BEFORE COMMISSIONERS APPOINTED BY THE WAIKATO DISTRICT COUNCIL

UNDER the Resource Management Act 1991

IN THE MATTER of a further submission on the proposed Waikato District Plan by the **LIFE SCIENCES NETWORK INCORPORATED** (further submission no. 1295)

EVIDENCE OF ARTHUR GRIMES FOR THE LIFE SCIENCES NETWORK INCORPORATED

18 December 2019

QUALIFICATIONS AND EXPERIENCE

1 My full name is Arthur Grimes.

2 I hold an MSc (Distinction) and PhD in Economics from London School of Economics (University of London) and a BSocSc (Hons, 1st class) in Economics from University of Waikato.

3 I am a Professor at Victoria University of Wellington's School of Government where I hold the Chair of Wellbeing and Public Policy. I am also a Senior Fellow at Motu Economic and Public Policy Research Trust, and Principal of GT Research and Consulting. I am a member and former President (from 2015-2017) of the New Zealand Association of Economists. In 2005, I was awarded the NZIER Economics Award recognising outstanding contributions of lasting importance to New Zealand in the field of economics, and in 2014 I was awarded a Distinguished Alumni Award of the University of Waikato. I am currently one of approximately 50 members of the World Wellbeing Panel, a panel of wellbeing experts coordinated from the London School of Economics.

4 I have previously held senior policy roles including Chair of the Board and Chief Economist of the Reserve Bank of New Zealand, Board Member of the Financial Markets Authority, Member of the Urban Technical Advisory Group (to the Minister of the Environment), Member of the National Infrastructure Advisory Board, Member of the (2009) Tax Working Group, and Chair of the Postal Network Access Committee. I therefore have a strong appreciation of public policy processes and issues. My evidence is based on my own expert judgement and should not be attributed to any of the organizations to which I am currently or previously affiliated.

5 I have published over 100 academic journal articles/book chapters, and written/edited 5 books. Over the past decade, my research work has focused on the relationship between wellbeing and public policy, and on regional and urban economics in New Zealand. In this latter field I have published several papers on

what is known in economics as "real options theory" and in the environmental literature as "adaptive management".[1] This field of study deals specifically with optimal policy decisions in the face of uncertainty, such as may be faced in the consideration of policies surrounding GMOs.

6 In preparing this evidence, I draw on the insights from my studies on real options theory and adaptive management. I also draw on others' work in this field, which I have reviewed in Byett et al (2017) *op cit*.

7 I am not a subject matter expert on the science of GMOs. My evidence refers, in part, to evidence by experts in this field. I have reviewed and considered evidence prepared in hearings to the 2018 Northland Regional Council Hearings Panel in the matter of the proposed Northland Regional Plan GE/GMO Provision (particularly the evidence of John Small and of Andrew Allan). I have also considered the issues papers prepared in 2016 by the Royal Society of New Zealand in its investigation of gene editing. Other relevant materials are listed in footnotes to this evidence. My main expertise and contribution lies in providing economic insights including economics-based interpretations of results from scientific research.

8 I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

[1] Grimes, A. 2014. "Infrastructure and Regional Economic Growth", Chapter 28 in *Handbook of Regional Science* (eds. M. Fischer & P. Nijkamp), pp.331-352. Heidelberg: Springer.
Byett, A, Grimes A, Laird J, Roberts P. 2017. *Incorporating and assessing travel demand uncertainty in transport investment appraisals*. Research report 620. Wellington: New Zealand Transport Agency.
Grimes, A. 2012. *Optimal Infrastructure Adaptation to Climate Change*. Motu Note #11, Wellington: Motu Economic and Public Policy Research.
Grimes, A. 2011. *Building Bridges: Treating a New Transport Link as a Real Option*. Motu Working Paper 11-12, Wellington: Motu Economic and Public Policy Research.

SCOPE OF EVIDENCE

9 I have been asked by the Life Sciences Network (LSN) to prepare evidence in relation to the request by some submitters to include controls and prohibitions on genetically modified organisms (GMOs) in the proposed Waikato District Plan. My evidence will cover:

- Precautionary and enabling approaches to uncertainty;
- Importance of innovation and learning;
- Understanding growth in incomes;
- Incomes and wellbeing; and
- Sustainability.

EXECUTIVE SUMMARY

10 Key issues discussed in this evidence are as follows:

(i) Precautionary versus enabling regulatory approach

There are two important policy considerations to take into account when dealing with technological and related uncertainties. The first is to understand that, in some circumstances, a precautionary approach is warranted. New Zealand has a precautionary approach through the HSNO Act. The second is that, in other circumstances, an enabling approach is warranted. When risks regarding costs are low and benefits may be high, the second approach to dealing with uncertainty is likely to dominate.

(ii) Uptake of innovation takes time

Even with an enabling policy environment in place, uptake of new technologies takes time, with innovators bearing considerable risk (i.e. that the new technology may be unsuccessful). Followers (or laggards) learn from the experience of innovators, especially local innovators, and so may adopt the technology once financial risks to themselves are seen to be reduced. If a potential new technology is barred, there is no local innovator to learn from; hence adoption (even of an optimal new technology) after the lifting of a prohibition is likely to take considerable time, so reducing benefits of adoption.

(iii) Growth in incomes versus one-off premium

Growth in incomes and a one-off change to the level of income are two different phenomena. A price premium (if it exists) affects the level of income but not its growth rate. Prolonged growth in incomes (which over time dominates a level shift in income for raising living standards) requires continued adoption of technological advancements. If the adoption of technological advancements is curtailed, so too is income growth.

(iv) Wellbeing

Maintenance of people's subjective wellbeing (i.e. people's own assessment of their wellbeing) requires their incomes to keep pace with those of others that they see around them, including in comparable regions and countries. Unnecessary or unreasonable curtailment of the adoption of technological advancements therefore acts to reduce people's wellbeing as they see themselves becoming relatively poorer than people, for instance, in other parts of New Zealand or in Australia.

(v) Sustainability

In addition to personal wellbeing, policy-makers need to consider wider aspects of sustainability, especially climate change. The New Zealand Government has committed to ambitious greenhouse gas reductions. Half of New Zealand's greenhouse gas emissions are from the agricultural sector, and Government has committed to substantial reductions in biogenic methane emissions. Significant technological advancements are required to reduce or eliminate these emissions. As with other forms of innovation, this process inevitably takes time and it is undesirable to curb adoption of mitigation technologies unnecessarily through unreasonably restrictive or inefficient GMO and other policies.

(vi) Regulatory barriers inhibit innovation

Unnecessary, unreasonable or inefficient regulatory barriers discourage science organisations and scientists from researching and developing new cultivars suitable for New Zealand if they expect such regulatory barriers to be in place that inhibit or prevent adoption. Similarly, unreasonable regulatory barriers to uptake (including delays to uptake) discourage private firms from product innovation involving GMOs, despite the possibility that the innovative products may assist in dealing with greenhouse gas emissions or with other pressing environmental problems.

(vii) Onerous regulation has long-lasting effects

Even if there is no near-term intention to introduce a GMO to the Waikato District, there are opportunity and actual costs of a ban on GMOs. Local bans reduce the likelihood that new crops will be developed that suit local conditions since the incentive on researchers to develop such crops is non-existent. Furthermore, even if a suitable crop were developed, the costs of a plan change for the initial innovators in order to facilitate a GMO introduction is likely to make introduction uneconomic. Similarly, the costs of overturning the status quo when it comes time to replace the existing plan would significantly deter innovators from leading the way in this respect. Each of these costs would reduce innovation, incomes and the wellbeing of future residents in Waikato District with little or no corresponding benefit given that the risks pertaining to any new GMO will already have been evaluated by the EPA in light of the precautionary approach of the HSNO Act.

I PRECAUTIONARY AND ENABLING APPROACHES TO UNCERTAINTY

11 Economic science includes a branch that deals specifically with the optimal treatment of investments and public policies when decision-makers are faced with issues that have three characteristics: (i) uncertainty, (ii) choice of the time period when an investment can be made, and (iii) the ability to learn through time about the factors causing the uncertainty. This branch of economics is known as "real options theory".[2] In the environmental management field the corresponding approach is known as "adaptive management".[3]

12 One result that stems from this approach and that has been discussed with reference to policies concerning the introduction of GMOs, is that a precautionary approach may be warranted until such time as uncertainty about GMOs is significantly (or totally) reduced.[4] Once uncertainty is reduced (or eliminated), a decision can be made based on the (almost) certain benefits and costs of introduction. This precautionary ('waiting') result would be particularly germane where there is the potential for very large costs as a result of a GMO introduction. As I note below in paragraph 18, the HSNO Act is precautionary. The potential for large costs arising from a GMO introduction will therefore already have been considered, in a precautionary manner, by the EPA. Henceforth, I treat any potential GMO introduction within the Waikato District as being in the context that the organism has already been approved, through a precautionary process, by the EPA.

[2] Two key reference works in this field on which I have drawn are:
Dixit, A., Pindyck R. 1994. *Investment under uncertainty*. Princeton, New Jersey: Princeton University Press; and Guthrie, G. 2009. *Real options in theory and practice*. New York: Oxford University Press.

[3] For further discussion of the congruence of these two approaches, see: Byett A, Grimes A, Laird J, Roberts P. 2017. *Incorporating and assessing travel demand uncertainty in transport investment appraisals*. Research report 620. Wellington: New Zealand Transport Agency.

[4] For instance, this argument was presented before the 2018 Northland Regional Council Hearings Panel in the matter of the proposed Northland Regional Plan GE/GMO Provision in the evidence of John Small.

13 An equally important general result to the precautionary approach is that an enabling approach may be warranted where there is uncertainty about benefits, and especially where potential benefits could be large. In work published in *The Handbook of Regional Science*[5] I demonstrate this result in relation to a new infrastructure investment (e.g. a bridge such as the Auckland Harbour Bridge) which has uncertain, and potentially large, future benefits. The rationale in the Harbour Bridge case was that the bridge enables, but does not obligate, subsequent investment by a myriad of private firms and households who will invest only if they judge the net benefits of investment to be positive after the bridge has been built. Without the bridge, these prospective investments could not profitably take place.

14 The corresponding case for GMOs in the Waikato is to consider a ban (similar to the "no bridge" case) versus a permissive regime (similar to the "bridge" case). With the ban, no planting of GMO crops for example is possible whether or not the net benefits (i.e. benefits less costs) of planting are subsequently deemed to be positive by private sector participants. By contrast, with a permissive regime, planting will take place if and only if it is privately beneficial for the farmer to do so. If this net benefit is not positive at a particular time, a farmer will not plant at that time, so in that case the immediate outcome would be the same as with the ban.

15 There is an important qualification made in the paragraph above. The qualification is that the farmer makes a judgement based on *private* net benefit rather than on the broader *social* net benefit. Thus a farmer typically will not take account of costs that accrue to others as a result of their planting ('external costs') and nor will they take account of benefits that accrue to others as a result of their planting ('external benefits'). Both external benefits and costs may arise in this situation.

[5] Grimes, A. 2014. "Infrastructure and Regional Economic Growth", Chapter 28 in *Handbook of Regional Science* (eds. M. Fischer & P. Nijkamp), pp.331-352. Heidelberg: Springer. This chapter is being republished with minor modification in the 2nd edition of the *Handbook*, due in 2020.

16 An external cost may arise if a farmer's GMO crop reduces the returns to other farmers in the district. This may be, for instance, if there is a reduced price premium for non-GMO crops grown nearby where a GMO crop is planted. This could cause a step-shift downwards in other farmers' incomes. The relative importance of a step-shift in income versus changes to the growth rate of income is discussed further in section III below.

17 An external benefit may arise if a farmer's GMO crop proves to be successful (e.g. increased yield, reduced need for insecticide, reduced carbon emissions, reduced pest pressure for neighbouring non-GM farmers, etc) and where other farmers learn from this experience. The remaining farmers may then decide to plant their own GMO crops in order to reap similar benefits. This 'learning by doing' or 'learning by copying' external benefit is discussed further in section II below.

18 The optimal balance between favouring a precautionary approach versus an enabling approach to new technologies is influenced by the nature of risks and the size of the potential costs and benefits that may arise – which are uncertain. Here it is appropriate to draw on the scientific consensus regarding the potential costs that may arise from adoption of GMO crops, and the commercial experience of the net benefits from planting GMO crops. My (non-expert) reading of the scientific evidence is that there is a similar level of consensus regarding the risks of GMO technologies as there is on the impacts of climate change. The scientific consensus is overwhelming that climate change is occurring and that both mitigation and adaptation are required, while the scientific consensus is that the use of genetic modification per se (particularly using CRISPR technology) is highly unlikely to cause major harms, especially where those technologies are closely regulated and subject to assessment by an expert independent body – as is the case with the Environmental Protection Agency and the HSNO Act.[6] As discussed further below, the revealed behaviour in other countries demonstrates that the financial benefits of GMO plantings are deemed to be considerable by farmers. In light of these

[6] For instance, see the evidence of Andrew Allan on behalf of Federated Farmers of New Zealand Inc, before the 2018 Northland Regional Council Hearings Panel in the matter of the proposed Northland Regional Plan GE/GMO Provision. In addition, see the series of issues papers prepared by the Royal Society of New Zealand: https://www.royalsociety.org.nz/major-issues-and-projects/gene-editing-in-aotearoa/.

conclusions, an enabling approach is likely to prove preferable to a precautionary approach in dealing with GMO plantings. This is particularly the case at the district level since considerations with regard to relevant risks (which I am advised can have regard to both national and local considerations) will already have been taken into account through the review process of the EPA. Given that the district plan would only address residual risks that remain after an approval has been granted by the EPA, I consider a permissive regime at the district level to be appropriate.

II IMPORTANCE OF INNOVATION AND LEARNING

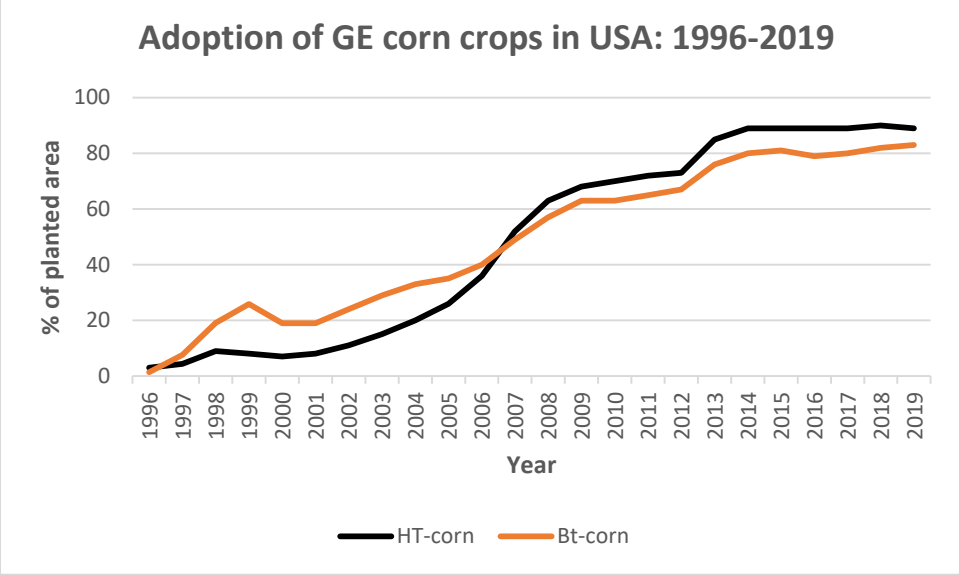
19 Bans on new technologies such as GMOs are sometimes justified on the grounds that if a ban is lifted in future (as a result of uncertainties being resolved) adoption of the new technology can then occur quickly.[7] This assertion overlooks the manner in which new technologies are typically adopted.

20 Innovations normally take considerable time to diffuse across most or all producers in an industry and/or a place for a number of reasons. First, considerable time often elapses between a presenting problem (or opportunity) and the invention of a new technological solution. Second, regulatory and licensing approvals take time. Third, it is common to find just one or a small group of innovative adopters who initially adopt a new technology. Fourth, other producers mostly lag behind the initial adopters in order to gauge whether the new approach results in net (private) benefits. Once others observe benefits occurring, the number of people or firms adopting the new superior technology rises. Typically, the pattern is one of adoption initially at an increasing rate and then subsequently at a slower rate as saturation of the new technology is reached. The result is the familiar sigmoid curve of technology adoption.[8]

[7] This argument was used for instance in the evidence of John Small before the 2018 Northland Regional Council Hearings Panel in the matter of the proposed Northland Regional Plan GE/GMO Provision.
[8] See: Rogers E. 2003. *Diffusion of Innovations (5th ed.)*. Simon and Schuster.

21 An example of this pattern occurred in the adoption of genetically engineered corn in the United States as shown in Chart 1 below. Herbicide-tolerant corn (HT-corn) comprised 3.0% of plantings in 1996 which rose to just 15% of plantings by 2003, seven years later. Over the following seven years, plantings rose from 15% to 70% of all corn planted in the United States. This was then followed by a much slower rate of adoption over succeeding years as saturation (at around 90% of planted area) was approached. Adoption of insect-resistant corn (Bt-corn) followed a more linear path but it also exhibited gradual adoption. In 1996, adoption of Bt-corn stood at just 1.4% of total planted area, and it took eleven years to surpass the half-way mark relative to the eventual adoption rate of 83%.

Chart 1: Adoption of GE corn crops in USA: 1996-2019



Note: HT indicates herbicide-tolerant varieties; Bt indicates insect-resistant varieties.
Source: United States Department of Agriculture, Economic Research Service: https://www.ers.usda.gov/webdocs/charts/58020/biotechcrops_d.html?v=8695.1

22 From both the general literature on technology adoption and the specific GM corn example above, it is apparent that the effect of a ban on GMOs is not just to limit near-term adoption but also to reduce adoption longer term even once a ban is lifted. Thus the lost opportunity for farmers can be very lengthy even once a ban is no longer in place.

23 One of the reasons that the diffusion of new technology is typically lengthy is that non-adopters can act as "free-riders", observing the degree of success experienced by the initial adopter(s), especially adopters from their local area. In previous work with colleagues,[9] I found that New Zealand exporters learn from other exporters in their local area about which products and which markets are suitable to expand into. This point is important for setting policy at the local level. Local producers learn more from observing the outcomes from decisions of their local peers than from actions elsewhere. Thus 'learning by doing' or 'learning by copying' benefits are primarily local with the corollary that curtailment of innovative solutions locally also acts to curtail beneficial subsequent adoption of new technologies locally.

24 The initial adopter bears the greatest commercial risk and this commercial risk is not spread across future potential adopters. Given this concentration of risk for an early adopter, public policy often aims to share the risk experienced by innovators, for instance through R&D grants that (optimally) subsidise the risk-taking innovator. An example of such a scheme in New Zealand is the government's 'Smart Ideas' grants for innovative ideas that impact on a range of economic, environmental and social objectives.

25 A corollary of this concentration of risk on the initial adopter is that policies should not unnecessarily act to increase the risk borne by the initial adopter. Adding extra burdens on the initial risk-taker – such as the need to seek consents to plant a new crop or the imposition of bonds for potential clean-up costs – act as an increased disincentive for technology adoption. Such policies contradict the government's support for the adoption of productivity-enhancing (and hence income-raising) technologies within agriculture and other sectors.

[9] Fabling R, Grimes A, Sanderson L. 2012. "Whatever Next? Export Market Choices of New Zealand Firms", *Papers in Regional Science*, 91(1), 137-160.

26 It is important to note that not all new technologies have lengthy adoption periods. Where the benefits of a new crop are large and highly certain then fast adoption may occur. An example in the United States is the adoption of herbicide-tolerant (HT) cotton which rose from 2% of planted acres in 1996 to 56% in 2001 (although it still took a further thirteen years to reach 90% coverage). The relatively quick adoption of HT-cotton indicates that a large majority of farmers considered there were profitability benefits arising from introducing the new crop. Similarly, the almost complete adoption of GM-corn in the United States indicates that, notwithstanding any loss of price premium for non-GM corn, farmers achieve greater profitability with the GM varieties. Internationally, across the five countries with the largest plantings of GMO crops, the net annual benefits in 2016 have been estimated as follows: USA (US$7.3 billion), Brazil (US$3.8 billion), India (US$1.5 billion), Argentina (US$2.1 billion), Canada (US$0.82 billion).[10]

27 In New Zealand, an example of 'quick adoption' relates to the introduction of new varieties of kūmara. According to Te Ara (The Encyclopedia of New Zealand):

> *In the 19th century, traditional kūmara grown by Māori were quickly superseded by larger and higher-yielding sweet potatoes from North America, brought by sealers and whalers. New Zealand's commercial kūmara crop is based on three more recent cultivars, the Owairaka Red, Toka Toka Gold and Beauregard, all of which produce tubers about 20 centimetres in length.*[11]

28 This description of the replacement of the indigenous kūmara with sweet potatoes from the Americas indicates quick (and full) adoption, although we cannot ascertain whether the adoption occurred fully over years or decades. Either way, it indicates that Māori have historically been at the forefront of seeking to plant improved crops for commercial gain.[12]

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[10] Source: Brookes G, Barfoot P. 2018. "Farm income and production impacts of using GM crop technology 1996–2016", *GM Crops & Food*, 9(2), 59-89.
[11] Source: https://teara.govt.nz/en/kumara/page-2
[12] Naturally, the introduced varieties of kūmara were not GM-crops, but their introduction did result in new cultivars that wholly replaced the former indigenous variety.

29 I am aware that in other prior plan processes, evidence has been given to the effect that the 'opportunity cost' of a ban on GMO releases is zero given that no releases are currently planned.[13] A second claim has also been made that if a release is sought (following EPA approval of a GM crop) then proponents can apply for a private plan change to lift the ban and provide for 'appropriate' controls at that stage (or, since a plan has limited life, a subsequent plan can reflect a more permissive approach if warranted at that time). [14] Each of these claims overlooks very significant contrary considerations with regard to costs.

30 With respect to the first claim, as discussed above (and as discussed further in paragraph 45 below), research programmes into new technologies are affected by the regulatory regimes that are in place. A proliferation of local bans on the introduction of GMOs (even if the EPA allows the introduction of a particular GMO) provides a major disincentive for the conduct of research into new crops that are suited to local conditions.

31 With respect to the second claim, the same type of "free-rider" problem exists as described in para 23. An early innovative adopter would have to bear the entire cost of a plan change. Other "laggards" could wait until after the plan had been changed before they decided whether to adopt or not. Because the costs of a plan change would be concentrated on the innovator while the benefits would be spread widely, it is likely to be uneconomic for an innovator to initiate a plan change. Thus, even if it is to the eventual benefit of most farmers in an area to have the plan change, no individual farmer (or small group of farmers) has sufficient incentive to lead the way.[15] A similar barrier exists even when the plan comes up for renewal. It is invariably more difficult to overturn the status quo in planning and other policy regimes than it is to argue for a 'clean slate' approach to an issue. Thus major costs would be involved to revoke a ban in the replacement plan if one had already been adopted in a prior plan.

[13] This claim is made, for instance, in para 89 of the evidence of John Small before the 2018 Northland Regional Council Hearings Panel in the matter of the proposed Northland Regional Plan GE/GMO Provision.
[14] This claim is made in paras 84-87 of the evidence cited in the previous footnote.
[15] This situation is an example of the common "prisoners' dilemma" issue in game theory whereby – in the absence of coordination – the exercise of private interests is contrary to the joint interests of society.

III UNDERSTANDING GROWTH IN INCOMES

32 One concern of opponents of GMO crops is that the prices (and hence incomes) received by growers of neighbouring non-GMO crops will be reduced as a result of a nearby GMO planting. In economics, such an effect – if it exists – is known as a 'negative externality' or 'negative spillover'. This negative externality will not be taken into account by a new adopter, except to the effect that that adopter also grows conventional crops or to the extent that farmers want to be, or be seen as, "good neighbours". It is an effect that legitimately needs to be considered by policy-makers.

33 The concern is most specifically related to a price premium that may be earned on non-GMO crops (e.g. because of consumer resistance to GMO crops in some market segments). If this premium exists and if it is long-lasting, then it is possible that the planting of GMO crops could reduce incomes earned by planters of non-GMO crops (i.e. if GM tolerance levels in those crops were exceeded). Offsetting this effect is the impact of increasing incomes for adopters of the new technology. This contrast in fortunes of incumbent producers versus technological adopters is experienced in almost all cases of new technology adoption so is not specific to the GMO case. For instance, blacksmiths' incomes were reduced with the adoption of motor vehicles, and printers' and journalists' incomes were reduced with the adoption of the internet. A new technology often raises productivity (and hence supply of a commodity) and this increase in supply can act to reduce the commodity's price. This fall in price benefits consumers but not incumbent producers who fail to adopt the new technology. Typically, therefore, a technological advance reduces the level of income for incumbents and raises incomes for adopters. It is the process of technological adoption that results in raised living standards over time for society as a whole through higher incomes following the move to superior technologies.

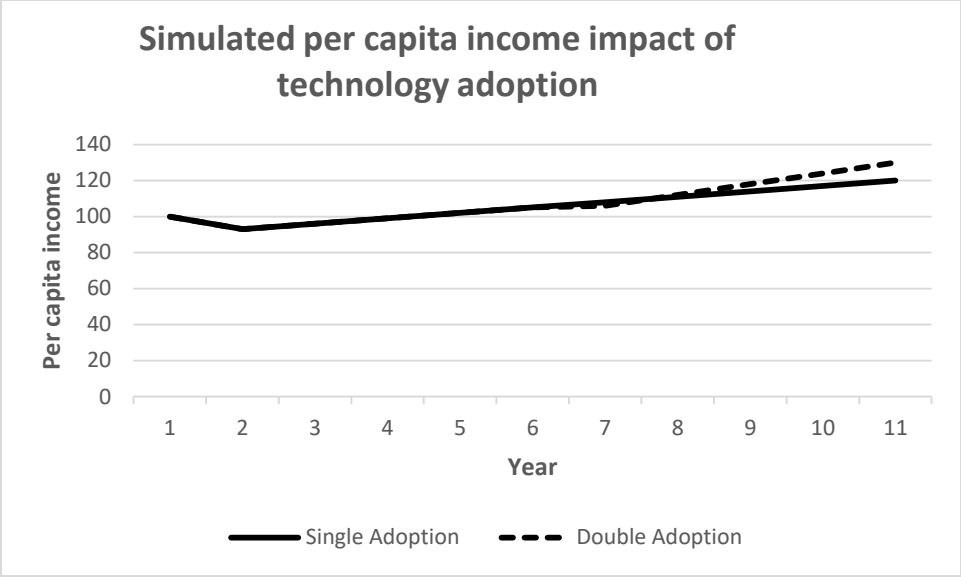
34 As an illustration of this process, I consider a hypothetical example of an agricultural sector in which all farmers use an existing technology in the initial year (labelled 'year 1'); each farmer earns an initial income indexed at 100.[16] I call users of this initial technology 'incumbents'. A new technology is then discovered that permanently raises the incomes of those who adopt it by 20% (e.g. through improved yields, lower pesticide costs, or better quality product with improved market prices as a result).[17] However its introduction is assumed to permanently reduce incumbents' incomes by 10% (e.g. through loss of a price premium or through generalized downward pressure on the commodity price as a result of increased supply). In the first year of adoption ('year 2'), 10% of farmers are assumed to adopt the new technology and the adoption rate is assumed to increase by 10 percentage points each year through to year 11 by which time all farmers are assumed to have adopted the new technology.

35 The resulting per capita (average) income across all farmers in this example is illustrated through the solid line in Chart 2 below. The new technology, which is accompanied by an assumed negative externality on incumbents, results in an initial 7 percent reduction in aggregate income, and per capita incomes are reduced for the first three years relative to the starting point. Thereafter, per capita incomes are (on average) higher than in the pre-adoption phase, rising to a full 20 percent premium by year 11. If there were no further technological advancements, this new higher level of income would henceforth be maintained.

[16] For instance, this could be $100,000 per farmer p.a.

[17] All three of these factors have been found to provide material increases in the incomes of growers of GM eggplant (brinjal) relative to growers of traditional eggplant varieties in Bangladesh in a randomized trial. Source: Ahmed A, Hoddinott J, et al. 2019. *Impacts of Bt Brinjal (Eggplant) Technology In Bangladesh*. International Food Policy Research Institute for United States Agency for International Development. https://pdf.usaid.gov/pdf_docs/PA00TZ7Z.pdf.

Chart 2: Simulated aggregate income impact of technology adoption



36 In practice, technological advancements occur repeatedly over time leading not just to level shifts in incomes (as above) but also to higher growth rates of incomes over prolonged periods. As a simple illustration, I modify the previous example to include a second technological advance in year 7 that results in incomes of 150 for adopters of the second technology but a reduction in returns for adopters of the first technology from 120 to 110. The adoption rate of the second technology is assumed to rise from 10% in year 7 to 50% in year 11 (progressively replacing adopters of the first technology, so leaving the incumbent shares as per the previous example).[18]

37 The resulting per capita (average) income across all farmers in this second example is illustrated through the dashed line in Chart 2. Again we see a (relative) decline in income as the second technology kicks in as a result of the decline in incomes for those who had adopted the first new technology. However, this decline is then offset and per capita incomes increase further by year 11 than they did in the single technology adoption case.

[18] These numbers are obviously arbitrary but are useful to illustrate the effect of sequential technological advances on the path of incomes over medium to long periods.

38 The history of rising per capita incomes since the start of the industrial revolution is consistent with the illustrative examples above. Technological changes often reduce the level of incumbents' incomes while raising average per capita incomes over time. The lesson from the historical experience and of the illustrations above is that policy should not pay undue attention to (actual or potential) income losses incurred by incumbents as a result of new technologies. If protection of incumbents' situations is given priority, then adoption of new technologies will be curtailed and hence so too will living standards across society. Technological change is required to increase society's long term living standards; the process does not benefit all people all of the time but it does raise living standards for all (or almost all) people over long periods of time.

IV INCOMES AND WELLBEING

39 The analysis above has emphasized the importance of technological adoption for raising per capita incomes. It is reasonable to question whether such income increases also raise the general wellbeing of society. This question is a key focus of the "wellbeing economics" literature, an area in which I have specialized in recent years. I briefly summarise the evidence on this issue below.

40 The dominant analytical approach to the consideration of overall wellbeing within society is based on two foundations: First, people are asked to rate their satisfaction with their own life as a whole (i.e. their 'wellbeing'). Second, statistical work estimates the key factors which determine how highly a person rates their life. An overwhelming result that flows from these studies is that, within countries at any point of time, people with higher incomes tend to enjoy higher wellbeing than do people with lower incomes. Countries that have higher per capita incomes also tend to have higher reported wellbeing than do countries with lower incomes.[19]

[19] For instance, see: Dolan P, Peasgood T, White M. 2008. Do we really know what makes us happy? A review of the economic literature on the factors associated with subjective well-being. *Journal of Economic Psychology, 29*(1), 94-122.

41 Early work in the field questioned whether rising incomes over time also raised average levels of wellbeing.[20] More recent analyses show that the expected positive relationship between rising incomes and rising wellbeing does hold both within and across countries.[21] Of relevance to New Zealand, my recent work with a colleague shows that wellbeing of citizens within a country depends not only on the level of their own income but also on how their income compares with incomes in other comparable countries.[22] For instance, people in Waikato District look at the incomes of other New Zealanders when judging their own wellbeing, while New Zealanders require their own incomes to be rising at a comparable rate to incomes in Australia in order to feel that they are not becoming poorer (at least in relative terms). A slower rise in local incomes (whether at the level of Waikato District or of New Zealand) relative to those elsewhere (e.g. in Australia) would reduce local residents' sense of wellbeing. We see the effects of the widening of such disparities through the migration of people from rural regions in New Zealand to the cities and through the periodic migration outflow of New Zealanders to Australia when Australian incomes are rising much faster than those in New Zealand.

42 The relevance of this observation is that incomes in New Zealand relative to those in countries such as Australia, Canada and in Europe – and increasingly also relative to countries within Asia – matter for our wellbeing. Given that income growth is reliant on the adoption of new technologies – as it has done for the past two centuries – it is important to enable adoption of new technologies (both at the local and the national level) that increase our overall incomes. As illustrated above, notwithstanding the potential for temporary income trade-offs that may arise from such adoption, the incorporation of new technologies into production processes is central to maintaining and increasing incomes and wellbeing within New Zealand.

[20]Easterlin R. 1974. "Does economic growth improve the human lot?" In M Abramovitz, P David & M Reder (Eds.), *Nations and households in economic growth: Essays in honor of Moses Abramovitz*. New York: Academic Press.
[21] Stevenson B, Wolfers J. 2008. "Economic growth and subjective well-being: Reassessing the Easterlin paradox. *Brookings Papers on Economic Activity*, 1-87.
[22] Grimes A, Reinhardt M. 2019. "Relative Income, Subjective Wellbeing and the Easterlin Paradox: Intra- and Inter-national Comparisons" in: Rojas M. (ed.) *The Economics of Happiness: How the Easterlin Paradox Transformed our Understanding of Well-Being and Progress*. Switzerland: Springer, 85-106.

V SUSTAINABILITY

43 In addition to near-term wellbeing, it is vital to consider the effects of the introduction of new technologies on sustainability.[23] The most pressing sustainability issue for public policy is climate change. New Zealand has committed to reducing greenhouse gas emissions by 30 percent from 2005 levels by 2030. The New Zealand Government has adopted a domestic target of a 24 to 47 per cent reduction below 2017 biogenic methane emissions by 2050, including a 10 per cent reduction below 2017 biogenic methane emissions by 2030.[24] The Office of the Minister for Climate Change stated that "49 per cent of New Zealand's emissions come from agriculture where there are currently few commercially viable options to reduce emissions".[25] In other words, technologies that are currently available are insufficient for New Zealand to achieve the biogenic methane targets to which we have committed except through very large reductions in agricultural production, and hence very large reductions in incomes and wellbeing, especially within agriculturally-based regions such as the Waikato District.

44 In light of this existential problem, policy needs to be as enabling as possible with regard to the introduction of new technologies that can facilitate the mitigation of carbon and/or methane into the atmosphere without reducing living standards. GMO-based technologies are one source of such new technologies. As with other new technologies, even if (for instance) a new variety of feed that reduces methane emissions is derived, adoption of the new feed will take considerable time to be diffused across farms as many farmers will wait to see how others fare with the new feed. This inevitable wait time before widespread adoption occurs makes it imperative that innovative producers are not deterred from adopting new options as they become technically feasible. It is the initial adopters, who achieve demonstrable benefits from their actions, that pave the way for subsequent adopters who can use this information as a basis for their own decisions. Policies that make it

[23] The 1987 Bruntland Commission definition of sustainability which informs this discussion is: "Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
[24] Source: Ministry for the Environment: https://www.mfe.govt.nz/climate-change/climate-change-and-government/emissions-reduction-targets/about-our-emissions.
[25] Office of the Minister for Climate Change. 2016. *Paris Agreement for climate change – ratification and domestic action*. Paper to the Cabinet Economic Growth and Infrastructure Committee.

difficult for early adoption or experimentation with new crops or other innovations that could mitigate methane emissions would be at odds with New Zealand and global commitments to reduce the extent and harm of global warming.

45 The discussion above is based on an assumption that new GMO cultivars which result in reduced greenhouse gas emissions from livestock will become available for farmers to adopt. However this is not guaranteed. In particular, science organisations and scientists will be discouraged from researching and developing new cultivars suitable for New Zealand farms if there are unnecessary regulatory barriers in place that inhibit or prevent adoption. Similarly, unnecessary regulatory barriers to uptake (including delays to uptake) will discourage private firms from product innovation involving GMOs, despite the possibility that the innovative products may assist in dealing with greenhouse gas emissions or with other pressing environmental problems (such as nutrients in rivers).

46 The EPA refers to these issues in its Briefing to Incoming Ministers in 2017. It discusses a prevailing climate of "science denial" stating: "Science denial, which often substitutes belief for data and evidence, is manifest in debates about the merits of fluoridisation, vaccination, genetic modification, 1080, and many other issues."[26] In light of regulatory barriers that reflect such attitudes, the EPA further notes (para 43): "Feedback from researchers indicates reluctance to pursue field tests in New Zealand because they believe regulatory barriers are too high."

47 Even if unnecessary regulatory barriers were removed in future years, one cannot fast-forward research or adoption to make up for the lost years taken to develop new cultivars or other technological advances that could assist environmental outcomes.

[26] EPA. 2017. *Briefing to Incoming Ministers*. Wellington; para 36.

48 Noting that there is already a strict precautionary national regime in place under the HSNO Act, additional regulatory barriers to the adoption of GMOs will therefore likely: (i) increase the time taken to develop emissions-reducing cultivars, (ii) reduce the ability of innovative farmers to be early adopters, and (iii) increase the time taken for 'laggard' farmers to copy the adoption practices of the innovators. These considerations will make achievement of the Government's biogenic methane targets extraordinarily difficult to achieve without major reductions in agricultural output and local incomes and wellbeing.[27]

VI SUMMARY OF KEY ISSUES

(i) When dealing with technological and related uncertainties, each of a precautionary approach and an enabling approach may be warranted depending on the nature of any remaining uncertainties that the District Council has to deal with after an EPA consideration and decision.[28] If there is considerable residual uncertainty about costs, and especially if those costs could be large and the risk is credible, then a precautionary approach is likely to be warranted. If there is considerable uncertainty about benefits, and especially if those benefits could be large, then an enabling approach is likely to be warranted. Given the scientific consensus on the low level of risk surrounding the introduction of GMO crops (especially those engineered using CRISPR) and the requirements of the HSNO Act, an enabling approach at District Council level is appropriate to the use of GMO crops.

[27] One possible counter-argument is that a decision to include a ban on GMOs within the WDC does not preclude research activities that enable the introduction of GMOs elsewhere. However, if all local authorities were to take the same narrowly focused view (especially in light of neighbouring council's prior decisions, which have a negative externality effect on innovation) then the effect becomes a national ban with the same consequences as for a national prohibition. Furthermore, this effective national ban would operate notwithstanding a positive decision by the EPA over introduction of a GM crop.

[28] Naturally, if there is little or no uncertainty then decisions should be made on the basis of the (almost) certain costs and benefits. The analysis here refers to how residual uncertainties (i.e. after EPA decisions have been made) should be dealt with.

(ii) Growth in incomes arise mostly from the continuous adoption of technological advancements. Adoption of a new technology does not occur overnight, and usually takes considerable time for development and widespread diffusion to occur, with the subsequent widespread growth in incomes. Income growth, in turn, raises people's wellbeing, especially in a context in which people see incomes rising in comparable regions and countries. Hence curtailment of the adoption of technological advancements acts to reduce people's wellbeing.

(iii) Any assertion that a ban on releases of GMOs in the Waikato District Plan has minimal (or no) costs is in my opinion, incorrect. In my opinion, such a policy is likely to impose costs in relation to the innovative endeavours of scientists, science organisations and private firms, and also on the ability of producers to directly mitigate their impacts on climate change. Significant technological advancements are required to reduce or eliminate methane (and carbon) emissions. The process of adopting crops based on new technologies inevitably takes time and financial risk for the initial adopters. It is undesirable to curb adoption of mitigation technologies unnecessarily through unreasonably restrictive or inefficient GMO and other policies given the imperative to encourage experimentation to reduce emissions that cause climate change.

18 December 2019

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