Agriculture in the Bioeconomy

Economics and Policies

Prof. Justus H.H. Wesseler

Inaugural lecture upon taking up the post of Professor of Agricultural Economics and Rural Policy at Wageningen University on 22 January 2015

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1 Introduction

Dear Rector Magnificus, colleagues, family, and friends,
the bioeconomy is high on the policy agenda. The Dutch government has identified the bioeconomy as one among the "Top Sektoren". Germany has introduced the Bioeconomy Council in 2009. The United States (US) government has published a National Bioeconomy Blueprint in 2012.

The European Union (EU) plans to spend more than 5 billion Euro for research on the bioeconomy and expects that *"each euro to be invested under the proposed Horizon 2020 programme for research and innovation could generate ten euros of added value in the different bioeconomy sectors by 2025."* (European Commission 2012, p. 4).

But what actually is the bioeconomy ? What does it have to offer? Why do we discuss this now and not twenty years ago? When we think about agriculture, did we not always have a bioeconomy? And is it not just a buzzword that may soon be forgotten? Or should we focus on the bioeconomy in our research on agricultural economics and policies? And what are the questions that need to be addressed?

These are issues I want to discuss in my speech today before I conclude with some personal remarks.

When we look at definitions for the bioeconomy than we can observe similarities and differences. Some explicitly consider public sector research and development activities, others consider only the renewable energy sector.
The definition I prefer is the one used by the European Commission as it includes the primary sectors as well as the up- and downstream sectors: "…the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy." This includes agriculture, forestry, fisheries, food, pulp and

paper production, as well as parts of chemical, biotechnological and energy industries. (European Commission 2012, p.9).

The European Commission mentions (2012, p. 17): "Based on available data from a wide range of sources it is estimated that the European bioeconomy has an annual turnover of about € 2 trillion and employs more than 22 million people and approximately 9% of the total EU workforce."

In addition to the sectors mentioned, we also need to consider research and development conducted in both the public and the private sector and I will come back later to why this is important.

2 Beyond the Agricultural Sector

In my opinion there are five major reasons why we should take the bioeconomy seriously. These reasons are:

- Advances in biological sciences
- An increase in horizontal and vertical integration in agricultural supply chains
- An increase in inter- and intra-industry trade
- Advances in information and communication technologies
- An increase in globalization

2.1 Advances in biological sciences

The development of recombinant DNA technology in the early 1970s was the start of modern biotechnology (Tramper and Zhu 2011). The Bayh-Dole act of 1980 in the United States (US), which provided universities and other forms of organisations with the right to exploit patents that had been obtained with public funding, has been seen as key for innovations in modern biotechnology (Stevens 2004). Some of the first successful products using rDNA technology were a vaccine for swine diarrhoea in 1982 by the Dutch company Intervet and the production of human insulin for diabetics from genetically engineered bacteria by the US company Eli Lilly. Since 1984, the Dutch Company Gist-Borcades (now DSM) started to insert the bovine chymosin gene in yeast cells, which allows for cultivating the yeast in large fermenters to be used for cheese production. In the late 1980s, the technology was adopted by cheese producers in Switzerland, followed respectively by producers in The Netherlands, Germany, and France, in 1992, 1997, and 1998. Parallel, applications for enzymes produced from GE bacteria for bakery products have been introduced (Tramper and Zhu 2011).

Today a wide array of applications is available including applications in the food and feed sector, biofuels, biomaterials, chemicals, biorefineries and more. These advances in the natural sciences allow us to address a number of societal challenges.

2.2 Increase in horizontal and vertical integration

In addition to this drastic technological change, supply chains became increasingly vertically and horizontally integrated (Wesseler 2014a). Looking at the agricultural sector only and not considering the increase in up- and downstream linkages through different forms of contractual arrangements may create biases in policy analysis. Contractual arrangements cause hysteresis resulting in delayed responses to changes in external factors such as in market prices. If farmers have signed up for an environmental service scheme, they may not easily change their mode of production. Horizontal integration through mergers and acquisitions in up- and downstream sectors or voluntary collaboration at farm level can change the market power of agents with economic and distributional effects along the value chain.

2.3 Increase in inter- and intra-industry trade

A further important aspect is the increase in inter- and intra-industry trade. The volume of world merchandise exports has more than tripled since 1990 (WTO 2014). The share of intra-industry trade more than doubled since the early 1960s (OECD 2010). Since 1960 agricultural production has tripled while the agricultural trade volume has increased by a factor of six worldwide (FAO 2013). This increase in trade with all the implications this may have for countries, producers and consumers has increased inter- linkages between international trade and agricultural production. A drought in Brazil, resulting in a decrease in soybean yields, has an effect on European animal farming as happened in 2007/08 (Backus et al 2009).

2.4 Advances in information and communication technologies

A further important development has been the increase in information and communication technologies. Internet and phone connections are now available almost everywhere and news about major events spread rapidly around the world. The speed at which information (news) is communicated (formally and informally) and its reach is positively affected by advances in the information and communication technology (ICT) sector: especially through mobile telephony and television networks, and the internet (including its social media platforms).

As ICTs improve, become more affordable, and their use spreads across the world – especially in developing countries – their impact on the bioeconomy and therefore society will gain in importance.

2.5 Increase in Globalization

A fifth important aspect which is closely related to the previous three is the increase in globalization. According to the Levin Institute (2015) this is understood “as a process of interaction and integration among the people, companies, and governments of different nations, a process driven by international trade and investment and aided by information technology. This process has effects on the environment, on culture, on political systems, on economic development and prosperity, and on human physical well-being in societies around the world." Globalization goes beyond increase in international trade and vertical and horizontal integration. We now find food chains such as McDonald's or Burger King and food processors such as Nestle or Unilever in almost every country and food retailers such as Walmart or the Schwarz Group are following closely behind. (Wesseler 2014a)

These five issues have important potential implications for players within the bioeconomy, especially concerning activities impacting consumer affairs and the environment.

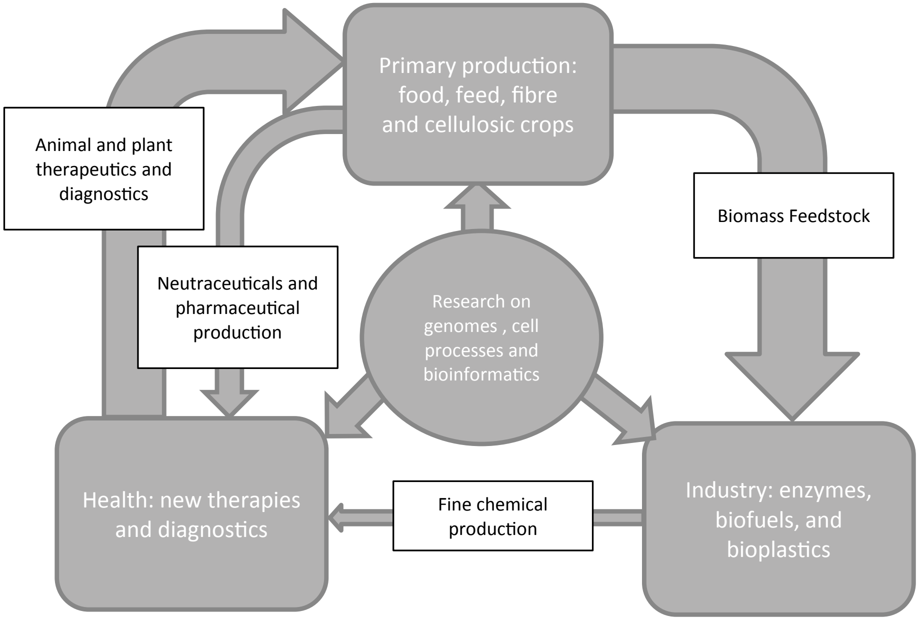
The rapid spread of imperfect information facilitated by ICTs and the immediate responses by players within vertically integrated, cross-border value-chains may be disproportionate and have undesirable outcomes for society. An example is the May 2011 outbreak of a foodborne illness in Germany caused by a Shiga-toxin producing strain of Escherichia coli (STEC) found in contaminated fenugreek seed, which was imported from Egypt in 2009 and 2010 (European Food Safety Authority 2011). Statements made by German officials falsely implicating imported cucumbers from Spain as the bacteria's source caused financial losses mainly to Spanish farmers and participants within the vegetable value chain, causing Russia to impose temporary import bans on all vegetables from the European Union (Chelsom-Pill 2011), strained diplomatic relations, and tainted the image of the industry.

The EHEC example illustrates the increase in horizontal and vertical interlinkages between the different sectors of the bioeconomy over space and time and how this requires us to look beyond the agricultural sector if we want to assess economics and policies. The implications for the whole value chain need to be considered, as the results of our economic and policy assessment might otherwise be biased.

But what kind of economic and policy assessments are of relevance? Every researcher may have her or his own ideas, but there are also issues of general interest formulated by different stakeholders representing civil society. The Dutch Government, The European Union, the OECD, to name only a few, expect a substantial contribution of the bioeconomy to address global as well as regional challenges.

To quote the European Commission: "With the world population set to approach an estimated 9 billion by 2050, against a background of finite natural resources, Europe needs renewable biological resources -not just for securing healthy food and animal feedstuffs but also for materials and other bio-based products such as bio-fuels. A strong bioeconomy will help Europe to live within its limits. The sustainable production and exploitation of biological resources will allow the production of more from less, including from waste, while limiting negative impacts on the environment and reducing the heavy dependency on fossil resources, mitigating climate change and moving Europe towards a post-petroleum society." (European Commission 2012, p. 4).

Accordingly, the sustainable production and exploitation of biological resources includes contributions to food security, the sustainable management of natural resources, reducing dependence on non-renewable resources, mitigating and adapting to climate change, and creating jobs and maintaining competitiveness.



Source: Adopted from European Commission (2012).

Figure 1. Current and expected integration across biotechnology applications

3 Economic Implications

In summary, developing the bioeconomy promises great opportunities for improving our well-being or equivalently sustainable development.

This requires some knowledge about sustainable development for examining whether or not the bioeconomy lives-up to its promises and leads to the question how we should define and measure sustainable development from an economic perspective.

Although there have been many attempts to measure sustainability, none has established itself so far. Examples include the Ecological Footprint (EF) (Wackernagel and Rees 1996), the UN's Human Development Index (HDI) (Sagar and Najam 1998), and Bhutan's Gross National Happiness Index (Mukherji and Sengupta 2004).[1]

Much discussed are the World Bank's measure of genuine savings and the Arrow, Dasgupta, and Mäler approach on inclusive wealth and genuine investment (Arrow et al. 2012). Both concepts serve as measures of sustainable economic development over time. To compute the genuine savings rate, resource depletion and environmental degradation are subtracted from traditional net savings, while investment in human capital is added (Hamilton 2000).

The concept of inclusive wealth and genuine investment is similar: a society's inclusive wealth is determined by measuring the shadow value of the economy's stock of capital assets (including manufactured capital assets, natural capital assets and human capital). Genuine investment is then defined as a measure of changes in the economy's set of capital assets weighted at shadow prices. Accordingly, positive genuine investment is used as an indicator of sustainable development. In contrast to other approaches, this has a forward-looking perspective.

Still, the approach does not explicitly consider the existence of opportunities, as the focus is on specific investments. Further, future opportunities are inherently uncertain and this uncertainty needs to be explicitly considered, in particular when opportunities involve sunk costs or other kinds of irreversible costs and/or benefits. I will get back to the importance of opportunities, uncertainties, and irreversibilities and their relevance for sustainable development in more detail.

1 The Dutch Wetenschappelijke Raad voor het Regeringsbeleid (Netherlands Scientific Council for Government Policy) published a report on the sustainability of the Dutch economy in 1987 using a dynamic multi-sector model including emissions and possibilities for emission control.

First I would like to address issues related to possible negative impacts of new technologies.

3.1 Negative Impacts of New Technologies

The possibility of producing and consuming new products may have negative impacts on human health and/or the environment. Exclusion of these negative impacts from users' net-benefit assessment may warrant a restriction or ban to reduce or eliminate their negative impacts. However, if the impacts are included in the assessment and there are positive net gains, additional constraints may be unjustified from a cost-benefit perspective. Hence, it is unclear ex ante if introducing a new technology warrants additional use restrictions or even a ban, merely because of a negative health and/or environmental impact. Those have to be compared with the benefits of the new technology. Further, the impact of a new technology on human health and/or the environment may be smaller than the impacts of the technology it replaces.[2]

Following Wesseler and Smart (2014), Figure 2 presents the standard framework for assessing health and environmental benefits and costs of a new technology. The x-axis depicts the quantity, Q, produced for either a single crop or a portfolio of crops, and refers to a specific plot, farm, or region. The y-axis represents the marginal benefit (MB) and marginal cost (MC) of producing quantity Q. An increase in the production of Q decreases the marginal private benefit (MPB) and increases the marginal private cost (MPC). For the private producer or sector, the optimal quantity produced, Q, is at c, where MPB = MPC. If no additional benefits or costs need to be considered, c reflects the optimal level of production for society.

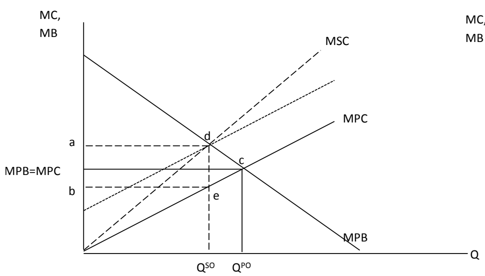


Figure 2. Internalised external effects of agriculture production

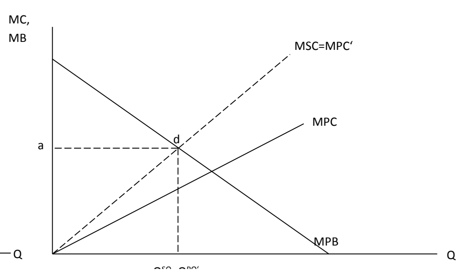


Figure 3. Internalised external effects of agriculture production where MSC = MPC'

2 This is the link to measuring the changes in capital assets at shadow prices in the Arrow et al. (2012) approach.

Now, let us assume that the production of Q bears additional costs not considered under private costs. If these costs are added to the marginal private cost, we get the marginal social cost (MSC) and the societal optimal level of production decreases from QPO to QSO. One way of reducing Q is by taxing production. The optimal tax rate, the Pigouvian Tax, should increase private cost so that MPC intersects with MPB at d. The external effects of production are then internalised and the producer pays for the extra environmental damages, equivalent to a - b.

Figure 2's important message is that although producing Q causes external environmental damage, reducing its production to zero is suboptimal. Merely observing that producing an agricultural crop causes negative environmental impacts when regulatory policies are in place does not necessarily justify additional intervention from a cost-benefit perspective.

Regulation of environmental externalities following the Pigouvian argument has been criticised, most prominently by Ronald Coase (1960). Coase argued that observing externalities does not necessarily justify government intervention, for example via a Pigouvian tax as often argued. Stakeholders themselves should have an incentive to reduce environmental pollution. An investigation is necessary to determine if government intervention can improve the current situation of observed environmental pollution, and all institutional arrangements available to address the problem should be considered. As a reference, Coase suggests comparing the outcome of alternative institutional arrangements with the existing situation (Coase 2006). An intervention by governments is warranted if a different institutional arrangement improves the outcome and requires so. The results of this reasoning are presented in Figure 3, where the MPC has been adjusted by internalising the external effects of production so that the MPC is equivalent to the MSC, indicated by MPC'=MSC.

Coase's view was challenged by libertarians; for them, the question of government intervention depends on property rights. They argued that the courts should settle the problem of externalities. To quote Rothbard: *"We have concluded that everyone should be able to do what he likes, except if he commits an overt act of aggression against the person and property of another. Only this act should be illegal, and it should be prosecutable only in the courts under tort law, with the victim or his heirs and assigns pressing the case against the legal aggressor."* (Rothbard 1982, p. 97). While ex-post liability can address a number of environmental externalities, this does not per se exclude the use of ex-ante regulations even under the libertarian view, e.g. if 'everyone' freely decides to work together in a group to implement regulations imposed on members of the group. Farmers may voluntarily form a group and decide their own production standards. Further, implementing ex-post liability has its own problems due to liability avoidance, differences in wealth, and more (Shleifer 2010).

However, the libertarian view does not necessarily contradict the situation shown in Figure 2. The expected ex-post liability cost increases MPC. Further, ex-post liability costs provide incentives for implementing ex-ante measures to reduce ex-post liability, hence increasing the MPC compared to a situation where this possibility is absent, as discussed, for example, by Beckmann et al. (2010) for the case of coexistence.

In conclusion, externalities create additional costs under the Pigouvian, Coasian, and libertarian views; views on measuring costs and appropriate responses differ. However, these views reach the same conclusion: the existence of externalities per se does not immediately justify government intervention and additional investigation on a case-by-case basis is needed.

3.2 The precautionary approach

The previous discussion fails to differentiate between different types of external costs. One of the concerns about environmental and health impacts is that they may be irreversible and/or catastrophic; this is one reason why the precautionary approach has been mentioned in many regulations of GMOs (see e.g. European Council for the Environment 1999) and other technologies, most prominently in the Rio Declaration on Environment and Development under Principle 15: *"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."* (United Nations 1992, Principle 15).

There are diverse interpretations of the precautionary approach. The one most widely held is that for a new technology, the prospect of harmful effects take precedence over the prospect of beneficial effects. As harmful effects are potentially catastrophic, and this potential cannot be excluded, and "the infinite costs of a possible catastrophic outcome necessarily outweigh even the slightest probability of its occurrence" (van den Belt 2003, p. 1123), the result would be a ban of new technologies.

This line of reasoning is logically inconsistent, as pointed out by the philosopher Henk van den Belt (2003). According to Pascal's Wager: "Given a known but nonzero probability of God's existence and the infinity of the reward of an eternal life, the rational option would be to conduct one's earthly life as if God exists.' (van den Belt

2003, p. 1124). The contradiction is the 'many gods' example: 'Consider the possible existence of another deity than God, say, Odin. If Odin is jealous, he will resent our worship of God, and we will have to pay an infinite price for our mistake. Never mind that Odin's existence may not seem likely or plausible to us. It is sufficient that we cannot exclude the possibility that he exists with absolute certainty. Therefore, the very same logic of Pascal's Wager would lead us to adopt the opposite conclusion not to worship God. Pascal's argument, then, cannot be valid." (van den Belt 2003, p. 1124).

In the context of new technologies, catastrophic negative effects cannot be excluded; this interpretation of the precautionary approach is unhelpful. Van den Belt recommends using as a guideline for approval: a comparison of the benefits and costs of possible errors. This corresponds with recommendations by economists who state: "… regulate until the incremental benefits from regulation are just offset by the incremental costs. In practice, however, the problem is much more difficult, in large part because of inherent problems in measuring marginal benefits and costs." (Arrow et al. 1996, p. 221).

A method of addressing potential environmental impacts in line with the precautionary approach, and in particular considering uncertainties and irreversible damages, is by performing an extended cost-benefit analysis. The economic literature suggests that if a new technology includes irreversible costs, the net benefits arising from the technology have to be larger than they otherwise would be (e.g. Pindyck 2000). The additional net benefits needed to compensate for irreversible costs are commonly calculated by using real-option models.

Wesseler et al. (2007) suggest using this modelling approach for assessing new biotechnologies. Because irreversible costs of GMOs are difficult to quantify, irreversible costs that are acceptable considering the net benefits of GM crop cultivation should be calculated◎a threshold value they call the maximal incremental socially tolerable irreversible costs (MISTICs). This threshold level is below the threshold level ignoring uncertainties and irreversible costs. In cases where irreversible benefits are larger than irreversible costs, policies supporting the specific policy can be justified (Wesseler 2009).

3.3 Valuing opportunities

Dixit and Pindyck (1994) suggest the application of real option theory not only to investment problems in new technologies but also to all kinds of decision making under temporal uncertainty and irreversibility. The methodology has been applied to assess a wide range of issues including the evaluation of firm investment in different sectors and in patents; the effect of subsidies and taxes on optimal investment decisions and on foreign direct investments; and more. Model applications not only include irreversible costs but also irreversible benefits, optimal abandonment, entry and exit, and uncertainty over several variables such as reversible and irreversible costs and benefits, discount rates, and others. Recent reviews by Mezey and Conrad (2010) and Perrings and Brock (2009) discuss these applications in more detail. Also, Smit and Trigeorgis (2004), Merton (1998), Trigeorgis (1996), and Dixit and Pindyck (1994) among others offer overviews on applications and methodologies.

The advantage of real option theory is that it allows us to measure the value of future opportunities. In the most basic setting, future opportunities can be interpreted as options, where the owner of the option has the right but not the obligation to exercise the option, similar to a call option in financial markets. An option may not be exercised unless the value of the option is greater than or equal to zero. The optimal timing of exercise is important to maximise option benefit. Maximum option benefit is important to value the option. The value of the option depends on a number of important parameters including its expected return, the related uncertainty, opportunity costs, and the costs of exercise (Dixit and Pindyck 1994).

As an illustrative example: assume a company holds the patent on a new technology, say a new seed. The patent provides opportunities for additional income if the company invests in the patented technology. These investment costs can be considered sunk costs. The value of the patent will depend on the future net benefits the technology will provide to the company. Those future net benefits are uncertain, as it is impossible to precisely predict how markets will develop. The required investments may include physical investments (green field investments) to produce the new product, or financial investments to merge and/or acquire a company that has the facilities and location to produce the new product. In addition, there may be extra costs to comply with environmental, food, and health safety standards. Real option theory tells us that although the investment opportunity yields a positive net present value (NPV), delaying the investment might be the optimal choice because losses can be avoided. Arrow and Fisher (1974) and Henry (1974) pointed this out in seminal papers in the early 1970s (Wesseler 2014b).

Leitzel and Weisman (1999) provide an interesting contribution. They argue that new government policies require sunk investments in the form of training government officials, hiring additional workers, and purchasing equipment. This argument has been picked up by Hennessy and Moschini (2006), although they do not explicitly refer to the contribution by Leitzel and Weisman. Their paper shows that the irreversibility effect delays changes in government regulations. Swinnen and Vandemoortele (2010) observe a similar effect for the case of biotechnology regulations in the EU, although they do not explicitly mention the application of a real option approach in their paper.

These studies show that, with respect to government policies, an irreversibility effect exists, regulations can induce hysteresis, and this may cause additional costs. What is important to note is that without capturing the temporal dynamics - that is agents have the possibility to move from one state of nature to another state of nature and back - policy changes and their impact on the allocation of resources and resulting economic effects over time are difficult to demonstrate. These dynamic affects are difficult to capture with comparative static models.

There is one additional issue that deserves attention and that is related to the economic value of opportunities not exercised. The conceptual framework for assessing those opportunities is introduced in Figure 4. The straight lines in Figure 3, the so-called 'Marshallian lines', show the NPV of an investment opportunity. Where the straight line intersects with the horizontal axis, the NPV is zero and onwards to the right it is positive. Applying the NPV criterion as a decision rule, it would be optimal to invest – invest is used as an equivalence to saying exercising an opportunity - if the returns V of the project are equal to or greater than the irreversible investment costs I.

The value of the option to invest F(V) is illustrated by the combination of the nonlinear and linear functions where the nonlinear functions smoothly match the Marshallian lines at V_i, i = 1, 2, 3, 4, the real option theory's points of optimal exercise. These points are to the right of the Marshallian trigger value, implying that a greater V is needed, compared to that needed to satisfy the NPV criterion, to compensate for the irreversible investment costs. The difference is due to the so called irreversibility effect (Henry 1974).

As a larger V is needed to induce investment, one implication is that many options will be exercised at a later point in time. The optimal threshold value for V_i depends on F(V). Changes in V caused by changes in uncertainty, trends, opportunity costs, or a combination thereof can change F(V). Further, changes in irreversible costs have an effect on F(V). While Figure 4 is a representation of a simple model with irreversible investment costs and uncertain returns that follow a geometric Brownian motion, more advanced models that consider entry and exit options, several stages, uncertainty about the irreversible investment costs, irreversible benefits, and more increase the complexity of possible effects. What is important to notice in the context of new developments in the bioeconomy is, that even if a project will not be exercised, the opportunity does not have a zero value. As we will observe only projects that have been exercised - values to the right of V1, V2, V3, and V4 - we will miss the not directly observable real option value (ROV). Assuming a number of companies with same investment costs but different V's, the area between the F(V) function and the horizontal axis to the left of the dashed lines can be used as an approximation for the ROV.[3]

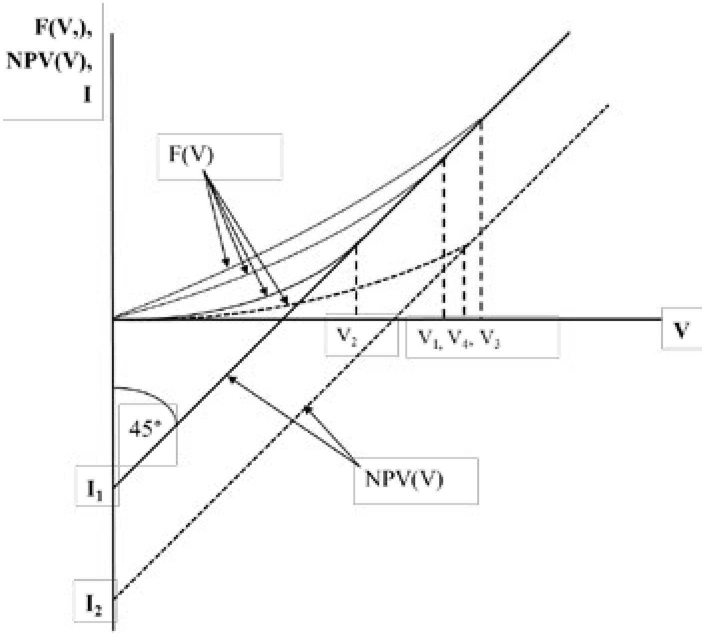


Figure 4. The Value of opportunities

If we compare the real option function for V_1, $F(V_1)$ with the real option function (dotted lines) for V_4, $F(V_4)$, the shift is caused by an increase in the irreversible investment costs caused by a more stringent regulatory policy. Now, assume that the current value for V would be to the left of V_1. In this case we would not observe any effect of the regulatory policy, while the policy has substantially reduced the real option value as expressed in the changes in the area between $F(V_1)$ and the horizontal axis and to the left of V_1, and the area between $F(V_4)$, and the horizontal axis and to the left of V_4. Further, the investment trigger has moved from V_1 to V_4 resulting in a delay of exercise due to changes in investment costs. As Dixit and Pindyck (1994) and others have pointed out, the irreversibility effect can be

3 This is a simplified illustration, the aggregation is much more complicated (see e.g. Mbah et al., 2010).

substantial and hence so can its effect on national welfare. The effects of changes in the real option value on national welfare can be expected to be substantial as well.

According to several authors, regulations of biotechnologies and GMOs in particular has unnecessarily caused a substantial increase in irreversible investment costs resulting in fewer products being developed, a concentration of the industry, reallocation of research priorities and reallocation of research and development to countries with less stringent regulations and even damaging sustainable development considering the environmental and health benefits of cultivating GE crops. (e.g. Bennett et al. 2013, Falck-Zepeda et al. 2013, Potrykus 2010, Kalaitzandonakes et al. 2007)

While several authors argue that regulations have negative effects on investments and reduce economic growth, others point out the positive effects of avoiding future damages. Porter has argued that environmental regulations may even have positive effects on firm-level growth (Ambec et al. 2014). While the effect of regulation and in particular of environmental regulation on firm investment has been investigated (Ambec et al. 2014), less is known about the effect of regulation on research and development in the public and private sector, or about the indirect effect on sustainable development via its effect on research.

3.4 The case of 'Golden Rice'

The study by Wesseler and Zilberman (2014) on the case of Vitamin A enriched rice indicates that those effects can be substantial and hence deserve attention. I would like to discuss this example in more detail as it illustrates the complexity of economic, social, and political issues related to new technologies and their controversies.[4]

Vitamin A enriched rice, 'Golden Rice', has been developed to address vitamin A deficiency among children by using modern biotechnologies. Research has shown that one cup of 'Golden Rice' per day adds enough supply of Vitamin A to prevent Vitamin A deficiency among children in South and Southeast Asia, has no negative health or environmental effects, and is substantially cheaper than alternative strategies. Despite the evidence, many groups are opposed to the technology with the result that until now it is not available. Greenpeace (2012) states " ...if introduced on a large scale, golden rice can exacerbate malnutrition and ultimately undermine food security." Scientists working on the topic have been accused of being "nazi collaborators" (Adams 2014); some have lost their jobs (Enserink 2013).

4 Adrian Dubock (2014) provides an excellent overview about the history of 'Golden Rice'.

Together with David Zilberman of UC Berkeley I developed a real option model to assess the health costs for India caused by not having access to the technology over one decade. According to our calculations, the delay over the last 10 years has caused losses of at least 1,424,680 life years for India, not considering indirect health benefits. Our calculation also shows that the additional perceived costs by the Government of India are at least US$1.7 billion (about US$200 million annually) that would justify a delay of introduction from an economic perspective. This is a substantial amount and reflects the economic power of the opposition against the introduction of 'Golden Rice'. Our model explains why it is more difficult to convince regulators when a strong vocal opposition exists that mainly stirs uncertainty about a new technology.

The 'Golden Rice' issue is an extreme case, but it shows how lobby groups can affect public opinion and off-set scientific evidence. The paper also shows how we can use economic models to assess the implications of specific policies and perhaps even generate impact. The paper has been downloaded several thousand times within a year and been widely mentioned in public media.

4 Outlook

As head of the AEP Group at Wageningen University, I am in the fortunate position of further broadening our analyses in the field of Agriculture in the Bioeconomy: Economics and Policies.

We together carry out research focusing on economic and institutional issues within the bio-economy, and teach across a wide range of aspects related to the contribution of the bio-economy and the agricultural sector in particular to sustainable development. Dynamic aspects of bioeconomy policies and their economic implications along the value chain are a priority.

Our research areas include
- Market and policies
- Spatial structures
- Institutional and organizational aspects of agriculture production, agribusiness, and rural development

Based on our vision, to further strengthen our expertise, visibility, and recognition in research and teaching in the field of Bioeconomy Economics and Policies our mission is to perform high quality scientific economic research through economic analyses grounded in relevant and up-to-date theory, using appropriate methodologies.
The objective of AEP is to create impact in science and in society by disseminating research results to other researchers, policy makers, students and societal actors.

Our group is focusing on developed countries, and the EU more specifically. However, the transformation of agriculture from being mainly a food producer to a producer of both food and other services of the bioeconomy in the western world is increasingly observed as a worldwide phenomenon. For this reason, the research of the AEP group is also directed towards economies in transition (e.g. Eastern Europe and China) and developing countries.

Markets and policies
Research focuses, among others, on impacts of the reform of Common Agricultural Policy of the European Union (e.g. milk quota abolition), the effect of the bioeconomy on food prices and the effects of price volatility on farmers' income. It also includes the issues of retailer and agribusiness-driven non-tariff barriers and emerging market participants. Issues that recently gained in importance within the TTIP negotiations.

Spatial structures
With more and more non-agricultural residents living in rural areas in some parts of the world and depopulation of rural areas in other parts, an increasing demand and supply of multifunction goods, such as recreation, wildlife and landscape, rural areas are changing rapidly in many parts of the world. Research issues relate to the contribution of the bioeconomy to regional growth, provision of green services (e.g. via contracting), landscape valuation, rural policy modelling and land use analysis.

Institutional and organizational aspects
This research theme is motivated by the historically and on-gong strong policy involvement in the agricultural sector, both at national and European level. Furthermore, increasingly complex relationships within the bioeconomy demand new ways of governance. Examples of research topics are contracts between processing companies and farmers, the uptake of agri-environmental schemes (contracts between the government and farmers to provide green services) and contracts ensuring food safety and animal welfare in supply chains of food production.

The research focus of the group calls for a strong interdisciplinary approach of combining social and natural sciences. This provides great opportunities for collaboration with other groups of Wageningen University and DLO institutes. We collaborate already e.g. on impact assessment of investments in plantation forests; on sustainable investments in tomato production; on the contribution of ecosystem services to crop yield to name only a few and like to further intensify collaboration in the future.

We are actively involved in the International Consortium on Applied Bioeconomy Research (ICABR), collaborate with a number of international organisations and participate in several international research consortia and will continue to do so in the future. In November this year we will be the local organizers of the GMCC-15 conference in Amsterdam. A major international event for leading experts from various academic disciplines and industry, regulators, policy makers and other key stakeholders to discuss the challenges and opportunities in managing different types of foods in global markets.

In summary, I see a number of important issues emerging related to agriculture in the bioeconomy where the AEP group can provide meaningful contributions to the scientific as well as societal debate as well as the mission of Wageningen University *To explore the potential of nature to improve the quality of life* [from a socio-economic perspective].

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References

Adams M (2014). Science for sale: The true history of silencing whistle blowers with corporate science. Available at: <http://www.naturalnews.com/046097_biotech_genocide_Monsanto_collaborators_media_sellouts.html#ixzz3afUnnpFA>.

Ambec S, Coheny MA, Elgiez S, Lanoie P (2014). The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness? Review of Environmental Economics and Policy 7(1): 2–22.

Arrow KJ, Dasgupta P, Goulder LH, Mumford KJ, Oleson K (2012). Sustainability and the measurement of wealth. Environment and Development Economics 17(3): 317–353.

Arrow K J, Cropper ML, Eads GC, Hahn RW, Lave LB, Noll RG, Portney PR, Russell M, Schmalensee R, Smith VK, Stavins RN (1996). Is There a Role for Benefit-Cost Analysis in Environmental, Health, and Safety Regulation? Science 272:221-222.

Arrow KJ, Fisher AC (1974). Environmental Preservation, Uncertainty and Irreversibility. The Quarterly Journal of Economics 88(2): 312–319.

Backus G, Berkhout P, Eaton D, de Kleijn T, van Mil E, Roza P, Uffelmann W, Franke L Lotz B (2009). EU policy on GMOs: a quick scan of the economic consequences. The Hague: LEI Wageningen UR.

Beckmann V, Soregaroli C, Wesseler J (2010). Ex-Ante Regulation and Ex-Post Liability under Uncertainty and Irreversibility: Governing the Coexistence of GM Crops. Economics: The Open-Access, Open-Assessment E-Journal, Vol. 4, 2010-9.

Bennett AB, Chi-Ham C, Barrows G, Sexton S, Zilberman D (2013). Agricultural Biotechnology: Economics, Environment, Ethics, and the Future. Annual Review of Environment and Resources 38: 19.1-19.31.

Chelsom-Pill C (2011). Russia lifts ban on EU vegetables. Deutsche Welle. Accessed March 20, 2013 <http://www.dw.de/russia-lifts-ban-on-eu-vegetables/a-15182434-1>.

Coase R (2006). The Conduct of Economics: The Example of Fisher Body and General Motors. Journal of Economics & Management Strategy 15(2): 255–278.

Coase R (1960). The Problem of Social Cost. Journal of Law and Economics 3:1-44.

Dixit AK, Pindyck RS (1994). Investment under Uncertainty. Princeton NJ: Princeton University Press.

Dubock A. (2014). The present status of Golden Rice. Journal of Huazhong Agricultural University 33(6): 69-84.

Enserink M (2103). Golden Rice Not So Golden for Tufts. ScienceInsider. Available at: <http://news.sciencemag.org/asiapacific/2013/09/golden-rice-not-so-golden-tufts>.

European Commission (2012). Innovating for Sustainable Growth. A Bioeconomy for Europe. Luxembourg: Publications Office of the European Union.

European Council for the Environment (1999) 2194th Council meeting, Luxembourg, 24/25 June 1999. C/99/203/.

European Food Safety Authority (2011). Tracing seeds, in particular fenugreek (Trigonella foenum-graecum) seeds, in relation to the Shiga toxin-producing E. coli (STEC) O104:H4 2011 Outbreaks in Germany and France. Technical Report of EFSA.

Falck-Zepeda J, Wesseler J, Smyth S (2013). The current status of the debate on socio-economic regulatory assessments: positions and policies in Canada, the USA, the EU and developing countries. World Review of Science & Technology and Sustainable Development 10(4): 203 - 227.

FAO (2013). Statistical Year Book 2013 World Food and Agriculture. FAO: Rome.

Greenpeace (2012). Golden Illusion: The Broken Promises of 'Golden' Rice. Amsterdam: Greenpeace International.

Hamilton K (2000). Genuine Saving as a Sustainability Indicator. In: OECD: Frameworks to Measure Sustainable Development. Paris: OECD Publications Service.

Hennessy DA, Moschini G (2006). Regulatory actions under adjustment costs and the resolution of scientific uncertainty. American Journal of Agricultural Economics 88(2): 308–323.

Henry C (1974). Investment decision under uncertainty: the irreversibility effect. American Economic Review 64: 1006-1012.

Kalaitzandonakes N, Alston J, Bredford K (2007). Compliance costs for regulatory approval of new biotech crops. Nature Biotechnology 25(5): 509-511.

Levin Institute (2015). Globalization 101: What is Globalization? Available at <http://www.globalization101.org/what-is-globalization/>.

Mbah MLM., Forster G, Wesseler J, Gilligan C (2010): Economically optimal timing of crop disease control under uncertainty: an options approach. Journal of the Royal Society Interface 7(51):1421-1428.

Mezey EW, Conrad JM (2010). Real options in Resource Economics. Annual Review in Resource Economics 2:33–52.

Mukherji PN, Sengupta C (2004). Indigeneity and universality in social science. A South Asian response. New Delhi: Sage Publications.

OECD (2010). OECD Economic Globalisation Indicators 2010. Paris: OECD.

Perrings C, Brock W (2009). Irreversibility in Economics. Annual Review of Resource Economics 1:1.1–1.20.

Pindyck RS (2000). Irreversibilities and the timing of environmental policy. Resource and Energy Economics 22(3): 233–259.

Potrykus I (2010). Regulation must be revolutionized. Nature 466: 561.

Rothbard M (1982). Law, Property Rights, and Air Pollution. Cato Journal 2 (1): 55-99.

Sagar AD, Najam A (1998). The human development index: a critical review. Ecological Economics 25(3): 249–264.

Shleifer A (2010). Efficient Regulation. In: Kessler DP (ed) Regulation vs. Litigation: Perspectives from Economics and Law. Chicago: University of Chicago Press.

Smit HTJ, Trigeorgis L (2004). Strategic Investment. Real Options and Games. Princeton, NJ: Princeton University Press.

Stevens AJ (2004). The Enactment of Bayh – Dole. Journal of Technology Transfer 29:93-99.

Swinnen JFM, Vandenmoortele T (2010). Policy Gridlock or Future Change? The Political Economy Dynamics of EU Biotechnology Regulation. AgBioForum, 13(4): 291-296.

Tramper J, Zhu Y (2011). Modern Biotechnology. Wageningen, NL: Wageningen Academic Publishers.

Trigeorgis L (1996). Real Options. Cambridge, MA: MIT Press.

United Nations (1992). Report of the United Nations Conference on Environment and Development. United Nations publication, Sales No. E.73.II.A.14 and corrigendum.

Van den Belt H (2003). Debating the Precautionary Principle: “Guilty until Proven Innocent” or “Innocent until Proven Guilty”? Plant Physiology 132:1122–1126.

Wackernagel M, Rees WE (1996). Our ecological footprint. Reducing human impact on the earth. Gabriola Island, British Columbia: New Society Publishers.

Wesseler J (2014a). Biotechnologies and agrifood strategies: opportunities, threads and economic implications. Bio-based and Applied Economics 3(3): 187-204.

Wesseler J (2014b). Financial, Real, and Quasi Options: Similarities and Differences. In: Pinto A, Zilberman D (eds.). Modeling, Optimization and Bioeconomy I, pp. 673-693. Springer Series Proceedings in Mathematics, Volume 73.New York: Springer.

Wesseler J (2009). The Santiello Theorem of Irreversible Benefits. AgBioForum 12(1): 8–13.

Wesseler J, Scatasta S, Nillesen E (2007). The Maximum Incremental Social Tolerable Irreversible Costs (MISTICs) and other benefits and costs of introducing transgenic maize in the EU-15. Pedobiologia 51(3): 261–269.

Wesseler J, Smart R (2014). Environmental Impacts. In: J Falck-Zepeda, K Ludlow, S Smyth (eds.), Socio-economic Considerations in Biotechnology Regulation, pp. 81-95. New York: Springer.

Wesseler J, Zilberman D (2014). The Economic Power of the Golden Rice Opposition. Environment and Development Economics 19(6): 724-742.

Wetenschappelijke Raad voor het Regeringsbeleid (1987). Ruimte voor groei: kansen en bedreigingen voor de Nederlandse economie in de komende tien jaar. Rapporten aan de Regering 29. 's-Gravenhage: Staatsuitgeverij.

WTO (2014). Modest trade growth anticipated for 2014 and 2015 following two year slump. Press/721, 14 April 2014, Press Release.

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The advancements made in the life sciences over the past decades gave rise to the bioeconomy. Together with an increase in intra industry trade, product differentiation, and globalization this has resulted in agriculture production to become more vertically integrated. The advancement in the life sciences also provide new opportunities for agriculture to address the different dimensions of the global challenge for sustainable development changing the economics of agriculture and the impacts of and requirements for appropriate policies.

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