CIRCULAR IMPACTS

Scenario Analysis for a Circular Economy

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Abstract

Executive Summary

The transition from a linear economy to a more circular economy requires systemic changes involving a wide range of interconnected actors, sectors and geographies. Prospective analyses of the systemic changes required can be carried out via scenario-based approaches. This report examines different approaches to carrying out scenario analyses, wherein not only circular scenario studies are discussed, but also scenario studies on resource efficiency and renewable energy that apply the same type of methodology as needed for circular scenarios.

The paper distinguishes three scenario approaches: opportunity-based, target-based and policy-based. In the opportunity-based approach, a list of cases studies on circular opportunities is developed wherein profitability is an important indicator. The opportunities are sorted from high to low profitability, and an analysis is undertaken of why the opportunities will not materialise in the baseline. The barriers identified indicate opportunities for the development of policies that address these barriers. Some of the scenario studies emphasise that circular opportunities are interdependent. Based on the listing of the circular opportunities to be realised in a circular scenario, an estimate is made of the extra investment needed to realise the scenario. In the report "Methodologies for Measuring the Macroeconomic and Societal Impacts of the Circular Economy" (Deliverable 2.3 of the CIRCULAR IMPACTS project) the calculation of indicators for macroeconomic evaluation has been discussed.

The target-based scenario approach is focused on the way specific targets can be reached. This makes it very suitable for policy makers because many policies are formulated as targets to be attained. The target-based approach typically uses a model. However, to do this, assumptions are needed. For example, the report by the Club of Rome on the benefits of the circular economy (Wijkman & Skånberg 2015) assumes cost neutrality of the new opportunities. Behind such an approach, some attention must be given to the list of available opportunities, while also the policies to be implemented to reach the targets must be kept in mind. Therefore, most target-based scenarios calibrate policies to reach the targets, or list the available opportunities to reach the goals, and therefore are very much related to the other two scenario approaches.

The policy-based scenario approach starts from analysing the fundamental causes behind why circular opportunities are not realised and derives policies from them. The most important types of policy are discussed along with their consequences for changes in the economy. Most policies are implemented through explicit or implicit changes in input-output coefficients or other parameters. The discussion focuses on parameters that will be changed in an economic model and the parameters in such a model that may explain the results. To prevent stranded assets, stability and a good timing of policies is important for optimal results.

The scenarios in the literature are typically informed by the vision of the circular economy transition as a disruptive transition. Authors like Braungart and McDonough argue that one should have an aim more ambitious than reducing pollution, and that a fundamentally new way of thinking is required. This report also examines the role of case studies in the analysis of circular scenarios and the role that circular scenarios may have for the European Semester, the policy process that is the motivation for the investigations

accomplished in the CIRCULAR IMPACTS project in the context of which this report has been written.

The key conclusions and recommendations are presented below:

- The three scenario approaches discussed in the report are distinguished by where they each place their particular emphasis. Each scenario implies insights into both opportunities and policies, even if these aspects are not mentioned explicitly, while all scenarios are evaluated based on indicators that have some relationship with targets to be reached.
- Circular scenarios describe those scenarios that analyse the consequence of specific circular policies or opportunities that are implemented and go beyond expected baseline developments. However, most macroeconomic effects of such policies are the consequence of the productivity increases of new technologies, extra demand because of extra investment, improved information, and tackling regulatory and other barriers that prevent the realisation of circular opportunities. All these policies could also be applied to opportunities that are not specifically circular in character, and therefore those scenarios don't prove that a circular policy is better than an alternative non-circular policy.
- Most circular economy scenarios are implemented in models. Implicit in these models are large numbers of very uncertain parameters that determine how policies and changes work out.
- In practice, the main outcomes from models can be derived relatively easily from the assumptions they are based on and the main mechanisms implemented in the model.
- The main focus on future research should be on empirical research to get better insight into the mechanisms relevant for the translation from circular policy towards macroeconomic and environmental outcomes, which may either be implemented in macro-econometric or general equilibrium models or be used for more causal-descriptive analyses of circular scenarios.
- Targeted case studies may provide important insights into the mechanisms related with the implementation of circular opportunities.
- Scenario analysis of circular economy policies may be relevant for the European Semester. Those policies may influence public finance, macroeconomic imbalances, the need and content of structural reforms and may influence total investment needs.

1 :: Introduction

The transition from a linear economy to a more circular economy requires systemic changes involving a wide range of interconnected actors, sectors and geographies. Prospective analyses of the systemic changes required can be carried out via scenario-based approaches. This report examines different approaches to carrying out scenario analyses. The report is aimed at analysts, business people and policymakers seeking to better understand how scenario analyses can be used to help anticipate and guide the transition to a more circular economy.

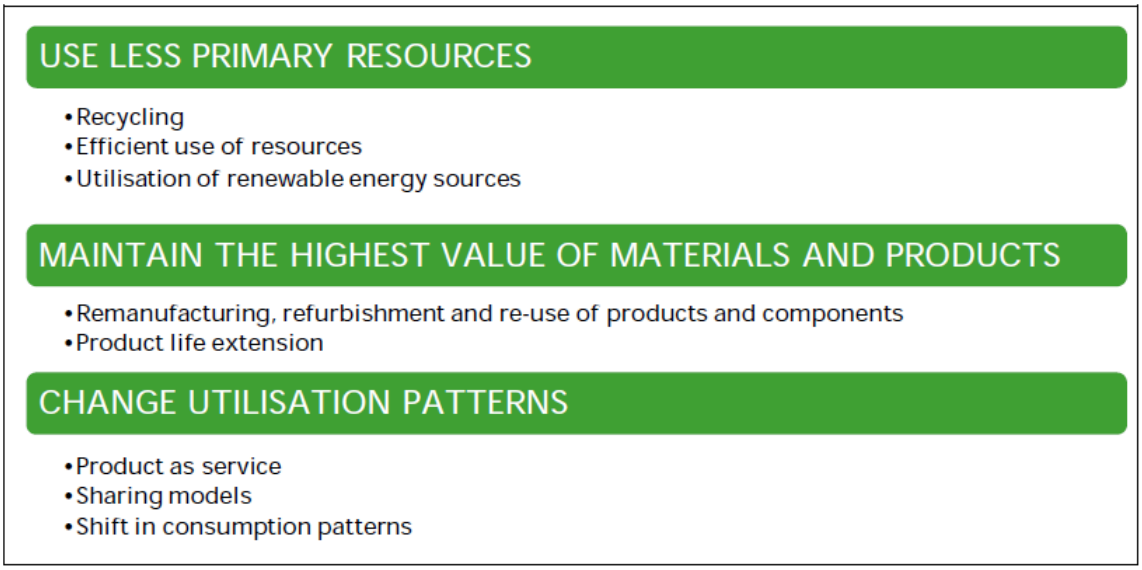
1.1 Definition of the circular economy

In its Communication entitled "Closing the Loop", the European Commission defines the circular economy as one wherein "the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised''. The Communication adds that the transition to a more circular economy would make "an essential contribution to the EU's efforts to develop a sustainable, low-carbon, resource-efficient and competitive economy' (EC, 2015, p. 2)'.

Other definitions of the circular economy include additional notions, such as maintaining the use value of resources and products as well as including renewable energy aspects. In prior work carried out within the CIRCULAR IMPACTS project, the project team reviewed an extensive collection of various circular economy definitions. For an overview of these definitions, see "The Circular Economy: A Review of Definitions, Processes and Impacts" (Rizos et al. 2017).

In this paper, we continue our team's operational definition of circular-economy processes established via the initial scoping work carried out within the CIRCULAR IMPACTS project (see Figure 1).

Figure 1. Main circular economy processes (Source: Rizos, et al., 2017a; Deliverable 2.1 of the CIRCULAR IMPACTS project.



The purpose of a more circular approach is to generate increased human welfare in the long term via reduced emissions and wastes; improvements in natural capital and the environment; and positive consequences for health and well-being. Less pressure on natural resources also reduces the risk of conflicts related to access to natural resources. In some forms of circular economy thinking the purpose is also to improve empowerment of citizens, i.e. fostering a more direct relationship with the production process, less reliance on anonymous markets and more sharing, implying more decentralization. This last line of thinking is defended by specific proponents of the circular economy, for example the blue economy approach, but is also included in policy documents referring to opportunities for social integration and cohesion.

1.2 Policy context

The main policy context for the CIRCULAR IMPACTS project is the European Semester, the yearly cycle of macroeconomic policy coordination between the EC and the Member States, wherein discussion is currently ongoing regarding to what extent circular economy policies should become part of this process. In recent work, the CIRCULAR IMPACTS project team assessed the extent to which the European Semester considers the circular economy, concluding that the European Semester process has so far devoted little attention to the circular economy. For the project team's full examination of these issues, see our report entitled "The Interplay between the Circular Economy and the European Semester: An Assessment" (Behrens & Rizos 2017).

The transition to a circular economy is at its core a transition towards less primary resource use, less pollution and conservation of natural capital. In making a switch of this magnitude, it seems logical that transition costs will be involved, implying stranded assets and unemployment brought about by the decline of some sectors. However, the circular economy is also seen as an opportunity to generate jobs and competitive advantages for Europe over the long term. Therefore, it is important to investigate how the transition towards a more circular economy can generate jobs and economic activity, and to what extent this transition can be organised in a way that helps solve the current macroeconomic problems with respect to employment, monetary stability and growth in the EU. An ability to address such macroeconomic issues would make the circular economy transition very relevant from the perspective of the European Semester.

1.3 GDP and arguments for a circular economy

The well-known study, "Growth Within" by the Ellen MacArthur Foundation (EMF 2015b), on the circular economy estimated an 11% EU GDP increase between 2010 and 2030 for the circular economy scenario, compared with 4% for the current development path. These particular figures have been quoted many times by scientists and politicians. Several other studies reach similar conclusions and are quoted in a similar manner. In Section 1.2, we have also seen that in the EU action plan for the circular economy, GDP and employment growth are important motives. In this section, we argue that instead of focusing on GDP and employment, an impact assessment of a circular economy scenario should be focused on a broad welfare concept that includes environmental aspects.[1]

[1] See Woltjer (2018) for further development of this idea.

As discussed in Section 1.1, the fundamental arguments for a transition to a circular economy are its environmental and natural-resource use benefits. The circular economy is meant to solve a number of externality problems, i.e. external costs due to emissions; reduction in biodiversity; increases in resource mining costs; and the monopoly power positions of resource suppliers. These externalities may have consequences for the health and well-being of current and future generations.

The control over strategic primary resources is often a cause of conflicts. Many wars have been started due to control over primary resources. A circular economy means less dependence on primary resources, and therefore fewer reasons for conflicts and corruption. The existence of natural resources in a country is sometimes called the "resource curse", because most resources are centralised and generate large amounts of rent income that provide power to, in most cases, a limited number of resource owners, thereby generating the possibility for corruption and, as far as government is involved, an opportunity to delay necessary reforms in government finance.

On the other hand, a transition towards a circular economy may, in the short term, increase political instability and conflicts as political power shifts. A circular economy will bring about winners, but also losers in the international political arena. For example, less dependency on oil will be unfavourable for the OPEC countries. Therefore, in a phase of transition, political instability may occur with conflicts as a result.

In policy documents, environmental and geopolitical aspects of the circular economy are often mentioned as an argument for the circular economy. However, subsequently the focus is on economic growth, often measured by an increase of GPD and employment. Despite the fundamental environmental and geopolitical benefits of a circular economy, the focus is on economic policy goals for which the circular economy concept is not developed. There may be good reasons to argue that a fast transition towards a circular economy requires sacrifices in GDP and employment to the benefit of improvements in general welfare. Policies may be implemented to mitigate these negative effects.

The concept of GDP has been developed to measure economic activity, not welfare. From a welfare theoretic point of view, very important parts of welfare, like the value of free time and health, are not included in the GDP concept, whereas the circular economy may also deliver on these aspects. Part of the benefits of the circular economy, like reduction in health care cost due to reduced pollution, will not be measured in standard GDP accounts. Despite this fact, there is a tendency to argue that the circular economy would generate increases in GDP.

GDP is not the right concept to analyse the advantages of a circular economy. A circular scenario that starts from a list of profitable circular opportunities will, by definition, generate an increase in GDP because only profitable opportunities are selected. However, if one would pick from a list of both circular and linear opportunities, GDP growth may be even higher. GDP is useful to measure economic activities, not to measure the welfare benefits of the transformation towards a circular economy.

1.4 Different types of scenario analysis

Scenario analysis may follow different pathways. One is the approach followed by, for example, the Ellen MacArthur Foundation, wherein circular opportunities are listed and sorted based on economic potential. Only the best opportunities are selected followed by a calculation of the economic, employment and environmental benefits of such a scenario.

A second approach sets targets for resource saving, recycling rates and reduction of pollution, changing input-output coefficients consistently and then calculates the consequences of these changes. The mechanisms behind how these resource savings are generated are secondary in this approach.

A third approach is to start with general policies to solve market failures that prevent the implementation of circular opportunities. Examples of this type of policy are green taxation consistent with external costs; abandoning restrictive legislation and making legislation on, for example, standardisation that facilitates circular opportunities; subsidies for research; providing public goods like infrastructure; green public procurement, wherein at least the life-cycle cost-benefit analysis is the foundation of procurement; and providing information services and institutions that make it easier to include long-term effects in private buying decisions. Then, based on the choice of policy instrument(s), an estimate is made regarding what improvements may be generated. This determines the macro effects of the scenario.

In summary, scenarios are sometimes developed as a list of new technologies and policies to be implemented, with any resulting changes in resource efficiency and costs identified, while sometimes the starting point is a particular target with respect to resource efficiency, wherein the policies needed or the technologies developed are not made explicit. A third approach is to t identify solutions to identifiable market failures, remaining open as to what extent the policies needed to solve them will increase or decrease GDP.

1.5 Conclusion and setup of the scenario analysis

Many scenario analyses start with a list of the most profitable circular opportunities and then select only the most profitable ones without checking if there are non-circular opportunities that have comparable or even better benefits. The idea that a circular economy approach is good for GDP growth in the EU is derived from such an approach. The study “Growth Within”, in combination with related reports of the Ellen MacArthur Foundation, provide an excellent and well-developed example of such an approach, but there are many other studies using such an opportunity-based approach to scenario development (Section 2).

The scenario analysis based on resource-efficiency targets will be discussed briefly in Section 3, wherein it is argued that this type of scenario requires elements of both the policy approach to scenarios and insights in opportunities as generated in the opportunity-based approach that is discussed in Section 4.

For the CIRCULAR IMPACTS project, the policy-oriented scenario approach, where the focus is more on the policies than on the circular opportunities, seems the most relevant approach. This is more relevant for the European Semester, which is a central policy context for the project and that is focused on the coordination of economic policies. Section 4 discusses such an approach, wherein it is argued that most policies are implemented through explicit or implicit changes in input-output coefficients. The focus is on coefficients that will be changed in an economic model as a consequence of changes in policies and the parameters in such a model that are essential to explain the results. It is argued that the focus of research must be on empirical research to get better insight into the mechanisms relevant for the translation from circular policy towards macroeconomic and environmental outcomes.

Section 5 briefly discusses to what extent the circular economy transition is a disruptive transition.

Section 6 takes up some issues around the use of case studies in scenario analysis. Case studies may be used to increase insights in mechanisms and parameters that are relevant for the evaluation of the transition towards a circular economy and may be a source of inspiration for the formulation of policies.

Section 7 makes explicit the potential role of scenario analysis of circular-economy policies for the European Semester. Those policies may influence public finance, macroeconomic imbalances, the need and content of structural reforms and may influence total investment needs.

Section 8 summarises some important final thoughts.

2 :: An opportunity-based scenario approach

2.1 Introduction

A number of well-known studies on the circular economy, resource efficiency or energy efficiency start with a listing of profitable business opportunities (Dobbs et al. 2011; IEA 2012; Morlet et al. 2016; EC 2014; Bastein et al. 2013; EMF 2015b; EMF 2017; IEA 2015).

The most widely known study using the opportunity based approach is the "Growth Within" study of the Ellen MacArthur Foundation (EMF 2015b). They start with an analysis of current technological developments and make an explicit description of how the technological developments influence production in the baseline. Some of these developments are already in the direction of more resource efficiency and an increase in energy efficiency. However, to achieve some extra benefits from these new technologies, explicitly mentioned policies are required, including greening of taxation. These new policies generate increases in factor productivity that are explicitly implemented in a CGE model (Böhringer & Rutherford 2015). As discussed in deliverable 2.3 of CIRCULAR IMPACTS, these increases in factor productivity explain the increases in GDP, where independently of this and based on a meta-study on employment effects of the circular economy, the authors argue that employment will rise.

The IEA also uses an opportunity-based approach in its "efficient world scenario" of the World Energy Outlook (IEA 2012; IEA 2015). This scenario "is based on the core assumption that all investments capable of improving energy efficiency are made so long as they are economically viable and any market barriers obstructing their realisation are removed. The scale of the opportunity is determined, by sector and region, on the basis of a thorough review of the technical potential to raise energy efficiency, and our judgement of the payback periods that investors will require in order to commit funds to energy efficiency projects" (IEA 2012, p. 35). This implies that they first analyse available energy-efficiency measures and only afterwards describe policies to realise them (being in the first instance, improvement of information on energy efficiency, then regulation to prevent the sales of inefficient technologies, and thirdly, financing instruments; see p. 297).

2.2 How to create a list of opportunities?

In order to create a list of opportunities, a systematic procedure is required. For example, EMF (2015a) uses a categorisation of types of opportunities summarised with the term RESOLVE, i.e., REgenerate, Share, Optimise, Loop, Virtualise, and Exchange (EMF, 2015a). The categorisation developed in the CIRCULAR IMPACTS project (see section 1,1 and Rizos et al. 2017) could also be used for this purposes. If the list is made, a fundamental question must be asked: why did the opportunities not materialise if they are already economically attractive (EMF, 2015b, p. 20)? Therefore, for each opportunity, the barriers must be listed, based again on a checklist such as, for example, described in Section 2.3 of Deliverable 2.3 of the CIRCULAR IMPACTS project (Woltjer 2018), including its importance and the precise character of the barrier.

For example, technology opportunities may be untapped simply because they are new, such as the reduction in the transaction costs of sharing and virtualisation of business models through smartphones and Internet; increased possibilities for recovery because of track and trace systems through the Internet of Things and improvements in waste technology. Administrative and legal barriers may exist because procedures were developed for older technologies or because collaboration in creating new infrastructures may be difficult due to competition laws. Unpriced externalities or externalities created by subsidies may also be a barrier. Sometimes, just the development of a measurement system for circular performance is needed, both in national accounting and in business administration. Related with this are also old customs and habits that may retard adjustment processes (EMF, 2015b, p. 22).

2.3 Representing the changes in technology

The transition towards a circular economy and the policies to accomplish this transition generate changes in technology. This implies that the input coefficients, i.e. the coefficients that represent the amount of input needed per unit of output, will change and also the emissions or unpriced natural capital used per unit of input or output will change. Some studies, like EMF (2015) translate the conclusions from their study on the circular transition into assumptions about input coefficients for a circular scenario compared with a business-as-usual scenario. Table 2 from Böhringer & Rutherford (2015) illustrates this for the transport sector. A distinction is made between private and external costs. The technological parameters for the costs in the transport scenario are formulated as a percentage of the costs in the business-as-usual scenario. In this example, the vehicle costs are reduced by 7%, while oil costs are reduced by 20%, wherein part of this cost implies a substitution towards electric cars, so electricity costs are increased. Maintenance cost remains the same, while in this case, also the private cost of transport time is included as a transport category and this is in the transport scenario reduced by 4%. If input prices do not change, the private cost index for transport can be calculated as the weighted average of these input-cost reduction changes, wherein the weights are the costs in the benchmark equilibrium, i.e. the situation in the baseline projection in a specific year. If input prices change, this will also influence private cost.

Table 1. Illustrative input assumptions for technology shift scenarios in private transportation (adapted from: Böhringer & Rutherford 2015)

N.B. Benchmark data are given in % of total private consumption, while transport cost is formulated as percentage of benchmark cost

	Total private cost					**Private cost index**
	Direct cash out cost for transport					
	Vehicle cost	Oil use	Electricity use	Maintenance cost	Transport time	
Benchmark	4.72	2.98	0.01	3.6	9.26	
Circular transport	93	80	107	100	96	97.7
	Total external cost			**Total cost index**	**Income and price elasticities**	
	infrastructure and governance	accidents, pollution and noise	external time		Own price elasticity	Income elasticity
Benchmark	6.1	2.23	3.97		-0.3	0.5
Circular transport	97	96	96	97.5	-0.3	0.5

The external costs are derived in the same manner, and in the end, the total cost reduction is calculated as the weighted average of private and external costs. This total cost index conveys how much cheaper the circular alternative is compared with the business-as-usual scenario.

One must be aware that changes in costs depend on prices. If, for example, the policy implementation to stimulate electric-vehicle use is taxation on oil, then the price of oil increases and, therefore, the change in oil costs is larger. Furthermore, the increase in electricity use may increase or reduce the price of electricity with consequences for the net benefits of the circular alternative.

Given these changes in cost, the own-price elasticity and income elasticity determine the direct and induced rebound effect. The own-price elasticity is the indicator that calculates how much of a cost reduction in transport is translated into extra demand for transport, while the income elasticity tells how much of the increase of GDP that is generated is translated into extra demand for transport.

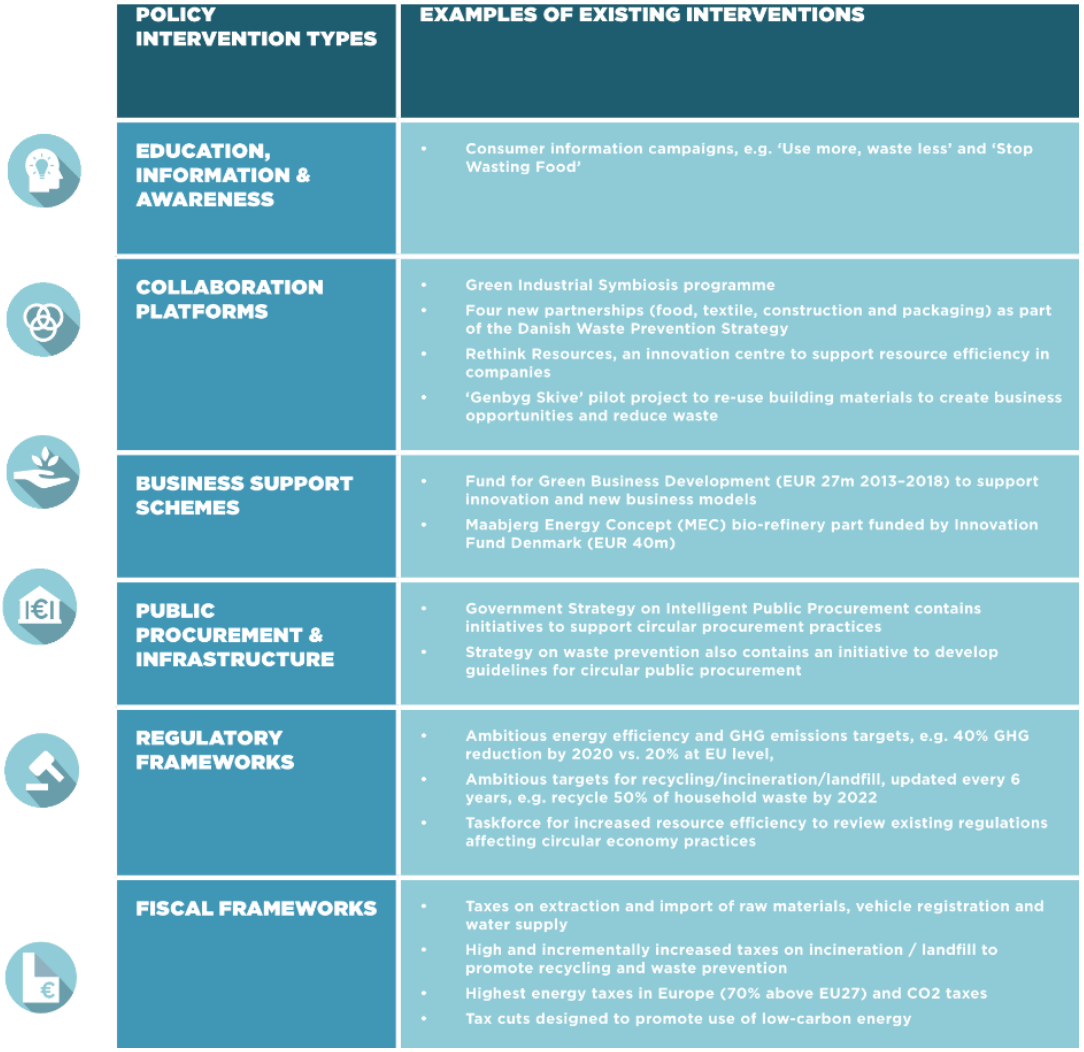
Next to the coefficients that represent input use per unit of output, one may also define coefficients of environmental variables per unit of input or output. The transition towards a circular economy may also change these parameters.

Cost reductions calculated only by technology change may overestimate the benefit if new technologies are applied on a large scale, in cases where the prices for the inputs used for the new technology increase with larger demand. If productivity is higher, this may translate in higher wages and higher profits if it happens in one sector. If the change in input and environmental coefficients is implemented in a macro-econometric or general equilibrium model, such a model can potentially calculate consequence for GDP, employment, import, export, investment, employment and environmental variables. These results depend on the price and income elasticities, but also for example on import elasticities. However, if one knows the most important model parameters, one may get a rough impression of the macro effects by simple calculations.

2.4 Listing of policy options

An important step in the analysis is the listing of policy options to realise the circular opportunities. While many reports (OECD 2011; UNEP 2017; UNEP 2011) start with pricing of externalities as the first policy instrument to realise a sustainable economy, many practical policy approaches to the circular economy (see for example the Dutch policies in Ministry of infrastructure and the environment & Ministry of economic affairs (2016) and also for example the approach by the Ellen MacArthur Foundation (EMF 2015a) have a primary focus on circular opportunities that are also beneficial from a private perspective and therefore start with information and collaboration options, followed by positive incentive schemes. The options that seem to be most suitable for correcting externalities like regulation and fiscal incentives are at the end of their list (see Figure 2).

Figure 2. Policy options (source: EMF, 2015a)



POLICY INTERVENTION TYPES	EXAMPLES OF EXISTING INTERVENTIONS
EDUCATION, INFORMATION & AWARENESS	• Consumer information campaigns, e.g. 'Use more, waste less' and 'Stop Wasting Food'
COLLABORATION PLATFORMS	• Green Industrial Symbiosis programme • Four new partnerships (food, textile, construction and packaging) as part of the Danish Waste Prevention Strategy • Rethink Resources, an innovation centre to support resource efficiency in companies • 'Genbyg Skive' pilot project to re-use building materials to create business opportunities and reduce waste
BUSINESS SUPPORT SCHEMES	• Fund for Green Business Development (EUR 27m 2013-2018) to support innovation and new business models • Maabjerg Energy Concept (MEC) bio-refinery part funded by Innovation Fund Denmark (EUR 40m)
PUBLIC PROCUREMENT & INFRASTRUCTURE	• Government Strategy on Intelligent Public Procurement contains initiatives to support circular procurement practices • Strategy on waste prevention also contains an initiative to develop guidelines for circular public procurement
REGULATORY FRAMEWORKS	• Ambitious energy efficiency and GHG emissions targets, e.g. 40% GHG reduction by 2020 vs. 20% at EU level, • Ambitious targets for recycling/incineration/landfill, updated every 6 years, e.g. recycle 50% of household waste by 2022 • Taskforce for increased resource efficiency to review existing regulations affecting circular economy practices
FISCAL FRAMEWORKS	• Taxes on extraction and import of raw materials, vehicle registration and water supply • High and incrementally increased taxes on incineration / landfill to promote recycling and waste prevention • Highest energy taxes in Europe (70% above EU27) and CO2 taxes • Tax cuts designed to promote use of low-carbon energy

In order to evaluate policy options for the circular economy, EMF lists for each opportunity the baseline policies as well as the extra or different policy options needed to realise the circular opportunities in the circular scenario. However, characteristic for the opportunity based approach, this list of policies has no consequences for the calculated benefits, assuming that the costs generated by policies to implement the opportunities are low compared with the benefits that are generated. This is for example also explicitly stated by IEA (2012) for their Efficient World Scenario.

2.5 Interrelationships between sectoral opportunities

In many studies and policy reports, the transition towards the circular economy is seen as a system change. One reason behind this may be that the benefits of many opportunities in the circular economy depend on the realisation of other circular opportunities. For example, if transport is electrified, this will have benefits for the reduction of pollution in cities, but the benefits for greenhouse-gas emissions may be limited as long as electricity is produced by fossil fuels. Therefore, the benefits of electric

transport depend on greening of electricity production. However, greening of electricity production implies that electricity is more difficult to adjust to supply, where intelligent timing of charging (and even discharging) of batteries in electric cars can be an important manner to store electric energy, implying that part of greening of the electricity system depends on electrification of electric cars (Cambridge Econometrics 2018).

Another example is in the study "Growth Within" of the Ellen MacArthur Foundation (EMF 2015b). In their circular scenario, policies focused on making public transport more attractive in combination with the technological development of autonomous cars reduces demand for privately owned cars because the autonomous cars can function as cheap taxis, where the University of Texas at Austin suggests that Austin could meet all mobility needs with 10% of the current car fleet by using autonomous vehicles (EMF 2015b, p. 61). If this is true, a lot of space would be freed in cities that could be used for more sustainable housing and greening the city. By producing more food in and near the city due to the freed space, less land expansion is needed for agricultural production and the cost of fresh food in the city may be reduced, increasing health. As far as the freed land is used for concentration of buildings, this may increase agglomeration benefits such as smaller transport distances.

2.6 Investment

The circular economy (or resource efficiency or energy) transition require extra investment. The opportunity-based approach provides a relatively easy means of estimating these extra investments, because the case studies behind all the opportunities and the calculation of the profitability requires insights into the investments needed.

For example, EMF (2017) estimates the extra investment needed to accomplish the circular transition defined in their "Growth Within" study. This is based on the listing of circular opportunities in EMF (2015b), and in this manner can be calculated relatively easily (p. 12). Based on EMF (2015b), they distinguish 10 investment themes (p. 57): integrating mobility systems; designing and producing circular cars; remanufacturing car parts; deploying regenerative agricultural practices; closing nutrient loops; farming through indoor urban farms; developing new protein sources; designing and producing circular buildings; closing loops in the building sector; and developing circular cities. It is obvious that all these investment opportunities are based on explicit assumptions about how the circular economy will develop and are still highly speculative. The cost analysis shows that profitability is normally not an issue for these investment opportunities, while the other barriers can be solved with modest policy reforms (p. 11).

One may argue that at this moment, with excess liquidity in many firms and very low interest rates, the EU has economic problems of underinvestment. Therefore, potentially the economy can be boosted by extra expenditures through investment (EMF 2015b; OECD 2017). At this moment, many investments are not profitable for private firms, but EMF suggests that with policies that are more consistent, these problems can be solved (p. 43). First, they suggest setting direction and showing commitment through targets, strategies, public investment, consistent international trade agreements and covenants with industries. Second, they suggest removing regulatory barriers. Third, they suggest the creation of platforms for dialogue, cooperation and awareness. Fourth, they suggest focusing public procurement, public circular investment and financial support on the circular themes.

EMF (2017) recognises a synergy between the EU digital agenda and the circular economy transition (p. 52). First, product IDs may reduce transaction costs for secondary markets and recycling. Second, IT may generate open platforms for trade in secondary materials. Third, IT may make it possible to develop a circular evaluation and measuring system. The last may help to monitor progress on the circular economy, but we might add, also generates the possibility of reducing transaction costs for taxation of externalities.

EMF (2017) refer to the risk of stranded assets should their projected transitions actually materialise. Reduction in demand through more office and car sharing as well as teleworking, and an increase in the lifespan of assets may generate excess supply in a large number of sectors, thereby putting pressure on prices in these sectors and reducing sales. This will reduce the value of those firms (EMF, 2017, p. 38, 40). They suggest that externalities in raw materials and fossil-energy production are very large (13% of GDP being greenhouse-gas emissions, overuse of water, negative land use effects, air pollution and waste generation) and if these would become priced, most production in these sectors would not be profitable anymore (EMF, 2017, p. 38). It is obvious that one cannot directly look at profitability at current prices, because if externalities would be priced, prices would be higher. However, with externalities priced, circular alternatives would become more competitive.

2.7 Conclusion

The opportunity-based approach starts with an explicit formulation of circular opportunities. The baseline consists of options that will be realised under current circumstances, while the circular scenario implements the options that become profitable or will be realised if government develops a package of circular-economy policies. From the circular opportunities identified, opportunity-specific policy options are derived. The calculations made in these types of scenario studies are based on the opportunities, not the policies, assuming that the cost of the policy will be lower than the benefits in terms of GDP. The approach shows that a list of circular opportunities exists, wherein the benefit crucially depends on the correctness of the cost and revenue estimates made for the different opportunities.

If the list of circular opportunities is correct and the assumption is correct that the policies are less expensive than the benefits of the opportunities and don't generate negative side effects, then such a list shows that GDP can rise by making the economy more circular. However, it is also obvious from such a list that if the targets for the circular economy become more ambitious, one is forced to also realise opportunities that reduce overall GDP. This is consistent with the conclusion of EC (2014) based on a model simulation that resource-efficiency improvements can be realised with a GDP increase while a more intensive policy will be at the cost of GDP.

The list of profitable circular opportunities shows that there are circular opportunities that when realised increase GDP, but does not show that this list is better from a GDP growth point of view than a more general list including both circular and non-circular opportunities.

3 :: A target-based scenario approach

3.1 Introduction

Instead of starting with profitable business opportunities to develop a scenario with a high potential for positive growth effects, one can also start with setting explicit targets for resource saving, recycling rates and/or reduction of pollution and then analysing how the targets can be realised (CE & BioIS 2014; Wijkman & Skånberg 2015; Meyer et al. 2015; OECD 2017; Hartley et al. 2016; Masui 2005; UNEP 2017).

3.2 Examples of target-based scenario studies

The report by the Club of Rome, entitled "The Circular Economy and Benefits for Society" (Wijkman & Skånberg, 2015) follows the target-based approach. The essence is that the circular economy is broadly defined as a regenerative economy, wherein energy efficiency, renewable energy, and material efficiency are included along with increased use of secondary materials and increasing the useful life of long-lived consumer products. The report analyses the carbon and employment effects of a scenario consisting of a 25% increase in energy efficiency, cutting fossil-fuel use in half and substituting it with renewable-energy sources (wind and solar energy, but also biofuels--of which the environmental effects are not certain--are included), increasing material efficiency by 25%, replacing 50% of virgin materials by secondary materials, and doubling the product life of long-lived consumer products (p. 6). The report uses an input-output model and generates mainly employment effects and trade-balance effects, neglecting feedbacks. Extra investment as well as the higher labour intensity of circular and energy-saving techniques generate employment.

The policies assumed are current measures like support systems for renewable energy, emission trading, further development of the Eco-design Directive, energy-efficiency standards, targets for recycling of materials, etc. (p. 9). Also included are public procurement, earmarking investment by EU funding schemes in the direction of resource efficiency, resource-efficiency targets for critical raw materials, promotion of new business models focused on sales of the services of products. Rethinking taxation is necessary (greening), and they suggest an exemption of VAT for recycled materials (p. 9).

The study lists several sectors needing circular-economy investment: agriculture, forestry, timber, pulp, paper for bio-based products and biofuels; installation services to increase energy efficiency and renewable energy sources, sustainable infrastructure, especially for mass-transport systems, electric vehicles and charging systems for them, maintenance and repair, recycling and development for material efficiency, engineering services and education for new competences and product design (p. 10). Their input-output model assumes that extra investments generate extra employment by assuming that investment for the circular economy is additional to baseline investment and that sufficient suitable unused labour is available to absorb the extra demand for labour. Basically, investment functions as a demand shock in a system with Keynesian unemployment. Obviously, even were total investment to remain the same, but investments are in more labour-intensive industries, total labour demand could also increase.

Wijkman & Skånberg (2015) assume that total production in the economy remains the same, implying cost neutrality, and that demand is simply satisfied in a different manner. No cost-benefit analysis of different circular options is made to underpin this cost neutrality; it is just an assumption. This is in contrast with many scenarios, like that of the Ellen MacArthur Foundation, that assume increases in productivity and therefore increases in GDP. Though policy instruments are discussed, these policy instruments are not used in their modelling.

The study for the European Commission by Cambridge Economics and Bio Intelligence Services also takes a target-based approach (CE & BioIS, 2014). Their method is relatively simple. A baseline is the starting point, and compared with the baseline, increases in resource productivity for different sectors are defined, wherein cost curves are estimated. Increases in resource efficiency are based on changes in prices (through environmental taxation) and R&D expenditures, and the relevant functions have been estimated. The extra investment generates extra employment and growth in the first instance, while the environmental tax reform generates extra employment through recycling of tax income in the labour market. The precise source of the changes in resource productivity is not made explicit, and therefore it is a very general type of scenario analysis. The focus of the study is on resource productivity, one of the targets of a circular economy, but it is not made explicit to what extent circularity plays a role in this increase in resource productivity.

Although the starting point of the CE & BioIS (2014) study is a target on resource efficiency, the implementation is through pricing and R&D investment and therefore is consistent with the policy oriented approach described in the following section (Section 4). This is in contrast with the Wijkman & Skånberg (2015) approach where no attempt is made to model the policies behind the transformation.

The ambitious climate scenario of (UNEP 2017) "assumes that resource use follows historical trends, but that the world shifts decisively to a 2˚C climate pathway, involving more ambitious emissions reductions. The modelling imposes stylised global abatement policies that are calibrated to achieve global emissions that match cumulative emissions in RCP2.6 to 2050. This is the lowest of the four IPCC benchmark trajectories, with around a 50:50 chance of limiting temperature increases to 2˚C above pre-industrial levels. With the target set and the model calibrated with policies to achieve the target, it becomes in the end a policy scenario.

3.3 Conclusion

The sketch of the target-based approaches shows that the results may depend on a priori assumptions about changes in technology, which is not very satisfactory from a theoretical point of view. However, most target-based scenario studies solve this problem either try to reach a target based on a choice of available technological opportunities or on a specific set of policies, wherein the policies are calibrated in such a manner that the targets are reached. For this reason, large parts of the insights from the opportunity-based and policy-based approaches are also valid for the target-based approach.

4 :: A policy-oriented scenario approach

4.1 Introduction

A number of studies (Distelkamp 2012; International Resource Panel ed. 2016; Lovins et al. 2016; Hu et al. 2015; Meyer et al. 2015; Schandl et al. 2016; UNEP 2017) start with policies, which is the focus of this section. However, policies are also needed to realise opportunities and targets and therefore should be included in all scenarios. In several studies, some policies are included either implicitly or explicitly in the scenario studies. The greening of taxation is in many studies one of the main causes of generating economic growth by greening the economy.

In this approach, it is not automatic that GDP increases, however. For example, the German energy transition (*Energiewende*) has reduced GDP because at the when that change in policy was initiated, green energy was still more expensive than grey energy, requiring increases in electricity prices to pay for the difference in cost. Such a policy may or may be good from a welfare point of view, but it is certainly negative for GDP growth in the short term (Böhringer et al. 2013). Such a policy is by definition not selected in the opportunity-based approach discusses previously, wherein only profitable circular opportunities are chosen.

4.2 Analysing different types of policy

4.2.1 Introduction

As the case studies in the CIRCULAR IMPACTS project and a lot of other research show, there are very large numbers of potential technological and business opportunities that may result in lower resource use and reduced pollution. It is not clear a priori, which of the potential trajectories are the best. For this reason, it may be best if government sets the targets to be reached, but to the extent possible, leaves technology choices open to competition (Coady et al. 2015). From that perspective, if there are externalities that partly or completely explain the environmental or resource problem to be solved, then the first solution to search for is internalisation of external effects through taxes or changes in property rights such as the extended producer responsibility of firms. However, when these solutions are not suitable because the cause of the problem is different or the transaction costs are too high, then one must search for other solutions. For example, network effects may require specific coordination, while infrastructure or fundamental research are public goods that are not supplied sufficiently because large parts of the benefits will not flow into the pockets of the actors who pay for the costs. Mazzucato (2013) argues that a large portion of research benefits are paid in practice by government, and therefore it is not logical that firms get full patents for technologies that were generated by government results. This line of argumentation by Mazzucato may be seen as an argument to rethink patent law and intellectual property rights.

One of the issues to take into account in the development of a circular economy scenario is that circularity is not the final target of the circular economy. The circular economy is meant as a means to reduce external costs with respect to resource use, natural capital stock and pollution, not as an end in itself. Therefore, one has to search for minimizing losses of resources and natural capital, and minimizing pollution, and the optimal amount of circularity to achieve this.

4.2.2 Environmental taxes

The existence of externalities is seen as one of the important barriers towards a circular economy. A straightforward method to address this issue is to introduce green taxes equal to the externality. Green taxation is one of the main arguments behind the idea that green growth is possible, i.e. that economic growth can be combined with greening the economy (Schmalensee, 2012). The fundamental idea is that green taxes are a source of tax income that is less distortive than taxes on labour, which implies that greening the tax system can be beneficial even if it has no benefits from the perspective of greening the economy, as long as the marginal green taxes are less distortive than marginal labour taxes (Franks, Edenhof, & Lessmann, 2015). As long as greening the economy is accomplished through taxation, it is generating tax income instead of requiring subsidies.

Environmental taxes may also be used for other purposes than a reduction in labour taxes. If a country has structural government-budget deficits, the tax income may be used to reduce the government deficit. Another important use of the increase in tax revenues is implement policies that increase environmental investment or increase R&D focused on the circular economy (see, for example, CE & BioIS (2014)). In order to analyse the combined effects of environmental taxation and investment in circular research projects or circular infrastructure, functions must be known regarding how the sectors and the economy react on changes in relative prices and increased expenditures on research. For this purpose, CE & BioIS (2014) estimated research and price elasticities for environmental production.

As an example of the use of environmental taxes in a green-growth strategy, we may consider Bouzaher et al. (2015). They simulate a circular-economy scenario for Turkey wherein environmental taxes on particulate matter (PM10), industry and household waste, industry and household water pollution and carbon taxes increase the total environmental tax income from a level of 2.83% of GDP in 2015 to 9.36% in 2030 (p. 60). The environmental taxes are based on estimated external costs, and it is suggested that much higher environmental-tax increases are possible. This suggests that the current average environmental tax in the EU of about 2.4% of GDP (EUROSTAT 2017) would have to be increased significantly to take into account all externalities and that the impact on government finance would be substantial.

If environmental taxes are introduced and the government budget is targeted to remain neutral, then other taxes may be reduced, or expenditures may be increased. Bouzaher et al. (2015) develop a scenario wherein environmental tax income is used to pay for productivity-enhancing R&D and to create green jobs in waste, water and pollution abatement activities (p. 56). By assuming that these green jobs are additional to current employment and by assuming a high return on R&D investment, the negative consequences of taxation for GDP are translated into positive GDP effects. However, even if environmental taxes would generate negative GDP effects because the tax income is spent by government for non-productive purposes, the increase in welfare may be positive if the health effects of less pollution are monetised.

Bouzaher et al. (2015) calculate their results through a general equilibrium model that, as is typical, has many implicit assumptions about trade, consumption, substitution elasticities, labour market flexibility, abatement cost curves, etc. These assumptions can, at the same time, be seen as requirements for further investigation. An important policy issue is to what extent increases in environmental taxes will have negative consequences for international competitiveness. In economic models this is implicitly calculated based

on the import functions (in most cases Armington functions) that are notoriously difficult to estimate and therefore have a weak empirical foundation. Therefore, it is important to assemble evidence regarding to what extent higher environmental taxes or stricter national or European environmental regulation will lead to the movement of polluting sectors outside the country or the EU. On the other hand, these extra regulations and taxes may stimulate innovation in the sectors to mitigate the cost increases (the Porter hypothesis), and in this way may prevent this international mobility and may even improve competitiveness if the same type of environmental taxation and regulation would be introduced in other regions of the world. Some studies suggest that the effect is relatively small (Thomas et al. 2015; Flues & Lutz 2015), where Vollebergh et al. (2014) suggest that currently many environmental tax exemptions that are meant to prevent employment leaving the country are in practice on sectors that are not competing on international markets. Therefore, in order to investigate the opportunities for green taxation and stricter environmental regulation, a lot of research is needed. Running a general-equilibrium or econometric model is no substitute for this, because the relations in these models are based on rough assumptions and many of the dynamics is too complex to estimate econometrically.

Decisions to use sharing are partly determined by relative costs of labour and raw materials. In many cases the decision not to recycle, reuse or share is based on a rational cost comparison. In many cases, the labour cost for repairing a product is higher than the cost of buying a new one, where factors such as fashion, addition of new features, higher energy-efficiency of new products may also make the utility of a new one higher than continuing the use of an old one (UNEP 2017, p. 163). Therefore, it may stimulate recycling if the relative cost if labour used for circular activities would be lower. Empirical analysis would be necessary to know the size of this effect.

4.2.3 Regulation

Although environmental taxation (and abolishment of perverse subsidies) seems a logical road towards a welfare-enhancing circular economy, it is not possible to correct all externalities through taxation. Precise targeting of externalities has important transaction costs and this may sometimes make taxation not suitable. Furthermore, not all decision makers are able or have the information to make rational decisions. Therefore, also direct regulation may be an important way to realise environmental targets. For example, investments in a sustainable house may be profitable in the long term because reductions in energy and maintenance costs may more than compensate the extra investment costs, while the focus of people buying a house is in the first instance on the investment costs of the house. Banks financing the mortgage for the house are also inclined only to look at the size of the mortgage payments required and not the long term profitability of the investment. If governments are better able to make such an evaluation then they may design minimum standards for energy efficiency and quality requirements for new and renovated buildings. Those building requirements may change with available technological possibilities. For environmental effectiveness, it is important that the regulation is focused as much as possible on the environmental performance of technologies and does not benefit specific technologies to accomplish these environmental requirements.

There are different types of regulation relevant for the circular economy. One important and obvious one is the definition of property rights (Coase 1960). The existence of externalities may be caused by the fact that the one who uses the natural resources to

produce a product is not responsible for the whole life cycle of the product. One step in changing property rights is to make the seller of a product responsible for defects in the product. Some EU policies focus on the extension of obligatory-guarantee periods, solving the problem that the buyer has in many cases insufficient information about the quality of the product that is bought. A step further is to make the producer also responsible for the processing of the product after use. This extended producer responsibility is already introduced in some way for producers of electrical products. Such an extended producer responsibility may go further towards the requirement that the product should be designed in such a manner that no toxic substances are included or that it is possible to recover all scarce materials used.

A fundamental problem in re-using parts and creating markets for spare parts is a lack of standardisation. Therefore, as with all markets, it is important that in some way standards are set that make it easier to repair, to remanufacture and to re-use parts. One must be aware that each standard implies a choice that restricts the freedom of choice for specific technologies. Choice of standards may reduce costs, simplify markets and increase recyclability, but it reduces also the possibility to develop tailor-made solutions. For example, buildings and cars can be made lighter if thickness is adjusted to the places where forces are strongest, but this implies that for each application a different form is required, which makes standardisation impossible (UNEP 2017, p. 156). This implies that optimal standardisation requires a type of cost-benefit analysis to analyse the trade-offs.

Use of toxic materials is a specific problem for increasing circularity in the economy. Pollution with toxic materials makes recycling difficult and may generate health problems. The list of toxic materials is very large, and it is not always known which materials are toxic. In order to reach a future world with a minimum of toxic materials, regulation would have to become gradually more restrictive. Toxic materials could be banned when substitutes in a broad sense become available at acceptable extra cost. This may be combined with a gradually increasing tax on the inclusion of toxic materials. Therefore, reduction of toxic materials may be set through standards that evolve with technological possibilities and requires cost-benefit analysis for optimisation.

As discussed in the analysis of environmental taxation, not having circular behaviour can be based on a more or less rational cost-benefit analysis. One of the possibilities to reduce these costs is a more circular design of products. However, buyers must be aware of these benefits at the moment the new product is bought. Imperfect information about the circularity of the product makes this difficult to evaluate for individual decision makers. Therefore, it may be useful to increase information about circularity of new products through labelling or even to set standards for circularity of a product, for example with respect to modularisation and ease of disassembly and recycling.

For recycling, it is essential that different materials can be easily separated and this implies also that the materials used are explicitly known. New IT technologies make it easier to create such a track-and-trace system of materials, but regulation is probably required to standardise the information and to require that the relevant information is publicly available.

The European Ecodesign Directive (2009/125/EC) gives a framework to set mandatory ecological requirements. It is primarily focused on energy, but in the EU Action Plan for the Circular Economy it is suggested to extend it to circular requirements. The Ecodesign Directive is only a framework; the effective regulations are set through explicit laws that ban all non-compliant products from being sold in all Member States.

In economic models, one may implement changes in regulation as changes in available techniques, for example through adjustment of the input coefficients. This requires insight into the technological possibilities available and the consequences if you reduce one input or environmental coefficient for the use of other inputs. One must be aware that changes in the input coefficients as a consequence of environmental policy normally implies an increase in cost price. Also abatement cost curves may be developed to organise this information. When the changes in input coefficients are known, we are back to the analysis of the consequences of input coefficients as discussed in Section 3.3.1.

4.2.4 Infrastructure

The introduction of new business models requires the introduction of new infrastructure. For example, in order to make electric cars generally accepted, a network for battery charging must be available. In order to use the storage capacity of batteries and to adjust electricity demand and supply to each other, an intelligent network has to be available that can be used by everyone. In order to introduce electric trucks, the highway system must be electrified (Wijkman & Skånberg, 2015; Scania, 2016). Public investment in infrastructure or at least strong coordination by government is required to realise the infrastructure needed for these circular opportunities.

The consequence of investment in infrastructure is that the costs and benefits of using different techniques are changed. This means that the input coefficients for different techniques or the utility of different commodities and services will change. For example, a better infrastructure for secondary materials will reduce input costs of these secondary raw materials. If a low-cost and fast electricity infrastructure for electric cars is available, this will reduce the cost and increase the utility of using electric cars. An intelligent electricity infrastructure makes it cheaper to store electricity and to adjust demand of electricity to supply. In summary, also investment in infrastructure can be seen as changes in input coefficients.

4.2.5 Technology policy

Technology development has positive externalities: the benefits from innovations diffuse to other companies that will also get part of the benefits, and to consumers who pay lower prices should competition increase. Therefore, there is an argument to partially finance technological innovation by government. Mazzucato (2013) argues that most important technologies are in the end largely developed with government finance, and that without government finance, fundamental breakthroughs will be much more difficult to accomplish. For example, yield growth depends highly on government involvement in research and diffusion of new technologies (Mogues, et al., 2012).

However, there is also a risk that government picks the wrong pathways for further development and that it is more guided by intelligent interest groups seeking rents from government funds instead of picking the optimal new technology trajectories. Furthermore, even if government were involved in important technology trajectories that turned out to generate new developments, this does not mean that it would not have happened without government intervention, or that not a lot of government finance went into dead ends.

In summary, government involvement in technological development seems crucial for the development of new opportunities, but it is difficult to prevent that part of these funds are spent to the benefit of rent-seeking agents. In order to capture the consequence of innovation policies it is important to get insights into the relationship between policy and

innovation activities and the relationship between innovation activities and the change in input coefficients.

4.2.6 Information and coordination

Current policies are largely focused on coordination and information issues, including education. This is based on the idea that opportunities exist that are beneficial for everyone, but which have only to be grasped. However, even in combination with other policies, awareness and coordination will be important, while for example “green deals” may be used to get relevant information for removal of legal barriers and the design of enabling legislation for the implementation of circular importunities. All these measure imply that perceived costs can change, and this may influence the choice of circular techniques. These type of policies may be modelled by adjustment of input and environmental coefficients.

4.2.7 Conclusion

A circular scenario based on policies requires that the input and environmental coefficient changes are explained by the policies implemented. Furthermore, the changes in input and environmental coefficients will change the economic system and essential mechanisms that determine this change have to be analysed carefully. Price and income elasticities are relevant in this context, but also import and export elasticities, substitution elasticities and many detailed insights into practical consequences of changes in institutional settings. The analysis of plastic recycling and bioplastics by Verrips et al. (2017) is illustrative in this context.

4.3 Timing and stability of circular policies

Policies cannot always be changed quickly because investment decisions must be based on long-term expectations and this will become much more difficult or almost impossible if one cannot rely on property rights and other government policies. Due to sudden policy changes, assets may become stranded, and this will not only generate losses but may also have as a consequence that people have reduced trust in government actions. Trust is a fundamental asset and this requires that policy changes do not generate unpredictable losses. Therefore, a transition path is needed to prevent large adjustment costs and disruption of trust in society.

4.4 Conclusion

Analysing a circular scenario based on policies requires that the input and environmental coefficient changes are explained by the policies implemented. When insights into changes in technology are assembled, consequences for the economy depend on a number of essential functions. An important one is how trade is changed with changes in cost profiles and a related one is how innovation may mitigate some of the disadvantages generated by regulation and taxation. Income and price elasticities determine the consequences of relative price changes and real income changes for demand. Substitution elasticities are relevant to understand the substitution between, for example, secondary and primary materials, and functions for innovation are needed to understand the relationship between innovation expenditures and changes in input-output coefficients. Functions explaining environmental coefficients are needed to

understand how policies change pollution while one must also explain the relationship between information generation and changes in input-output coefficients. In addition, functions are needed that explain changes in production functions due to changes in infrastructure, natural, social, physical and human capital. Typically, very little is known about all these relationships.

A traditional manner to analyse the macroeconomic consequences of circular policies is to put policies or input changes directly into a general equilibrium or econometric model. Although the models will predict the changes that are implemented, the results depend on the assumptions and parameters used. In most model analyses, these assumptions are implicit while it is difficult to trace the exact causal relationships that explain the model results. For this reason, it may be useful to focus scenario research on empirical information about the essential mechanisms that explain the economic, environmental and social results. Case studies, econometric studies and other studies that reveal plausible mechanisms and estimates of coefficients are needed for this.

Finally, with respect to target-based scenarios it must be clear from the discussion here that logically, targets require in some way or another both insights into circular opportunities that may be summarised in a stylised way within functions in models, and that opportunity-based and target-based scenarios each require explicit insights regarding which policies can best be implemented to realise the scenarios.

5 :: A disruptive transition?

Most scenario studies address relatively small changes compared with those sketched in the book "Cradle to Cradle" by MacDonough and Braungart (MacDonough & Braungart 2002), which has been a source of inspiration for many advocates of the circular economy. The book argues that one should focus on eco-effectiveness instead of eco-efficiency. Eco-efficiency is more or less the standard approach that is focused on reducing pollution and depletion, i.e. reducing the bad, instead of focusing on something inherently positive. They suggest that a completely new approach to design is necessary, wherein one does not stop using creativity until systems with only positive effects are developed that can recycle everything by nature or in human systems, implying that toxic elements cannot be used. The source of inspiration is nature, i.e. biomimicry, wherein an abundance of variety in combination with selection creates systems wherein more or less everything is reused (although one must be aware that also biological systems sometimes collapse or at least that the composition of species over time changes). One of the principles in this context is to use local materials as much as possible. Variation in approaches and encouragement to play with these approaches is essential: the forms developed follow the logic of evolution, i.e. one has to develop self-regulating systems as in nature instead of more and more advanced machines..

The EU action plan for the Circular Economy (EC, 2015, p. 2) refers explicitly to the report "Growth Within" of the Ellen MacArthur Foundation (EMF, 2015) that in its turn refers to "Cradle to Cradle" as an important source of inspiration. The "Growth Within" report and its further development with respect to investments needed in the report "Achieving growth within" (EMF 2017) provides a far-reaching perspective on the circular economy and includes all steps needed to go from circular innovations towards the macro effects, and shows how different circular processes depend on each other.

However, the scenarios of "Growth Within" and the EU action plan for the Circular Economy are perhaps not as far reaching as McDonough and Braungart would like, but they base their scenario on the fundamental idea that a revolution is occurring that is both technological and organisational (new business models and institutions). This may generate improvements in resource efficiency and welfare automatically, but can also be reinforced through a policy that focuses on removing barriers including perverse subsidies and regulations, investment in infrastructure, enacting regulation (building standards), pricing externalities and stimulating R&D (p. 13). According to the EMF, the circular economy idea is based "on three principles; preserve and enhance natural capital, optimise yields from resource use and foster system effectiveness (minimise negative externalities)" (p. 14). The first principle is obvious consistent with "Cradle to Cradle", but one may doubt if optimisation of resource use and minimisation of negative externalities is not more part of eco-efficiency in the terms of McDonough and Braungart.

The article "Strategies for Manufacturing: Waste from one industrial process can serve as the raw materials for another, thereby reducing the impact of industry on the environment" by Robert Frosch and Nicholas Gallopoulos (Frosch & Gallopoulos 1989) was the starting point of Industrial Ecology. It is obvious from the subtitle that closing loops and increases in resource efficiency are at the centre of the approach. Industrial ecology has a focus on material and energy flows in industry and looks at natural systems as a source of inspiration (Bocken et al. 2017).

A recent issue of the Journal of Industrial Ecology provides many insights from industrial ecology that warn against too optimistic an approach to the circular economy. First, it is important to focus not only on flows, but also on stocks. In the current growing global economy, the stock of materials needed for infrastructure and increased commodity use also increases, and therefore, the supply of recycled materials will, even with 100% recycling, not be sufficient to prevent the need for primary materials (Fellner et al. 2017; Moreau et al. 2017). This also implies that attention is required for sustainable mining (Lèbre et al. 2017). Second, circular processes don't lead automatically to less resource use and less pollution. Therefore, it is important to assess the consequences of circular opportunities with respect to resources and especially also energy use (Cullen 2017). Third, there are clear limitations to recycling because many materials are not suitable for recycling (Schiller et al. 2017; Cullen 2017; Fellner et al. 2017). Fourth, it is not easy to reduce toxic material use and in the short term a lot of closed material cycles don't take the risk of leakage of toxic materials sufficiently into account (Goldberg 2017). Fifth, the development of a circular economy may imply a change in institutional structure (Moreau et al. 2017). For example, in a circular economy, labour may become more important as a substitute for energy from nature, people should become more central to economic life and solidarity may become more important because inequality is an important driver of excessive resource use. Happiness research that shows that the relationship between material welfare and happiness is smaller than commonly thought may also imply that institutional focus should more on wellbeing and less on material production (Easterlin 2001). Finally, one must be careful to develop the right indicators. For example, Haupt et al. (2017) argue that many circularity indicators like the collection rate of paper don't give the right message. For example, In Switzerland 97% of paper is officially collected, while in practice it is only 74% and from the collected paper only 80% is recycled.

It is very difficult to take all the more far-reaching issues that are sketched above into account in circular scenarios. Most current studies on macroeconomic impacts are not on the circular economy, but on resource or energy efficiency, and therefore fall by definition in the category of eco-efficiency instead of going beyond this to incorporate eco-effectiveness. The development of reasonable circular scenarios remains a challenge.

6 :: Case studies and scenario analysis

What is the role of case studies for scenario development? It is obvious that the case studies to be analysed in the CIRCULAR IMPACTS project only represent a very small portion of the process changes on the way to a circular economy. However, they can show the type of mechanisms involved, and potentially one may use case studies to derive potential consequences for input-use changes. This is, for example, the method used by EMF (2015), as described in Section 2. However, as seen by the EMF study, several steps and assumptions regarding technological change are needed to reach a conclusion. The resource-benefit curves that may be derived from case-study analyses are highly speculative in most cases and have to be compared with alternatives pathways that are typically much less clearly defined.

Another use of case studies is the definition of a response function for changes in factor prices or prices of externalities. For example, one may investigate in a case study to what extent pricing the externalities may change the competitiveness of different techniques or business models. The IEA/OECD World Energy Outlooks (IEA 2015; IEA 2012) derive abatement cost curves for the different energy options based on thousands of case-study analyses. Such an analysis may help to search for the cost (or benefits) involved by setting specific targets, and it may suggest which options may potentially be implemented at different prices. Interestingly, it also shows that several options for energy saving are available that pay off over time, and therefore have a high return on investment that is not realised because agents have difficulties financing it, agents are not aware of the returns or do not take the effort to investigate the return, or the benefits go to other agents than the one who invests (the principle-agent problem). Therefore, such an approach to case studies shows how potential regulation, improvement of financing conditions and changes in institutional settings and information mechanisms may increase welfare. Additional to the cost information in such case studies, the full costs and unintended consequences of such policies should be investigated.

However, such an approach does not tell what happens if several targets must be reached at the same time. For example, if both material productivity, greenhouse-gas emission reductions and biodiversity-degradation targets have to be realised, insight into the total cost structure, including substitution possibilities must be investigated. This makes the case studies much more complicated, and probably will also involve many more relevant techniques. However, if case studies provide this type of detailed cost information, this may improve insights into the way in which substitution processes change when relative prices change as a consequence of a policy change, e.g. environmental taxation.

Deep investigation into the practical dynamics that are generated when certain policies are implemented may be an important target of case studies. For example, Verrips et al. (2017) analyse the consequences of different policies for plastic recycling. In contrast with many optimistic visions on opportunities for recycling and the production of bioplastics, they conclude that bioplastic and recycling are only to a limited extent a solution for environmental problems related with fossil plastics because neither process will reduce the pollution of seas nor street litter, although both processes may help to reduce the carbon footprint of plastics. They also conclude that intensification of the separation of waste is not beneficial from a welfare perspective, certainly at current prices. Carbon pricing may change the benefits for recycling, but is still not a solution for the other environmental problems of the plastics economy.

Verrips et al. (2017) provide an important warning about pricing or systems that generate a negative incentive for unsorted waste. Putting costs to unsorted waste may stimulate inclusion of more plastic in the compostable part of waste, increasing already existing problems of plastic in compost. Price incentives may have perverse effects. For example, payments per unit of pollution generate negative effects by increasing illegal dumping.

Case study analysis may be used as an inspiration for policies to be implemented. For example, the case studies in the "Growth Within" report of the EMF list barriers to circular opportunities and policies to solve these barriers. This is also one of the aims of the case studies in the CIRCULAR IMPACTS project.

In summary, case studies may first be used to make explicit how input coefficients and environmental parameters may change with implementation of a circular scenario. Second, if a large number of case studies is available, these cases may be used to define response functions. Third, case studies may be used to grasp the precise dynamics involved. Finally, case studies may be used as an inspiration for the implementation of suitable policies in a circular scenario. Case studies show new technologies and processes in an early stage, identify barriers and enabling factors for these new technologies and processes and provide suggestions how policy can solve the barriers or create suitable enabling conditions.

7 :: The European Semester and circular economy scenarios

The European Semester focuses on the coordination of economic policies. Important issues are sound public finances, prevention of excessive macroeconomic imbalances, support of structural reforms and stimulating investment (see Deliverable 2.2 of the CIRCULAR IMPACTS project). There are different views as to what extent the circular economy or environmental and energy targets should be included in the European Semester, but to the extent that the circular economy is relevant for the issues above, it should obviously be included in the analysis.

Circular tendencies in the baseline may not be very relevant for the European Semester. The Ellen MacArthur Foundation suggests that many technological innovations automatically generate a more circular world (see Section 2.3). This implies that these tendencies have to be included in the baseline. However, as far as circular transformations in the baseline have consequences for public finance, macroeconomic relations, structural reforms or investment, there is no indication that these developments are different in size or character from non-circular developments. This would suggest there is no need for a specific circular lens for the baseline development for the European Semester. The baseline development wherein, for example, solar and wind energy may partly replace fossil energy, where energy efficiency of buildings increases, where electric cars gradually replace fossil-fuel cars, where the balance between products and services gradually changes and where self-driving cars make life easier seem not to be a priori fundamentally different from the past or non-circular developments.

In contrast, circular policies may influence variables that are relevant for the European Semester. First, in many reports on the circular economy it is suggested that the transition to a circular economy requires extra investment. For public finance, it is relevant to what extent these investments will be financed by government or by private agents. Furthermore, extra investment has consequences for macroeconomic imbalances. If the analysis is correct that part of current unemployment and low growth is caused by a lack of investment opportunities then enabling new investment opportunities may help to solve the problem of Keynesian unemployment and with that, government income and a reduction in social-security payments.

Second, a fast transition to the circular economy may imply structural changes in labour demand. In some studies; it is argued that the circular economy will generate demand for labour where there is excess supply, solving some of the structural labour-market problems, but it is more possible that a fast transition implies new skills that are not automatically available when people in old sectors lose their jobs. Therefore, it may be that a fast transition to a circular economy requires extra efforts for labour market policy, i.e. structural policies.

Third, if the circular economy is accomplished through environmental taxes and environmental regulation, this will have consequences for international competitiveness. Regulation and taxes may reduce competitiveness of some sectors, but especially environmental taxes may also reduce costs in other sectors. In many cases, circular and other environmental policies that may increase production costs with current technologies are not implemented due to several concerns: fear of loss of export position;

the related risk of stranded assets and structural unemployment; and the fear that the net environmental effect may be small because environmental problems are shifted to other regions of the world with less regulation.

Fourth, as far as the circular economy is accomplished through environmental taxes and reduction of perverse subsidies, this has direct consequences for public finance. It may solve structural budgetary problems in some countries while it may allow for reduction of labour-market problems and extra investment in infrastructure and research in other countries.

Fifth, a transition towards a circular economy will normally reduce the import of raw materials in the EU, making the economy less dependent on price fluctuations on those markets. This shift in imports may have consequences for the trade deficit. Because the trade deficit and investment are related, this will also have consequences for investment. The exchange rate of the euro and the competitive position of different countries within the EU may also change. Although these changes will happen, it is not a priori clear that the size of the effects will be big enough to be interesting to investigate deeply in the context of the European Semester.

In summary, the transition towards a circular economy is related with a number of issues that are directly relevant from the current perspective of the European Semester. Next to that, the European Semester may or may not also monitor environmental targets related with the circular economy as far as this is seen as a structural reform.

8 :: Conclusion

This report has provided a view of the circular economy from the perspective of several types of economic analysis and has elucidated approaches to scenario analysis for the transition towards a circular economy. We distinguished and described three approaches to scenario analysis: an opportunity-based scenario approach, as for example developed by the Ellen MacArthur foundation; a target-based approach that starts from environmental targets; and a policy-based approach, as for example modelled for Turkey by Bouzaher et al. (2015). Such a policy-based scenario approach is developed further in this report and it has been shown that changes in input coefficients and environmental parameters can also be used for the opportunity-based approach.

Opportunity-based approach

The opportunity-based approach starts with an explicit formulation of circular opportunities. The baseline consists of options that will be realised under current circumstances, while the circular scenario implements the options that become profitable or will be realised if government develops a package of circular-economy policies. From the circular opportunities identified, opportunity-specific policy options are derived. However, the calculations made in this type of scenario study are typically focused on unrealised business opportunities, not policies, and by having this focus, implicitly assumes that the cost of the policy will be lower than the benefits in terms of GDP. The approach shows that a list of circular opportunities exists may indeed have positive macroeconomic benefits vis-à-vis the present situation, but it does not demonstrate that this list results in higher GDP growth than an approach that includes a more general list of business opportunities with both circular and linear opportunities. While using such an approach demonstrates that a move towards a more circular economy can also grow the overall economy, it avoids the comparison with how much an economy could otherwise grow, e.g. compared to one with explicitly growth-maximising policies.

Target-based approach

The second approach starts from environmental and resource use targets that must be reached. This may be very relevant from the perspective of policy, which is, in most cases, target-oriented. Normally, targets are implemented in a model by changing some policy or technology variable, i.e. variables relevant in the opportunity-based and policy-based approaches. In analysing the opportunities to realise targets, one may start from a list of circular opportunities and selecting a sufficient number of them to reach the targets, or select a number of policies that in the end satisfies these targets.

Policy-based approach

The third approach starts from an analysis of market and government failures that cause environmental, natural capital and resource-use problems and implements specific policies to solve them. As in the opportunity-based approach, one may doubt to what extent the growth effects of the policies analysed in most policy-based scenarios are specific for circular scenarios. They are basically scenarios that analyse the consequence of circular policies above the baseline policies, assuming that the alternative is to have no policies above the baseline policies. However, most macroeconomic effects of the

policies are the consequence of the productivity increases of new technologies, extra demand because of extra investment, improved information, and tackling regulatory and other barriers that prevent the realisation of the circular economies. All these policies could also be applied to opportunities that are not specifically circular in character, and therefore, the circular scenarios don't prove that a circular policy is better than a more general policy that is not specifically circular in character. However, because there are good arguments for a circular economy from an environmental and welfare perspective, scenarios that suggest that a carefully designed circular policy may also generate growth and employment can be very useful.

Relationship between the three approaches

Opportunities are implicit in all scenario approaches, although the empirical source and the listing of these opportunities is in most cases not explicit. In the real world, there are choices between opportunities and the final choice determines the scenario. However, there are so many opportunities with so much uncertainty, that it is not easy to make a listing of them that is reliable. Many opportunities that have been examined in the past, like nuclear fusion as a source of energy or robotisation, didn't materialise or developed much more slowly than expected, while other developments like the development of Internet were not predicted by anyone. Therefore, there may be an argument not to list all opportunities, but use some general options to summarise the future technological development and the available substitution possibilities in some general functions. These functions may be derived from bottom-up information, i.e. knowledge about some specific case studies, but also may be based on econometric analysis of historical experience. However, one must be aware that the dynamics in the future may be different from dynamics in the past, and therefore, in practice, functions are in most cases chosen based on intuition and experience along with econometric evidence. As far as it is true that the development of the circular economy is disruptive, more or less by definition, these processes cannot be captured by historical experience or current case studies alone.

In addition, policies have to be in the background of all circular economy scenarios, because in the end such a scenario must be realised by public policy. In the opportunity-based scenario approach, it is implicitly or explicitly assumed that these policies can be tailor made for the realisation of the different opportunities and that the costs of these policies are small compared with the benefits. However, policies like green fiscal reforms have fundamental influences on prices and therefore alter the benefits of the different opportunities.

Targets may also be in in all scenarios. One may start with targets and then design policies to reach these targets assuming the availability of opportunities, but also the other two types of scenario are relevant in the context of making progress towards targets or at least providing information on indicators for progress. The three approaches are distinguished by a matter of emphasis and how that primary focus relates to and affects the other aspects of interest.

Implications for macroeconomic evaluations

In the macroeconomic evaluation of a circular-economy scenario (see Deliverable 2.3 of the CIRCULAR IMPACTS project), the first step is a welfare analysis of the environmental results of the scenario, because these are the primary targets of the circular policy.

Furthermore, reduced imports of raw materials implies that geopolitical risks are also lessened, with potential consequences for economic stability. The second step is to investigate to what extent employment and economic activities are changed. Employment and welfare effects depend on the current situation of the economy. For example, in a situation with a negative output gap (i.e. aggregate demand is smaller than aggregate supply) cyclical employment exists that can be reduced by extra investment and other expenditures. If the circular policy generates an extra incentive for investment, this may generate extra employment and extra growth when the economy starts in a situation with excess macro-economic supply.

A rapid transition towards a circular economy will generate adjustment costs. Stranded assets and qualitative structural unemployment are examples of these costs. As EMF (2017) states, these adjustment costs will be smaller, the slower the adjustment process is and thus the sooner the adjustment process starts. In addition, stability in the policy environment is relevant from this perspective, because this reduces uncertainty and therefore increases investment, and it reduces the risk of stranded assets. Explicit policies for labour mobility may be required to adjust the qualitative characteristics of labour supply to the new demand pattern for labour.

The importance of empirical analyses

The analysis in this report shows that in current macroeconomic evaluations of the circular economy, the assumptions generating the outcomes remain hidden for the normal reader and even for specialist readers. Many results in such analyses are the consequence of policy adjustments, but it is not transparent what the empirical background is of the mechanisms that are in the models. In many analyses, profitable circular opportunities are listed but it is not made explicit to what extent these opportunities are more or less profitable than other opportunities that may also be realised. In order to get deeper into the fundamental issues around the macroeconomic evaluation of the circular economy, empirical analysis is required. Case studies, econometric studies and other studies that reveal plausible mechanisms and estimates of coefficients are necessary for this. These empirical insights may be included in complex models, but it may be more useful to calculate the consequences of the empirical insights in a more transparent manner with simple calculation tools.

9 :: References

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