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Circular Approach and the Sustainability of the Agro-food System –
Closing Resource Loops to Improve Sustainability

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Opportunities and the Policy Challenges to the Circular Agri-foodSsystem

paper prepared by

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Abstract

The circular economy is not a new concept in economics. Francois Quesnay and the Physiocrat's of 18th Century France introduced the concept into economics recognizing that households provide inputs to private sector companies and that companies provide outputs that households use as inputs. From a bio-chemical perspective the law of conservation of mass needs to be considered implying mass can neither be created nor destroyed but allocated differently over space in a closed system similar to planet earth.

Recently the concept of the circular economy received high policy attention. In the agri-food system the debates are related to issues such as reducing food waste and emissions in food production including greenhouse gases, recycling of food packaging materials and plastic in particular, and cascading use of food products including the use of fertilizing products.
This background paper provides an overview about the relevance of the circular economy concepts in current policy debates with a focus on the agri-food system.

1. Introduction

The circular economy is a concept with a long history in economics. It can be dated back to the Physiocrat's of 18th century France. The economic table of Francois Quesnay shows the circularity within the economy where households supply labor to firms that in return pay salaries which are used to buy the goods produced by firms. These tables have substantially improved over time and developed into today's national accounting systems and the related input-output tables. They are important inputs for applied general equilibrium models (McCarthy et al. 2018). The short-comings are the models show economic values and the quantities are not directly visible. The advantage is results can be compared as they are all expressed in monetary units.

An accounting system on its own neither ensures that all issues that are of relevance are covered, nor accounting results in improvements. Nevertheless, proper accounting is important for informing policy makers (Stiglitz et al. 2009) and as an input for policy modelling (McCarthy et al. 2018).

Cingiz and Heijman (2019) provides a value added analysis approach to measure the bioeconomy share of GDP with input output tables. First they differentiate sectors in an economy as sector 1 (S1) which is agriculture, forestry, fishery, aquaculture and veterinarian services. And the rest of the economy sector 2 (S2). They calculate the downstream and upstream effects between these two sectors, and calculate the part of the value added of S2 that is actually S1 and so bioeconomy. Here the downstream and upstream effects move in a circular motion, as in the circular economy models. The growth and value added is shown in Figure 1 and Figure 2. The figures also illustrate one of the shortcomings. The share of recycling or the biomass being used and their flows are not visible. Data providing these information, with a few exceptions, are missing and generating these data is an important part for monitoring the circular economy.

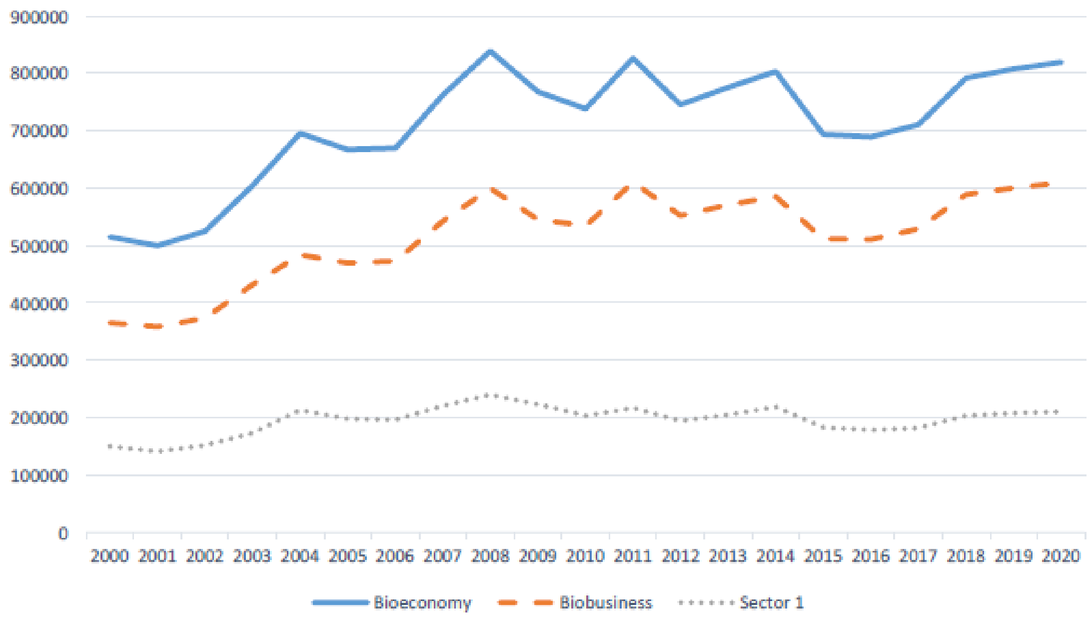


Figure 1. The growth of value added from 2000 to 2020 in the EU.

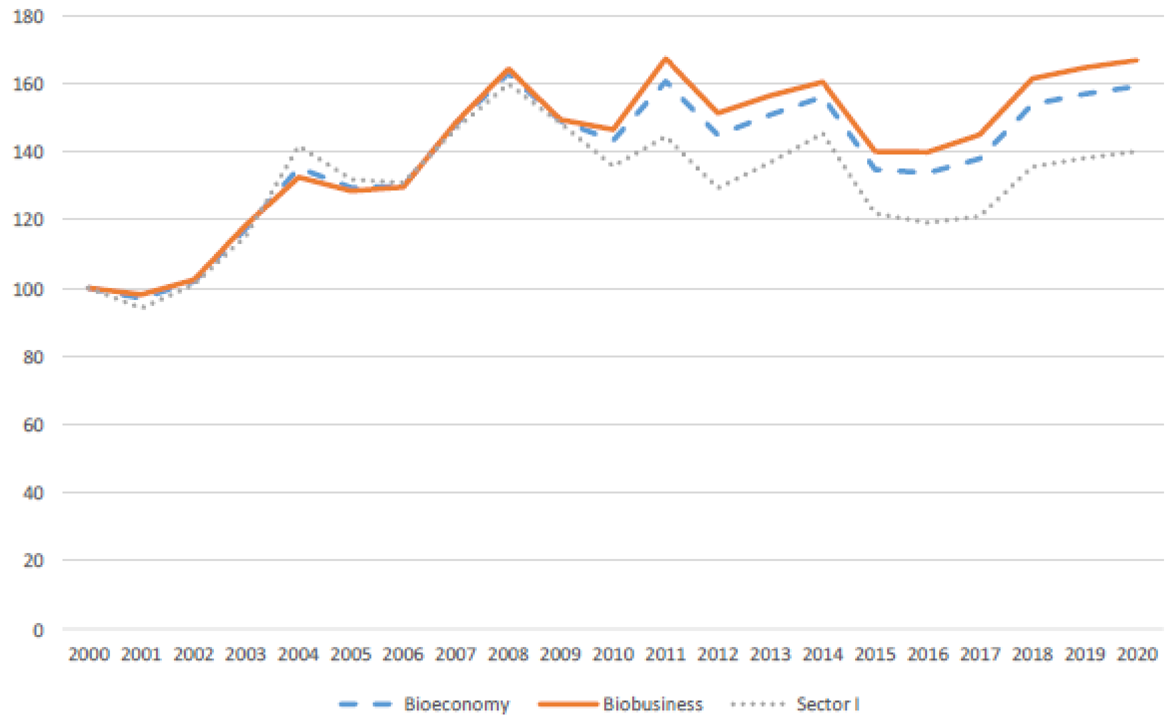


Figure 2: Indexed growth comparison between 2000 and 2020 for the EU.

Current accounting systems have in particularly been criticized for not properly measuring natural resources, environmental pollution and other damages to the environment, as well as non-market goods. Especially environmental pollution and other damages to the environment have raised substantial concern about the future of humankind. Strengthening circularity within an economy is expected to address these concerns. Prominent examples include the recycling or substitution of plastic material and the reduction of greenhouse gas emissions.

This often goes hand-in-hand with a call for moving from a linear economy towards a circular economy. Proponents stress more emphasis at policy level should be placed on policies that support the recycling of materials, the extension of product life-cycles for durable goods, and shortening supply chains over space. This requires for many a change in how we think an economy is organized, how economies are modelled and how policies are designed (Kalmykova et al. 2018, Korhonen 2018a, 2018b).

The circular economy concept is closely linked with the closed loop economy concept (Matthews and Tan 2011). A notable statement is dated back to 1848 of August Wilhelm von Hoffman that “In an ideal chemical factory there is, strictly speaking, no waste but only products. The better a real factory makes use of its waste, the closer it gets to its ideal, the bigger is the profit.” (Lancaster 2002: 21, after von Hoffman, 1866). An additional link is the “closed loop economy” of “spaceship Earth” by Boulding (1966, Stahel and Reday-Mulvey 1976). The concept of the closed earth economy is important as it highlights some important issues that need to be considered. The law of conservation of mass tells us that the mass of a system, the Earth, has to stay constant over time.[1] Circular economy addresses the problem that is related to the accumulation of matter over time and space. Accumulation of CO_2 in the atmosphere causes the problem of climate change, accumulation of nitrogen in the soil causes water pollution. Changing the carbon cycle by burning less fossil fuels, that have been produced over thousands of years from biomass where release is much faster than sequestration, is expected to reduce the human impact on climate change and develop into “closed loop economy” from “spaceship Earth”.

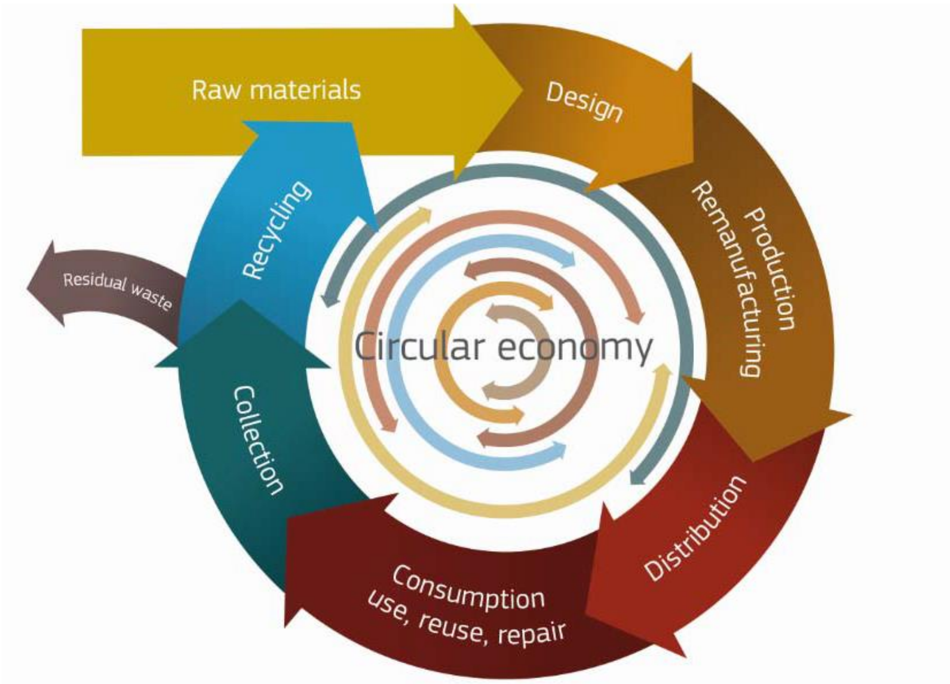


Figure 3. Visualization of the Circular Economy by the EC. (Source: European Commission, 2014.)

In relation to this concept Mathews and Tan (2011) state that the circular economy is the aim of eco-initiatives. One example is Karl-Henrik Robèrt 1991, the founder of non-profit, non-

[1] This is not exactly correct according to the mass-energy equivalence, but for the chemical elements of interest such as carbon or nitrogen this simplification is acceptable.

governmental organization The Natural Step who states: “Most environmental problems are based on the same systemic error - linear processing of material. Until resources are processed in cycles either by society or by biogeochemical processes the global economy and public health will continue to deteriorate. Consequently, we will never be in a better position than we are now to make the necessary changes; every minute we delay increases the final cost.” (Lancaster 2002) and illustrated in Figure 1.

A strong driving force is the Ellen MacArthur foundation, a charity formed in 2010 with the mission “to accelerate the transition to a circular economy”. They have since published a number of reports and case studies on the topic. They define the circular economy as “... an economic system where products and services are traded in closed loops or `cycles'. A circular economy is characterized as an economy which is regenerative by design, with the aim to retain as much value as possible of products, parts and materials. This means that the aim should be to create a system that allows for the long life, optimal reuse, refurbishment, re-manufacturing and recycling of products and materials.” The is not the only definition for the concept. Kirchherr et al. (2017) find 114 definitions of the circular economy.

Table 1. Examples of policy documents among OECD countries related to circular economy policy strategies

Country	**Strategy Document**
Australia	Green Industries SA Strategic Plan (2018), A circular economy for NSW
Austria	Circular Futures - Austria's Circular Economy Platform
Belgium	Let's make the economy work by developing the circular economy in Belgium
Canada	CIRCULAR ECONOMY LEADERSHIP COALITION
Chile	Circular Economy Forum of the Americas, Strategic Partnership in Chile – Innovation and Sustainability through Circular Economy
Czech Republic	State Environmental Policy
Denmark	The Advisory Board for Circular Economy Recommendations for the Danish Government
Estonia	Circular Procurement Congress 'Mainstreaming Circular Procurement’
Finland	Finnish road map to circular economy - Sitra
France	50 measures for a 100% circular economy
Germany	German Resource Efficiency Programme (ProgRess II) Closed Substance Cycle Waste Management Act
Greece	Greece National Action Plan on Circular Economy
Hungary	Business Council for Sustainable Development in Hungary (BCSDH)
Iceland	Waste Management Policy 2013–2024
Ireland	Moving Towards the Circular Economy in Ireland- NESC
Israel	Israel Sustainability Outlook 2030
Italy	Towards a circular economy model for Italy
Japan	Law for the Promotion of Effective Utilization of Resources
South Korea	Introduction of the Framework Act on Resource Circulation toward Establishing a Resource-Circulating Society in Korea,
Latvia	N/A
Lithuania	National waste management program
Luxembourg	Climate Pact under the sign of the circular economy

Mexico	Global Green Growth Forum
Netherlands	A Circular Economy in the Netherlands by 2050 Agriculture, nature, and food: valuable and connected
New Zeeland	Circular Economy Accelerator
Norway	Unlimited opportunities in the circular economy
Poland	Mazovia Circular Congress
Portugal	Green Growth Commitment
Slovakia	Waste act
Slovenia	Roadmap towards the circular economy in Slovenia
Spain	Spanish Chamber of Commerce "Circular Economy: the role of business in developing the green economy"
Sweden	Smart City Sweden
Switzerland	Circular Cities Switzerland, Circular Economy Incubator
Turkey	Türkiye Materials Marketplace (TMM) Project
United Kingdom	LWARB circular economy report
United States	National Bioeconomy Blueprint, Chamber of Commerce Circular Economy Summits

The call for strengthening the circular economy has entered the policy agenda of many OECD countries. Table 1 shows policy documents of OECD countries published in English with references to the circular economy indicating that almost all OECD countries in one or the other way pay attention to the circular economy from a policy perspective. The European Union has published a strategy document "Towards a circular economy: A zero waste programme for Europe" in 2014 and an action plan "Closing the loop - An EU action plan for the Circular Economy" in 2015. The Dutch Government has launched in 2016 the programme "A circular economy in the Netherlands by 2050" under the leadership of the Ministry for the Environment and Ministry for Economic Affairs. Germany's Resource Efficiency Program "Deutsches Ressourceneffizienzprogramm II" of 2016 emphasizes the circular economy approach for reducing waste and improving resource efficiency. In the United States members of the Democratic Party call for a "Green Deal" including a circular economy approach. While in the literature more than a hundred definitions of the circular economy have been found there are major reappearing topics. They include:

- substituting fossil fuel use;
- increasing resource use efficiency/reducing waste;
- increasing the rate of recycling.

The concept of the circular economy is also closely linked with the development of the bioeconomy and can almost be used interchangeably as the objectives are very similar. An example is the bioeconomy strategy of the European Union (EC 2018) and the "Closing the loop - An EU action plan for the Circular Economy" (EC 2015).

2. Link between the circular agri-food system and sustainability

In the economic literature, Arrow et al. (2012) introduced the concept of genuine investment as a measure for sustainable development. They define intergenerational well-being $V(t)$ as the discounted flow of current and future generations' utilities U. Utility is derived through consumption C of the economy's stock of capital assets K, including manufactured goods, services provided by nature, health services, and many more. The term $U(C(s))$ is interpreted as felicity at date s. Accordingly, δ denotes the felicity discount rate. Continuous time is denoted by s and t, $s \geq t$ (underlying assumptions: closed economy, infinite time horizon, constant population, changes in time-varying factors are exogenous). Consequently, intergenerational well-being $V(t)$ is formalized thus (Arrow, p. 322):

(1) $$V(t) = \int_t^\infty \left[U\left(\underline{C}(s)\right)e^{-\delta(s-t)}\right]ds, \delta \geq 0$$

Arrow et al. (2012) then define sustainability as non-declining intergenerational well-being over time $dV/dt \geq 0$. Genuine investment is determined as a measure of changes in well-being, where well-being is a function of its determinants, namely the economy's stock of capital assets K and time t: $V(t) = V(\underline{K}(t), t)$. Let $r(t)$ $(= \partial V/\partial t)$ denote the shadow price of time at t, and $p_i(t)$ ($\equiv \partial V(t)/\partial K_i(t)$, for all i) the shadow price of the i^{th} capital asset at time t. By letting $Q_i(t)$ equal $\Delta K_i(t)/\Delta t$, genuine investment is (Arrow et al., 2012, p. 325):

(2) $$\Delta V(t) = r(t)\Delta t + \sum p_i(t)Q_i(t)\,\Delta t$$

According to equation (2) the changes in an economy's set of capital assets weighted at shadow prices, including the capital asset time, equals the change in well-being. Looking at Equation (2) in more detail, it shows that positive genuine investment increases, while negative genuine investment decreases intergenerational well-being. Possible irreversibility effects are implicitly included and can be made explicit by modelling $\Delta V(t)$ as a stochastic process and where the shadow price of capital assets includes possible irreversibility effects. Hence, positive genuine investment facilitates sustainable development. The link with a circular economy is that a circular economy is also expected to improve well-being by using resources more efficiently which would be the result of a social innovation that matches the genuine investment criteria.

The important issue is that both the genuine investment as well as the circular economy approach stress the importance of technical change. A circular economy strategy that relies on the substitution of fossil fuels in production processes can in principle contributes to sustainable development. Producing plastics from biomass can increase the possibilities for recycling but important trade-offs need to be considered. The biomass may compete with alternative uses and sources for food in particular. In a comparative-static setting this will increase food prices with negative implications for less wealthy households. This has been in particular an issue in the debates on biofuel policies (Zilberman et al. 2018).

In a dynamic setting, social innovations such as technical change will not happen only within the processing of biomass for bioplastics but also the processing of biomass for food. Recent developments in food production such as clean meat (Shapiro 2018), closed aquaculture systems (Tacon and Metian 2018), animal protein from insects (Bukkens 1997), and urban farming are developments that are expected to increase the economic efficiency in food production (Thorrez, H Vandenburgh 2019) and to move food production to metropolitan areas as it is less land dependent. Time and scale of these disruptive developments are difficult to predict precisely, but they are happening. They are expected to make food production more sustainable and to shorten food supply chains. Moreover, they may reduce the pressure on land for food production and provide opportunities for alternative uses of biomass such as the aforementioned bioplastics. The rate of technical change needed will depend on the resources allocated for further developing these technologies. Increasing the financial resources allocated to R&D can be expected to shorten the time needed, but expenditures on R&D are not sufficient enough. A supporting policy environment will also be needed. The recent judgment of the CJEU on gene editing technologies serves as a case in point where policies are expected to have negative implications on R&D for the circular economy (Purnhagen and Wesseler 2019).

If technical changes are realized, they can improve the efficiency and resilience of the agro-food system. The innovations will increase the portfolio of potential uses of biomass. An increase in the rate of recycling is expected to increase the efficiency in resource use. (The recycling of paper serves as an example). But recycling per se is not necessarily improving resource efficiency. There is a long debate about soft-drinks sold in glass versus PET-bottles and resource efficiency. Beverage producers claim that the use of PET-bottles requires less resources as the recycling of glass bottles requires more resources for collecting and cleaning the bottles than producing additional PET-bottles. Packaging material for food produced from sugar cane might be biodegradable, but have the properties compliant with food safety requirements or not having the properties needed for maintaining a long shelf-life of the wrapped product. Many of the different solutions will be case dependent and one needs to be careful with generalizations.

There might also be potential trade-offs possible between the agro-food system and the move towards a circular economy. Market prices not only reflect the scarcity of a resource but are also affected by policies including taxation, subsidies, food and environmental safety standards and more. In some cases, differences in environmental and other taxes might result in prices that are not fully reflect all costs if environmental benefits or costs are not completely internalized. As a result, product prices might be biased. The difference in gasoline prices in the EU serves as an example. The price differences between countries cannot be explained by differences in transportation costs but are rather a result of differences in taxation and regulatory policies (Rietveld and Woudenberg 2005). The price differences for resources between countries can be expected to result in differences in incentives for participants in the food sector to get involved in circular economy activities. In some cases, intermediate and final consumers might not be able to differentiate between products if the circular economy attribute is a credence good. Certification and labelling schemes can help to overcome resulting asymmetries in information between buyer and seller.

Many participants in the policy debates on strengthening the CE argue for taxes and other policies to internalize "externalities". One needs to carefully assess such kind of proposals as many "externalities" are internalized via a number of public policies. A tax is one possibility to address environmental concerns, but it is far from obvious, that a tax (or subsidy) is from an economic point of view is always the first best solution as implementation costs need to be considered as well. Hence, a number of possible solutions might be available and their benefits and costs need to be compared for identifying the most promising one (Coase 2006; Wesseler and Drabik 2015).

A stronger circular economy has the potential to increase sustainability, efficiency, and resilience of the economy. If the solutions offered are properly priced and competitive they will be adopted and be considered to be efficient and improve sustainability. As these are new solutions they increase the portfolio of solutions to address the challenges mentioned and this increases the resilience of the economy. As with all new policy strategy ideas the danger exists that they will come at the expense of existing strategies. Lobby groups might be able to change policies for their own benefit by creating biases that endanger sustainability, efficiency, and resilience (Rausser et al. 2011, Shao 2018a,b).

3. Link between circular agri-food systems and innovations in the agri-food supply chain

The diffusion and the adoption of an innovation is strongly correlated with critical mass. If such a threshold satisfied, then the innovation becomes self-sustaining. A stronger circular economy means innovations with certain characteristics that matches to the society, strong interaction between agents in the economy through for example media, shorter time in innovation acceptance decision process and the norms of the social system in the sense that policy makers can influence in the right direction. All these affects help the society to reach the critical mass.

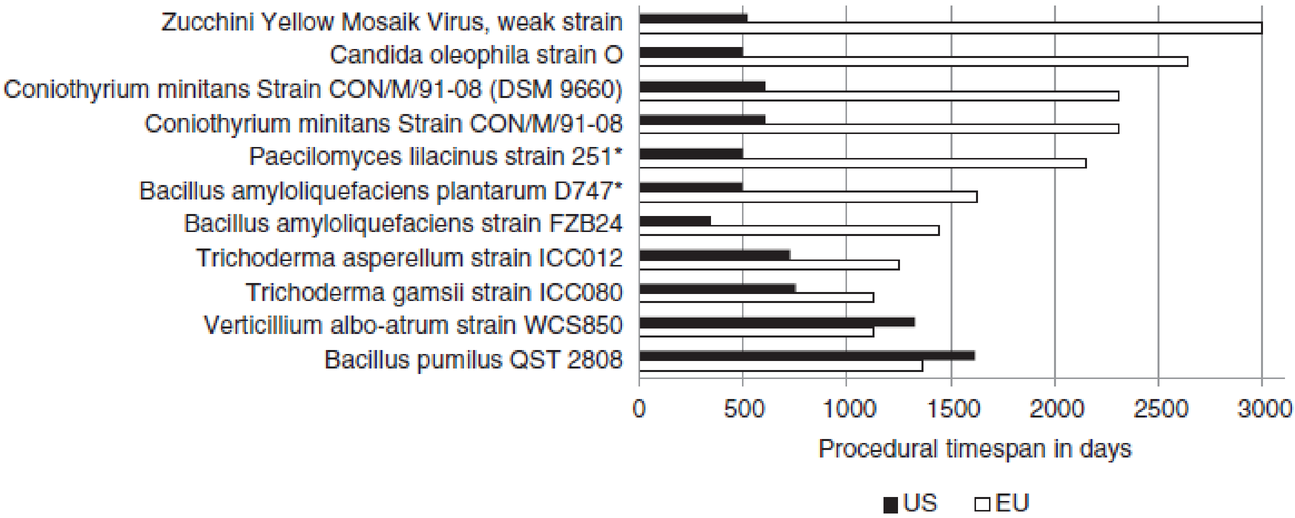


Figure 4. Differences in time-length for the approval of biological control agents in the European Union and the United States (Source: Frederiks and Wesseler, 2018).

A possible trade-off for the diffusion and adoption of innovations may exist if policies introduce biases against specific forms of innovations that would be economical at firm or farm level but due to regulatory and/or policies, e.g., too expensive to adopt. One case in point is the regulation of biological plant protection agents in the European Union. They are in general be considered preferable over alternative synthetic control agents because of their environmental properties. A comparison of the approval processes between the European Union and the United States shows that the approval costs for the same agents and almost same environmental safety standards in the European Union are much more costly. Similar observations have been made for other innovations for the control of pest and diseases in agriculture (Smyth et al. 2008), while the innovations are considered to improve resource use efficiency.

New innovations for strengthening the development of the circular economy such as biodegradable packaging material, new fertilizing products, or the recycling of waste may face similar problems. The example also illustrates that difference in regulatory standards can be a barrier for scaling-up circular economy technologies. The experience with the approval of GMOs, new plant breeding technologies, and biological control agents mentioned before, shows, cost for innovations can be reduced without compromising on environmental and food safety.

Several authors have stressed the importance of not only changing policies but also the norms and beliefs within society (e.g. Ritzén and Sandström 2017). This can have important implications for the diffusion and adoption of technologies as attention may shift. Developing business models that take this into consideration are a challenge. Processing of biomass at regional level may require more than just one farmer being involved. Cooperative structures where several farmers may own a facility, contracting supplies, licensing or franchising of production systems are some of the possible models. At local level a number of grass-root activities can be observed. Examples include weekly delivery of milk in bottles where empty bottles are returned to the supplier and refilled or the sharing of urban gardens. Other possibilities include leasing of durable household goods such as washing machines or dishwashers or agriculture equipment such as tractors.

Other models that are discussed include voluntary contributions for carbon emissions. A prominent example includes contributions for carbon neutral flights, where the voluntary contributions are used for investments in carbon sequestration. Another example is the afforestation of land where tourists or people in general buy land that will be afforested and receive a certificate ensuring a minimum life-time of the trees and related carbon sequestration. In this case consumers are directly linked with projects. This carbon swap for nature has been established in the Federal State of Mecklenburg-Western Pomerania in Germany (http://www.waldaktie.de/). Possibilities for scaling-up such kind of projects from a regional to national to international level in general are possible. A challenge for scaling-up such kind of activities is maintaining the credibility of the projects. Auditing the implementation of projects can contribute to maintain credibility.

A reoccurring question is at what level circular economy should be assessed. Farms, local, and regional communities are involved in international trade of goods and services. A change in products being produced may have trade implications as the inputs required and the products sold may change. Higher product standards in one country may reduce export opportunities in other countries with possible negative economic implications for the exporting country. The higher standards may also increase production costs and reduce the competitiveness of farms and firms affected and move production to countries with less costly production standards. In general, these effects should be considered for an economic assessment of the circular economy approach and models used be improved to be able to model the circular economy. In this direction, improvements need to be made and in particular with respect to measuring the implications for natural resources.

Scaling-up the circular economy from regional to national to international level may at first sight look as a contradiction. The circular economy stresses the recycling of consumer goods and intermediate products, the strengthening of local production and shortening of value chains over space, the closing of nutrient cycles at farm level. The opportunities are not for scaling-up the production of specific products but for scaling-up business models for solutions at local level that can be replicated. In this sense, the circular economy approach will not so much contribute to international trade in goods but in services. Trade policies affecting the service sector will become important. As these are intangible assets, their value is in general more difficult to assess and they suffer from non-rivalry and non-excludability reducing private sector incentives for investment. The protection and trade in intellectual property rights will be an important factor and a challenge (Lele et al. 1999).

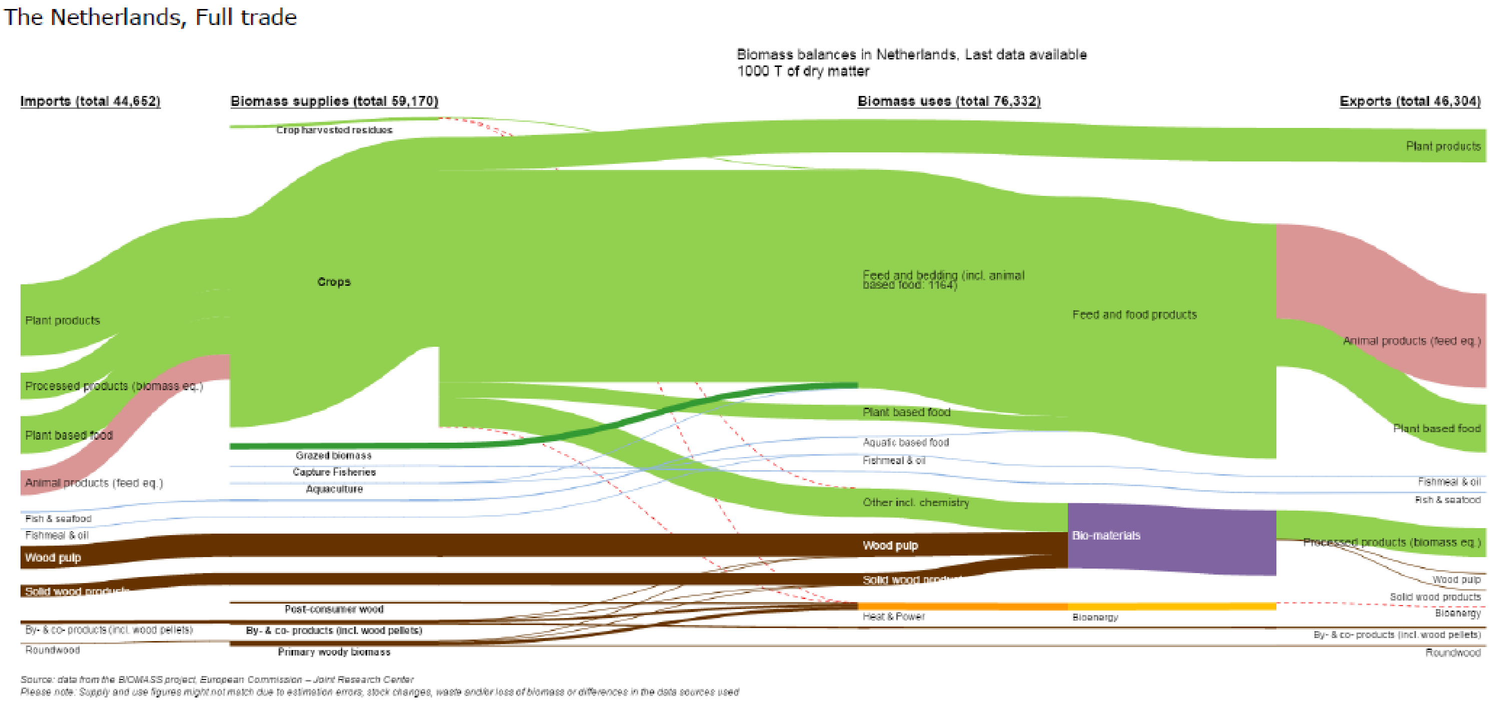


Figure 5. Sankey Biomass Diagram example. Source: JRC (2017).

The international trade issue also relates to the scope of circularity within an economy. Supply chains have become more and more global as well as more and more integrated. This integration of supply chains allows to transfer value systems from one place of the world to another. Consumers can demand specific production standards to be met by the products they buy including for those parts produced abroad. Whether specific standards are met abroad will depend on a number of factors. The production costs for meeting the standards will be of high importance. Opportunity costs are another important factor. It might be just cheaper to not meet the standards and serve markets that require less costs standards. These issues will be relevant for waste reducing strategies, biomass use for biodegradable products, as well as overall resource use efficiency. Stopping assessments of resource use efficiency at national boarders may generate biases in case of international trade as those effects from a material flow only can already be substantial. Often, only bilateral flows are considered but third country effects can also be important, and sometimes even more important (see section 4 below).

4. Link between the circular agri-food system and policies

Strengthening the circular economy will be in line with many current agriculture policy reforms towards a more environmental friendly agriculture. The possibilities for recycling nutrition on the farm by processing products such as straw and other crop residues for bioenergy can provide additional on-farm income and reduce nutrient emissions and allows to develop new fertilizing products that can be traded. Fresh biomass can be used to extract valuable biopolymers that can further be processed and residues be used as high protein animal feed or converted into fertilizing products. This all provides new income opportunities for in particular young farmers with a long time perspective which is part of many agricultural policies. It is also expected that many of the technologies for converting biomass using biorefineries will be smaller in scale and more suitable for rural areas close to the biomass source (Wesseler and von Braun 2017). This is not only relevant for the agricultural sector but for rural development in general. Many OECD countries observe a decline in rural population challenging the provision of basic services. Providing new economic opportunities for rural areas might be able to stop and perhaps even change this trend. Many of the new opportunities mentioned are still in the development phase and the opportunities they generate will depend on their profitability. Some might reach the market earlier than others.

From this perspective strengthening the circular economy will support such kind of agriculture policy reforms. This might also explain the strong support the circular economy strategy receives form agriculture policy. Agriculture and circular bioeconomy policies are expected to reinforce each other (Strategic biomass vision for the Netherlands towards 2030, Visie Biomassa 2030). The circular economy strategy can strengthen the agro-food system. Prominent examples include by-products generated by biogas facilities that are used as fertilizers bringing back the nutrients previously extracted from the land. Other examples include the use of organic fertilizer and other fertilizing products.

Case: Extracting cyanophycin from tobacco.

At Wageningen University the GRASSA Technology has been developed (more details at: http://grassa.nl/). This allows to extract from fresh biomass such as grasses biopolymers. The fresh biomass is separated into a press cake and a whey. From the whey amino acids and biopolymers can be extracted. Those can be further processed into food and feed ingredients while the press cake can serve as a protein rich feed. The technology can be used at farm level and fits in a movable container. The technology is also tested to extract the biopolymer cyanophycin from a cyanophycin rich tobacco plant in Argentina. The tobacco plant has been produced using transgenic methods. The project could not be done in Europe because of regulatory requirements. What makes the project interesting as a case for the circular economy is that the tobacco is expected to be cultivated as an intercrop improving soil conditions while also increasing farmer income. The harvested tobacco leaves are used to extract the cyanophycin. The by-products of the extraction process are expected to be used as fertilizing material on the farms cultivating the tobacco. The cyanophycin, which is rich in arginin and aspartic acid, can be used as a food and feed ingredient, for developing biodegradable plastics or in medical biotechnology for scaffold production. What makes the case interesting aside from the uncertainties related to the production costs is the implications of regulatory policies on the development of markets for biobased cyanophycin from transgenic tobacco. Will those products be considered to be a GMO in international trade? To what extend do consumers care that a biobased product has been produced for a transgenic crop?

Source: Horizon20202 ERA CoBiotech Project: sustainable co-production.

Many of the strategies further down the supply chain result in further product differentiation. If those product differentiations will be combined with certification strategies, consumers will be able to differentiate and this might result in a higher willingness-to-pay, hence covering additional costs. (See the case study example).

But there are also limitations to such kind of strategies. Revealed preferences often do not show a strong support for environmental good characteristics. The success of voluntary solutions might be limited. Consumers might not be against circular economy strategies, but they prefer those being implemented via policies as observed in other policy areas such as animal welfare policies (see e.g. Uehleke and Hüttel 2019). This moves the choice from the consumer to the policy maker. The live of the consumer will become easier, s/he can simply chose on e.g. prices knowing her basic preferences are met via mandatory production standards, while the live of the policy maker will become more difficult, as s/he needs identify the appropriate policies.

Policy examples include mandatory production standards such as minimum standards of biodegradable components for plastics and plastics for certain products to be 100% biodegradable. A comparison of benefits and costs as well as feasibility of such kind of policies requires further investigation, in particular from an environmental benefit-cost perspective. The policy choice can have implications for the development of markets. In general, voluntary labels for safe product attributes, such as the degree of biodegradability, are preferable over mandatory ones (McCluskey et al. 2018). The standards for labelling are also important: if they are too demanding, the label will not be used and products not produced according to the standard (Castellari et al. 2018, Venus et al. 2018). Labels that are considered signals to consumer environmental friendliness, may not necessary hold-up to that claim. Labelling policies can also be a result of pressure from different lobby groups as the case for GMO labelling in the United States and Europe illustrates (Bovay and Alston 2018, Kalaitzandonakes et al 2018, Lusk et al. 2018, Zilberman et al. 2018). This relates to another important issue and that is the political economy of circular economy policies. Lobby groups do and will continue to influence circular economy policies and they will do this be serving their own interest, which is not necessarily in line with the objectives of circular economy policies.

Other possible policies include the geographical shortening of supply chains such as local purchasing. These policies can be supported by labeling of local products. The certification system at EU level for regional products is one example. These strategies may support the local economy from an environmental point of view, but this might not always be the case. Some products that are produced locally may require a higher quantity of resources being used than imported once. In agriculture differences are often driven by differences in production conditions. Growing cacao or coffee plants in Western Europe might be possible in glass house but requires a substantial higher amount of resource input than growing those crops in Africa or Southern America. The example for cacoa and coffee is a drastic one, where the advantages of importing those products than rather producing them locally are obvious. For other products, the trade-offs are less obvious but need to be investigated as well for identifying the comparative advantages. There seem to be substantial gains to be made from a resource efficiency point of view by making those trade-offs visible. In many cases the benefits from exploiting comparative advantages are not obvious and masked by regulatory policies. A study by Felbermayr and Larch 2013 shows that not much could be gained by removing tariffs, but much more by removing non-tariff barriers (NTBs) to trade as a result of a Transatlantic Trade and Investment Partnership (TTIP) agreement.

The results of the study by Felbermayr et al. (2013) also illustrate one of the possible dangers of a move towards a circular economy, such as policy makers that are tempted to introduce regulatory hurdles that reduce the possibility of exploiting comparative advantages. One possible example is the requirement to use only inputs with a certain percentage of biobased material. This might not necessarily improve resource use efficiency.

In 2018, OECD released the Policy Coherence for Sustainable Development with institutional, analytical and monitoring elements. They show, both national and internationally, the challenges and also the opportunities of the implementation of the

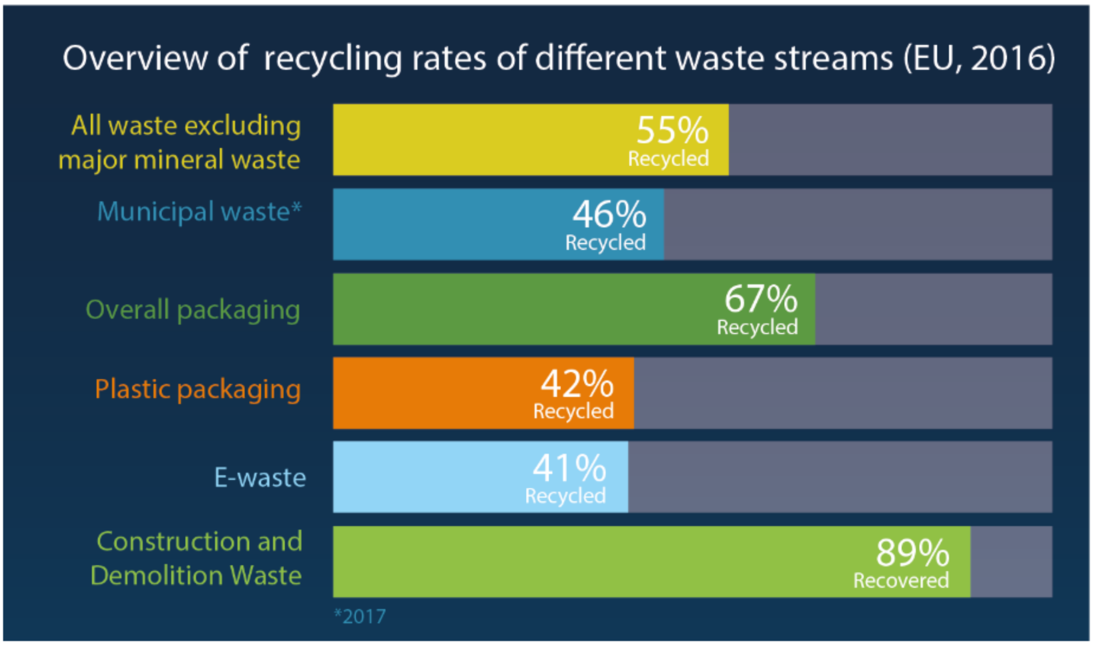
Sustainable Development Goals. The report states that integrated, coherent policies, and strong institutional mechanisms lead to a sustainable and resilient society. Moreover, it provides eight building blocks for stimulation of policy coherence which are political commitment, policy integration which aims for interactions between economic, social and environmental policies, long term planning horizons, the effects of policies in time and location, policy coordination, subnational and local involvement, stakeholder engagement, monitoring and reporting.

Matthews (2007) states that to promote coherence for the agro-food system, countries needs to take into account both improvement in market access opportunities, financial and technical assistance for developing countries and integrated trade objectives to national development strategies. The 2018 OECD agricultural policy report and evaluation states the following policy recommendations:

- Eliminating policies causing disincentives at increasing productivity, sustainability and resilience
- Redirecting the agricultural support in such a way that the society overall benefits.
- Ensuring knowledge transfer and generation between public and private sectors on different levels
- The increase usage of information, education, regulation, payments and taxes, to achieve environmental and climate change goals
- Clear definition between normal business risks and catastrophic risks
- Farm-income support measures by critical evaluation of the overall financial and well-being situation of farm households.
- Better developed policies to match the opportunities and challenges.

Continuing policy reforms along those lines will also be to the benefit of a circular economy.

The success of the policy reforms supporting the transition towards a circular economy requires monitoring the transition. Monitoring the transition is not a trivial task. This requires a precise definition of what is meant by a circular economy, the identification of relevant indicators describing the state of the circular economy and the changes of those states over time for illustrating the developments. Defining and measuring the circular economy in general is well developed with respect to economic indicators. In most cases they lack the link with respect to the material flows. This results in the difficulty of expressing the contribution to the changes in the emission of greenhouse gases, nutrients and more. Further, the rate of reuse of materials is also difficult to deduct from those numbers.



Source: EUROSTAT 2019. https://ec.europa.eu/eurostat/web/circular-economy/indicators

Some steps in that direction have been made by developing and monitoring indicators. EUROSTAT (2019) reports on 10 indicators grouped under four major topics: production and consumption, waste management, secondary raw materials, competitiveness and innovation. The information provides a first snap-shot on the development of the circular economy. These are indicators that are believed if increasing over time reflect a positive development of the circular economy. If this indeed is the case needs further investigation. An increase in recycling rates not necessarily implies a reduction in resource use nor an improvement in economic efficiency. In particular, if some of the recycling activities or the conversion and reuse of biomass are not profitable, one needs to be skeptical if those activities improve overall well-being. This does not imply that those activities move into the wrong direction, but that further improvements (e.g. technical change) are needed. Assessments are complicated by international trade effects, leakage, indirect land-use effects and more.

5. Implications of OECD country policies

The CE receives support at policy level in almost all OECD countries. While the definition of what is meant by a CE differs there are common elements in policy strategies.

Standardization and harmonization of products via certification and labelling systems is expected to increase the market potential for CE products. Standardization and harmonization of products at international level can further contribute to increase the size of potential markets. This might be in contradiction with some CE policies that emphasis local markets and can results in an important trade-off.

New business models for investing in the CE are mentioned by several authors in the literature. They are required as investments in the CE often require a substantial amount of investments and face markets characterized by a high level of uncertainty, including policy uncertainty. This substantially increases the investment threshold. Business models that reduce market uncertainty can increase the stimulus for investment by lowering the investment threshold. Policies can also help lowering the investment costs by simplifying approval systems for new technologies. Appropriate policies include setting voluntary standards supported by a certification and labeling system that is harmonized as much as possible among OECD and other countries. This is expected to increase the market for circular economy products.

Another important policy is to increase investments in research and development of the circular economy. The circular economy very much depends on technical innovations that increase efficiency in resource use, the substitution of fossil fuel based products such as the plastics by bio-based products, and to increase the recycling rate in the economy. The generation of innovative ideas requires investment in specific human capital. This also includes investment in education at university level by providing bachelor and master programs.

For many of the new products developed new business models will be needed. While this is primarily a task of the private sector, government policies can support by making it easier for starting new business by removing regulatory hurdles. The business models provide opportunities for scaling-up. As these are intangible assets the protection of intellectual property rights in international trade the pros and cons of different models to protect IPRs will become important.

A circular economy strategy also requires monitoring for checking if policy objectives are achieved. Monitoring the circular economy is not a trivial task as many of the objectives are difficult to measure. Monitoring requires defining the scope of the circular economy and a set of indicators. In particular deriving indicators that measure circularity is a challenging task. Some indicators have been proposed, but they still have a number of short-comings. Efforts in improving methodologies and providing data-bases for applications are required.

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Box: Impacts of polices on investment in R&D (Adopted from Purnhagen and Wesseler, 2019)

Let F denote the value of the option to invest. The firm has to invest into research, R, for developing the new technology. These investments are paid at the start of the research phase. In addition there are annual research costs r_t, with t indicating time. The time needed to complete research is not known but expectations exist. The time length for this research will be denoted by the random variable $\kappa_1 \in (0, \infty)$. κ_1 follows an exponential failure function with $g(\kappa_i) = h_i e^{-h_i \kappa_i}$ and $E(\kappa_i) = \frac{1}{h_i}$, where h_i denotes the failure rate. At κ_1 an application for approval will be submitted. The submission for approval includes approval costs, A, that are considered to be sunk, and some annual reversible costs a_t. The time length for approval is not known but expectations exist and is denoted by random variable κ_2. At κ_2 the product will be approved for market entry generating a benefits stream, B, expressed in net-present-value terms at time κ_2. Firms may face ex-post tort liability and/or reputation costs, θ, if damages linked to the product introduced occur, again modelled as being random and denoted by κ_3.

The expected value of the investment can be written as follows:

(1) $$E(V_0) = \left\{-R + \int_0^\infty \left(\int_0^\infty \left(\int_0^\infty \left[-\int_0^{\kappa_1} r_t e^{-\mu t} dt - A e^{-\mu \kappa_1} - \int_{\kappa_1}^{\kappa_1+\kappa_2} a_t e^{-\mu t} dt + B e^{-\mu(\kappa_1+\kappa_2)} - \theta e^{-\mu(\kappa_1+\kappa_2+\kappa_3)}\right] g(\kappa_1) d\kappa_1\right) g(\kappa_2) d\kappa_2\right) g(\kappa_3) d\kappa_3\right\}$$

This provides the following solution assuming r_t and a_t are constant:

(2) $$E(V_0) = -R - \frac{r + A h_1}{\mu + h_1} - \frac{a h_1 \mu}{\mu(\mu+h_1)(\mu+h_2)} + \frac{B_0 h_1 h_2}{(\mu+h_1)(\mu+h_2)} - \frac{\theta h_1 h_2 h_3}{(\mu+h_1)(\mu+h_2)(\mu+h_3)}$$

Equation 2 is the expected value of immediate investment. This expectation may change over time. As can be seen from equation 2, if the expectations about the length of the approval process reduces and/or the fixed approval costs are reduced and/or the benefits, B, increase the expected value of the investment increases, while, if the opposite happens, the expected value decreases.

For keeping the model simple, two future possibilities are considered, one, the future looks bright, B is high, B_h, and $E(V_0)$ increases with probability q to $E(V_h)$ and one where the future looks less bright and $E(V_0)$ decreases with probability $1-q$ to $E(V_l)$, $q \in]0,1[$. For keeping the model economical relevant the following is assumed:

Assumption: $E(V_l) < 0 < E(V_0) < E(V_h)$.

Solving the model for a one unit of time, $t=1$, delay such as one year, provides the following solution, with subscript p for postponement:

(3) $$E(V_p) = q\left(-R - \frac{r + A h_1}{\mu + h_1} - \frac{a h_1 \mu}{\mu(\mu+h_1)(\mu+h_2)} + \frac{B_h h_1 h_2}{(\mu+h_1)(\mu+h_2)} - \frac{\theta h_1 h_2 h_3}{(\mu+h_1)(\mu+h_2)(\mu+h_3)}\right) e^{-\mu}$$

The objective of the firm assuming profit maximization and abstracting from potential issues related to competition among firms is as follows:

(4) $$\max F\{E(V_0), E(V_p)\}$$

Equation (4) allows to identify the threshold for immediate investment versus postponement by taking the difference between equation 2 and equation 3. Immediate investment is economical, if:

$$(5) \qquad B_0 > (1 - qe^{-u})\left(R\frac{(\mu+h_1)(\mu+h_2)}{h_1h_2} + \frac{r(\mu+h_2)}{h_1h_2} + \frac{A(\mu+h_2)}{h_2} + \frac{a}{h_2} + \frac{\theta h_3}{(\mu+h_3)}\right) + qe^{-u}B_h$$

If all the costs are normalized to one the weighing factor or hurdle rate for the costs can be summarized as:

$$(6) \qquad (1 - qe^{-u})\frac{(\mu+h_1)(\mu+h_2)(\mu+h_3)+[(\mu+h_2)(\mu+h_3)](1+h_1)+h_1(\mu+h_3)+h_1h_2h_3}{h_1h_2(\mu+h_3)}$$

Equation 6 shows this factor is clearly larger than one. Table 1 shows weighing factors for different parameter values. The second row shows hurdle rates for changes in expected values for κ_1, holding κ_2 constant at E[κ_2] = 10, while the third row shows the hurdle rates for different expected values of κ_2, holding κ_1 constant at E[κ_1] = 10. The expected values range between one and 10 years. This are reasonable numbers. Smart et al.[13] estimated the time for approval of GMOs to be about 6.7 years on average while Fredericks and Wesseler[14] estimated the approval length to be about microbial biological control agents to be about 4.7 years. The reported hurdle rates are substantially larger than one stressing the importance of regulatory policies on investment. The hurdle rates decrease with a decrease in the expected values of κ_1 (κ_2). The last row shows the hurdle rates for zero approval costs.

Table 1. Hurdle Rates for Different Parameter Values

$E(\kappa_1)$	10	5	2.5	1
Hurdle Rate	14.59	10.80	8.91	7.78
$E(\kappa_2)$	10	5	2.5	1
Hurdle Rate	14.59	10.70	8.76	7.59
Hurdle Rate Zero approval costs	8.66	4.88	2.99	1.86

Note: the hurdle rates are calculated applying equation 6. Other parameter values are fixed at μ = 0.04, q = 0.5, $E(\kappa_i) = 10$ if not otherwise.