawaya, 2009). Sectoral specific subsidy policies that enable customers to purchase new innovations may be considered appropriate in some contexts, rather than conventional production-based supportive instruments (OECD, 2006; Cooke, 2009). These developments also have the potential to blur boundaries of public and private benefits. Managing the decline of less competitive sectors, ensuring unhindered trade, bureaucratic streamlining, improvements in productivity and output quality, and encouragement of technology adoption will be enormous policy challenges (OECD, 2006; Arundel and Sawaya, 2009; RRDC, 2011).

BIOECONOMIC BARRIERS: REGULATORY AND IP ISSUES

A number of scientific, technical, industrial, social, and governance issues will require addressing, including regulatory reform (OECD, 2006). Regulatory systems can impose very significant constraints on the innovation system (Tait et al., 2007). In the primary industry sector

before 1980, there were relatively few regulations related to the production of even crop seeds, while there is now a proliferation of national and international regulation focussing on primarily food safety, biosecurity, intellectual property (IP), and international trade (Herdt, 2006). In this complex space there is a critical need to develop forward-looking primary industry regulatory frameworks that balance profit, competition, and innovation, based on empirical scientific evidence and experience (Hilgartner, 2007; Jordan et al., 2007; Fedoroff et al., 2010). Particular market structures are often the focus of regulation, and concerns surround the usual suspects of business oligopolies. However, perceived oligopolies should be assessed on their impact on market function, and many fears are somewhat unfounded in most agricultural sectors areas. One example is the food security risk from the agricultural seed supply concentration. Farmers often have several close substitutes available from a variety of formal and informal markets which creates both supply security and consumer benefits (Lence et al., 2005; Herdt, 2006; PMSEIC, 2010a; RRDC, 2011). Additionally, many consumer benefits from seed supply investment have been due to research consortia facilitating upstream research and also to the complex post-commercialisation value chain. Interestingly, such consortium members are often in direct competition with each other in downstream markets (Arundel and Sawaya, 2009). In general, claims about whether or not new biological regulatory structures, markets, or technologies assist food security and promote economic development is essentially an ethical inquiry about the desirability of an activity (Herdt, 2006). Thus, policy development is required to find a balance between primary industry, sustainable development, water and energy security, climate change, and environmental quality necessary to sustain entire value chains and geographical production systems (UNFCCC, 2008; RRDC, 2011). The development process of a successful rural bioeconomic strategy must be inclusive, consultative, and transparent to regulators, research providers, governments, and the general public to achieve productivity objectives of the RD&E investment within a relatively stable policy environment (ACIL Tasman, 2008).

IP and rights will critically influence the role and form a bioeconomy takes (Herder and Gold, 2008). The relatively recent explosion of IP rights and related commercialisation activities undoubtedly add upstream cost and time pressures, leading to higher consumer prices. Transferring patentable information into the public sphere from publically funded research may be a suitable means to decrease upstream costs, although it must be ensured that RD&E was not impeded in the process (Herder and Gold, 2008). In addition, small and poor countries often struggle to participate in international IP negotiations with larger nations and powerful businesses, and are also exposed to variable external advice and pressure (Smith, 2005; Herdt, 2006). In the main, international IP rights enforcement has aimed to capture returns from both public and private RD&E to further increase institutional capability and national competitiveness (Birch, 2006). However, the knowledge of the role that IP rights play in impeding, driving, or disseminating overall trans-national innovation is largely incomplete and requires the development of acceptable metrics to measure system performance, rather than simply counting patents or licensing revenues, etc. (Lence et al., 2005; OECD, 2006; Herder and Gold, 2008; RRDC, 2011). The efficacy of various biotechnology IP rights employed to foster innovation in the myriad of subsectors in each of the health, primary production, and industry sectors is extremely complex to analyse (Herder and Gold, 2008). Treating IP rights merely as a mechanism to increase commercialisation without regard to the particular innovation space within a sector and the final market, creates an incomplete and over simplified picture (Lence et al., 2005; Birch, 2006; Herder and Gold, 2008). Even the assumption that IP rights do provide an incentive for biotechnology sectors to produce benefits is often ambiguous, as many existing incentives clearly fail to develop products or optimise their use in less affluent regions (Birch, 2006; Herder and Gold, 2008). Indeed, strong IP protection may benefit RD&E firms at the expense of the rest of society which generates a lower total welfare benefit (Lence et al., 2005; Birch, 2006). The present lack of evidence to support wholesale IP efficacy commonly expresses itself in a tendency for many stakeholders to be publically selective in the evidence they choose to cite and define. This results in a polarisation of professional and public opinion, and the simplification of future for IP policy direction (Herder and Gold, 2008). To redress this potential stagnation, the innovation sector can

actively explore and foster combinations of IP rights to avoid genuine commercial oligopoly concerns. Options include research prizes, grants, philanthropy, open source initiatives, patent pooling, licensing that enables humanitarian use, and basic public research (OECD, 2006; Herder and Gold, 2008). Exploration and analysis of IP policies such as prizes will likely generate insights into suitable IP law innovation customised to the Australian space (Cutler and Company Pty Ltd, 2008). Open source biotechnology (akin the software model), has also attracted significant public and private funding to serve both social and technological goals in targeted initiatives (Herder and Gold, 2008), and thus Australian governments should explore international standards for open publishing (Cutler and Company Pty Ltd, 2008).

CONCLUSION

The bioeconomy concept reconsiders fundamental science and education in the complexity of biologically-dependent cross-sectoral issues, such as climate change, food security, energy and water security, improving health outcomes, long-term production security, development objectives, etc. A refocus of the bioeconomic potential into the “rural” space requires interdisciplinary thinking and collaboration to place the rural sector within a more engaging context within other sectors, such as health, minerals and energy, information and communications, climate change, etc. Ultimately, the impact of any bioeconomic framework is dependent on both governance and the competitiveness of technological innovation (Arundel and Sawaya, 2009; RRDC, 2011). A greater expansion of skill-sets from fields outside of traditional higher education and rural sectoral capability is required to refocus, optimise, and internationalise RD&E activity to provide continued benefits. In contrast to many areas of higher education, the recent increase in the number of skilled individuals in bioscience and related disciplines is good news for the global bioeconomy, primary industry productivity, bioindustry, climate change and science, and rural development in general (Arundel and Sawaya, 2009). However, smaller nations such as Australia may see this talented and highly mobile capability migrate towards larger labour markets if national innovation systems do not evolve beyond the historical paradigm of “more funds, higher wages, more graduates, and higher productivity”.

ACKNOWLEDGEMENTS

Thanks to Dr. Mikael Hirsch for your advice and great conversation; Dr. Kate Grenot for motivation to put pen to paper; and Dr. Julia Anwar McHenry for suggestions and support.

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