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## **In the Loop – A CGE Analysis of Circular Economy in Finland**

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### **Abstract**

Circular Economy has attracted considerable interest in the past few years. In Finland, a country with a long culture of nurturing its renewable resources, the coming of the circular economy is claimed to revolutionize the whole economy. It is difficult to see whether all the fanfare is justified. On the one hand, it is clear that many of the large material flows have already been closed in the Finnish economy - say, in the forest industries; on the other, new technologies utilising hitherto unutilisable flows constantly emerge, suggesting there's much more to the circular economy than meets the eye.

This paper is part of a larger study commissioned by the Prime Minister's Office, studying the potential of Circular Economy in Finland, and advising on its advancement. The paper analyses the potential of Circular Economy in Finland in the light of several, recent case studies covering the flow of food from agriculture to food industries to retailing to consumption; the role of recycling; the possibilities of radically different new technologies such as 3D printing and new lignine/cellulosic processes; and the emergence of a new kind of consumerism. We integrate each of these cases into the VATTAGE/FINAGE CGE model of Finland to assess the economic potential of these new technologies. We find that it is not unrealistic to expect gains from the Circular Economy. Even with conservative estimates of the effects in our cases, the gains from increased material efficiency outweigh the costs, and most likely, also the costs of climate policies.

The trick is of course how to make it happen. At first glance, there seems to be precious little in common between our technology cases. This seems to imply that convenient top-down policies are unlikely to achieve very much. Indeed, the new technologies and markets need to be analysed in much more detail than customary, to see where and how new markets are forming, and where the economic incentives are. But in most of the cases covered, we do find that the new technologies contribute to economic growth via technology-induced productivity gains that can be modelled, and that lend to cost-efficiency comparisons that are directly policy relevant.

## **1. Introduction**

Circular Economy has attracted considerable interest in the past few years. It is supposedly revolutionizing the economy, but it is sometimes difficult to see whether all the fanfare is justified. In essence, circular economy is about discovering new ways to use and re-use flows of material in the economy that have previously been more or less wasted or only imperfectly utilised. In Finland, a country with a long history of nursing its renewable resources, many of the large residual flows have been utilised in this way for decades. On the other hand, the circular economy is thus more about the new technologies enabling the utilisation of hitherto unutilisable flows that suggest there is much more to circular economy than meets the eye.

For economic policies, the circular economy poses new challenges. New technologies are essentially about discovering and utilising previously neglected material flows, for which there are not yet any markets. It is therefore almost impossible to use top-down, one-size-fits-all measures to study the role of policies. Rather, the circular economy seems to call for an understanding of concepts such as scalability (of new business models and small-scale technologies). And thus, this study presents an estimate of the potential for circular economy based on examples of new technologies and business models currently deemed most promising in Finland.

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## **2. Methodology**

From the point of view of economic policies aimed at accelerating a transition to a circular economy, the whole concept appears too vague to be particularly useful. Thus we take a practical approach here and let the examples demonstrate what a circular economy could entail. In our examples, the move towards a Circular economy is achieved through the introduction of new technologies to utilise previously un- or under-utilised material flows, as well as new business models based on these technologies creating, in essence, markets for the newly utilised flows. This may require investment in new technologies, which obviously are case-specific. In some examples, the whole earnings logic is changed.

The starting point for our study is a recent Circular Economy Roadmap –exercise conducted by the Finnish Innovation Fund SITRA (2014), a policy think tank, recognising some half a dozen promising areas for development. These areas share some characteristics: most of them involve the introduction of new technologies, changing existing value chains, and most of them are relatively small-scale. Some of them clearly display scalability, whereas others are probably unique to Finnish conditions. Most of them also involve more than one industry, which demonstrates the freshness of many of the technology and business concepts.

It is also clear that the examples interact with each other. Here, we have chosen to present the examples as a “sequence”, that is, cumulatively, to get an idea of the relative contribution of each of the cases. We have restricted the study to potentials that can be identified from the national accounts.

We focus on the following Circular Economy Potentials in seven stages:

- 1) Foodspill – reduction of foodspill or food waste in retailing and in domestic consumption
- 2) Nutrient flows – manufacture of fertilizers and biogas based on more efficient nutrient flows
- 3) Fishmeal – manufacture of fish fodder for agriculture, based on both increased fish farming and the production of fishmeal from roug fish
- 4) Broad bean – the introduction of broad bean to diminish the need for fertilizers and to increase the uptake of nitrogen
- 5) Recycling – introduction of new technologies to increase the recycling of plastics, textiles and electronics, especially precious metals
- 6) Transports – promoting new transport solutions esp. for consumer
- 7) Lignine – new forest industry technologies revolutionise the use of lignine

By cumulative we mean that by the last stage, all seven stages are operative.

We use the FINAGE model to study the potential for circular economy. FINAGE is a fairly standard, recursive, VU/MONASH-like AGE model of the Finnish economy which emphasizes the detailed structure of taxes and public sector transfers, as well as the structure of the industries, the labour force, capital stocks, and production. FINAGE assumes the linear expenditure system, as well as a mix of Leontieff for intermediate use of goods and CES nests on value added in the production function. It also allows for MONASH-dynamics in investment. A precursor to FINAGE is the VATTAGE model (Honkatukia 2009). In the present study, we also utilise material flow data stemming from extended input-output database of the Finnish economy.

We report the effects of the policies as deviations from a baseline extending to 2030. The baseline already contains many measures that could be taken for promotion of the circular economy, stemming from the EU energy and climate policy targets for 2020, and stipulating binding targets for the share of renewables in energy consumption. For 2030, such targets are not yet in place.

We have tried to make full use of the data on new technologies and the changes in value chains and markets they entail by allocating changes in material flows, investment and thereby capital-labour or value-added-material ratios by commodity and by industry as closely as possible. In most of the examples, it is possible to identify links from investments (in new technologies) to changes in input structure (more efficient or altered material flows), but some of the examples do assume changes in consumer or firm behaviour which are not necessarily justifiable on simple economic reasoning. In the latter case, improvements to technology are thus introduced more or less by assumption. In the former case, it is possible to identify the need for policies for bringing about the new solutions, for example, by introducing investment subsidies.

Tables 1 and 2 summarise the scenarios in terms of assumptions made and the immediate effect. Table 1 shows the how and in which industries processes are assumed to change, whereas Table 2 shows the immediate changes brought about in each case. For example, the effects on **food spillage** are introduced by assuming the demand for food by the households, the hotel and restaurant industry and the retail industry to grow slower compared to the baseline, which could happen as a result of better understanding of expiry dates and better management of retailing logistics at very low or even zero cost. The effects of these changes are reflected as diminished domestic demand for food by the food and agricultural industries in Table 2. Most studies on the circular economy do not go beyond recognising these “1<sup>st</sup> order” links (for example, the SITRA Roadmap), but in a CGE study there are many more links and effects. For example, the fall in the consumption of food is reflected as an increase in the purchasing power of the consumers, thereby increasing demand for other consumption goods, which in turn will have an effect on the equilibrium prices of these goods. Ultimately, also the labour markets will be affected with the resulting real wage adjustments.

The other cases can also be seen in the light of changes in demand and/or technology. The increased efficiency of the **nutrient flows** is based on better handling of manure in agriculture (which is largely used as a fertilizer, but is a very problematic one) as investment in the handling of nutrients (manure) in the waste sector enables the use of manure as a feedstock for biogas and facilitates the optimization of the use of fertilizers in agriculture; in addition, there is investment in biogas conversion plants, and changes in the passenger car vehicle fleet which will be able to run on the newly won biogas. The change in the fleet will also affect the average price of cars (the gas conversion is at least for the time being an additional cost), and as changes in the running costs of the cars compared to the petrol and diesel dominated baseline, both of which will affect the households' purchasing power. The full potential of biogas in Finland has been appraised to correspond to close a third of passenger car petrol use by 2030, but the economic potential is but a fraction of this, and amounts to about 10 per cent of the full potential by 2030, partly also because the necessary infrastructure needs to be installed, and because the car fleet changes relatively slowly (the average age of a passenger car in Finland is very high and exceeds 10 years).

In the **fishmeal case**, fisheries, and fishing, is directly affected, producing intermediate goods for the use of fodder production, are directly affected, but the changes spill to other sectors as domestic fodder is replacing imports, and as some of the residue is used for the production of fertilizers. The increased cultivation of **broad bean**, in turn, increases agricultural production and investments in agriculture (it is assumed old pastures are allocated for broad bean), diminishes the use of fertilizers on the whole and also redirects it towards domestic fertilizers.

In the **recycling case**, rather large investments in waste treatment are needed to facilitate the increased recycling of plastic, textile and electronics waste. In the case of textiles, it has been estimated that consumers would also have to become more receptive towards the use of recycled textiles, with solutions like leasing of clothes spreading from working clothes to everyday apparel. As for recycled plastics and precious metals recovered from electronics wastes, the recycled materials would more easily start competing with virgin ores or imports, especially when the prices of recycled materials are falling thanks to the introduction of some new recovery technologies.

The **transport case** falls in the category of (too) cheap new business innovations whose costs appear to be very low. There is an element of Uber in the scenario but it goes somewhat beyond Uber since the innovation here is that the new technology not only allows the coordination of taxi-like services very cheaply, but that car-sharing and pooling of ownership starts to replace household ownership of cars. The result is less imports of passenger cars but faster turnover of the car fleet since the rate of utilization is much higher than currently.

The final case concerns new **lignine-processing** technologies, the potential of which is already well established, but which are not yet in the market. Apparently, with fairly little extra investment it is possible to extract much more value added from wood than has been previously the case, partly because the new technologies allow new uses for the cellulose. The economic potential could be very large, and the first plants using the new technologies are to commence production in a couple of years.

**Table 1**

	Foodspill	Nutrient flows	Fishmeal	Broad bean	Recycling	Transports	Lignine
Agriculture (incl. fisheries and forestry)		Demand for domestic fertilizers increases	Demand for fertilizers decreases, fishing and fisheries expand	Imports of fodder decrease, acreage increases			
Food industry			Fishmeal factory				
Forest industry							Lignine processes
Chemical industry					Decreased imports of recycled plastic		
Waste treatment and processing		Increased biogas production			New technologies for plastic, textile and electronics waste treatment		
Retailing and servicing of vehicles							
Retail trade	Demand for food decreases						
Hotels and restaurants	Demand for food decreases						
Transport services						Improved energy efficiency	
Households	Demand for food decreases	Passenger car fleet changes			Demand for textiles decreases	Transport volumes decrease, imports of cars slow down	

**Table 2**

	Foodspill	Nutrient flows	Fishmeal	Broad bean	Recycling	Transports	Lignine
Agriculture	Demand for food decreases		Fertilizers, fish farms, fishing	Imports of fodder, new acreage			Demand for wood
Food industry	Demand for food decreases		Fishmeal plant				
Textile industry					Demand for textiles decreases, use of recycled textiles increases		
Oil refining		Biogas replaces petrol					
Forest industry							Use of wood
Chemical industry					Recycled plastics replace imports		
Manufacturing of metals					Recycled metals replace virgin ores		
Waste treatment and processing		CHP and biogas production			Production of recycled materials increases		
Generation of heat and power		Demand for heat decrease					
Construction		Investment in gas-plants and recycling	Investments in fishmeal factory and dioxine re-recovery plant	Investment in agriculture	Investment in recycling		
Retailing and servicing of vehicles		Passenger car fleet changes				Vehicle sales decrease	
Retail trade	Demand for food decreases						
Hotels and restaurants							
Transport services						Energy efficiency improves	
Households						Transport volumes, vehicle fleet	



### 3. Results

In all our cases, the effects on the economy stem from supply side effects from technological change, mostly brought about by investment in new plants, and often leading to reallocation of labour and other inputs, with also improvements in material efficiency. It is then natural to track the economic effects in terms of the changes in investments and employment, the supply side of the economy. For the time being, the exact investment schedules are yet to be announced; here, we assume that investment starts immediately, the new plants coming on line in 2-3 years.

Figure 1 reports the effect on aggregate investments in each of the cases. It is clear that most of the projects are actually fairly large even at a national level. The foodspill-scenario is an exception, as the effects there stem from changes in consumption patterns and in more efficient production of services that do not require outright investment, but that result in redirecting consumption towards relatively more labour-intensive services. In the nutrient flow scenario, in turn, there is a large surge in investment initially, but by 2030, investment falls relative to the baseline. The largest investments, in turn, are related to the CHP and biogas plants in the nutrient flow case, in the fishmeal and dioxine removal plants in the fishmeal case, and also to increased acreage in the broad bean case. The transport case postulates no extra investment, but the change in production and demand patterns and the implied improvement in energy efficiency induce more investment. Likewise, the forestry case does not assume an increase in investment, but as the new lignine processes improve material efficiency, an increase in investment is induced by the growth in production.

Figure 2 shows the effects on employment. We model labour supply with a standard Monash/VU approach, where real wage rigidity affects the level of employment in the short run, whereas in the long run, unemployment tends to return to its long-run equilibrium. Here, we do allow also the long run equilibrium to be affected by the changes in real wages, and thus it is possible for aggregate employment to change permanently compared to baseline. A significant source for growth in employment is the boost in construction industry output the new investment creates. Employment also increases in primary production, driven by the expansion of agriculture (broad bean) and fish farming (fishmeal) and in several service sectors, driven by the households' increased purchasing power brought about by savings in the consumption of food and transport services and also by the rising real wages. The real wage effects also constrain growth in some of the scenarios – in the recycling case, household demand shifts towards services, but as services are relatively more labour intensive than the textile industries that face a decrease in demand, real wages are pushed up and this effect dampens the growth in labour demand.

Figure 3 shows the effects on GDP. It is clear that the largest potentials lie in the transport sector and in the forest industry processes, which each increasing GDP by as much as the other cases combined. The potential from these smaller but well-known and realisable cases to affect GDP thus appears limited at first sight. But to put the overall effect of some 0,6 per cent additional growth into perspective, the most recent Finnish climate strategy is estimated to decrease GDP by about 0,6 per cent by 2030. The significance of the circular economy appears clearer from this perspective – if environmental concerns are systematically followed, the costs of higher energy prices will be compensated by the new opportunities.

Figure 1

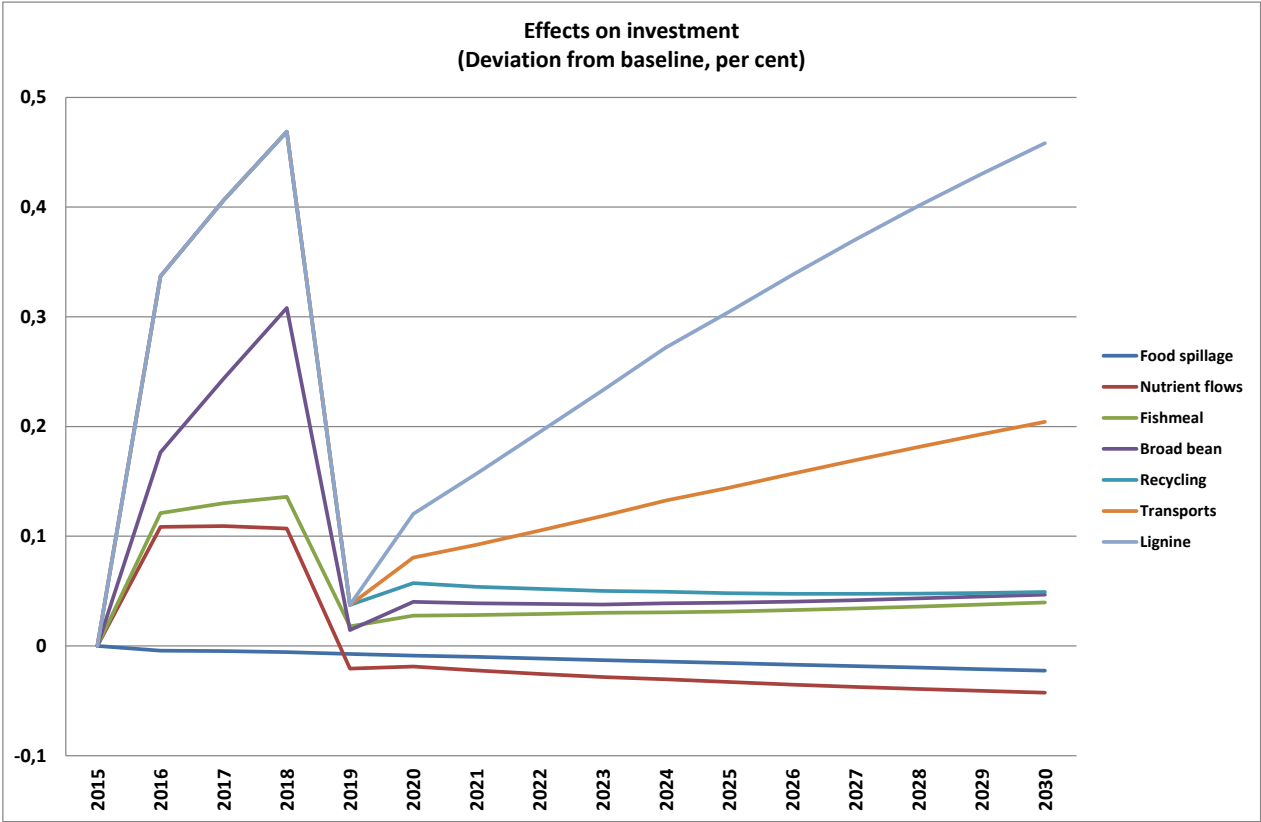
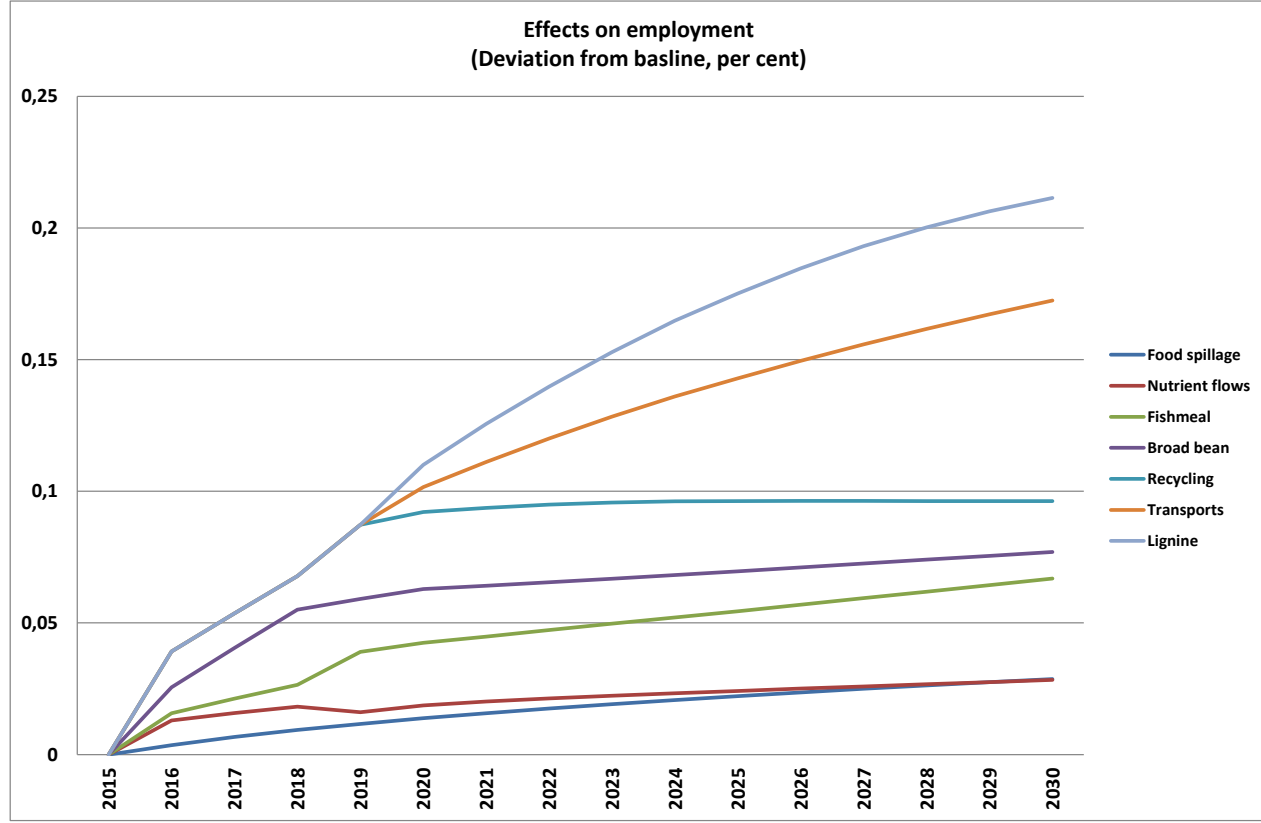
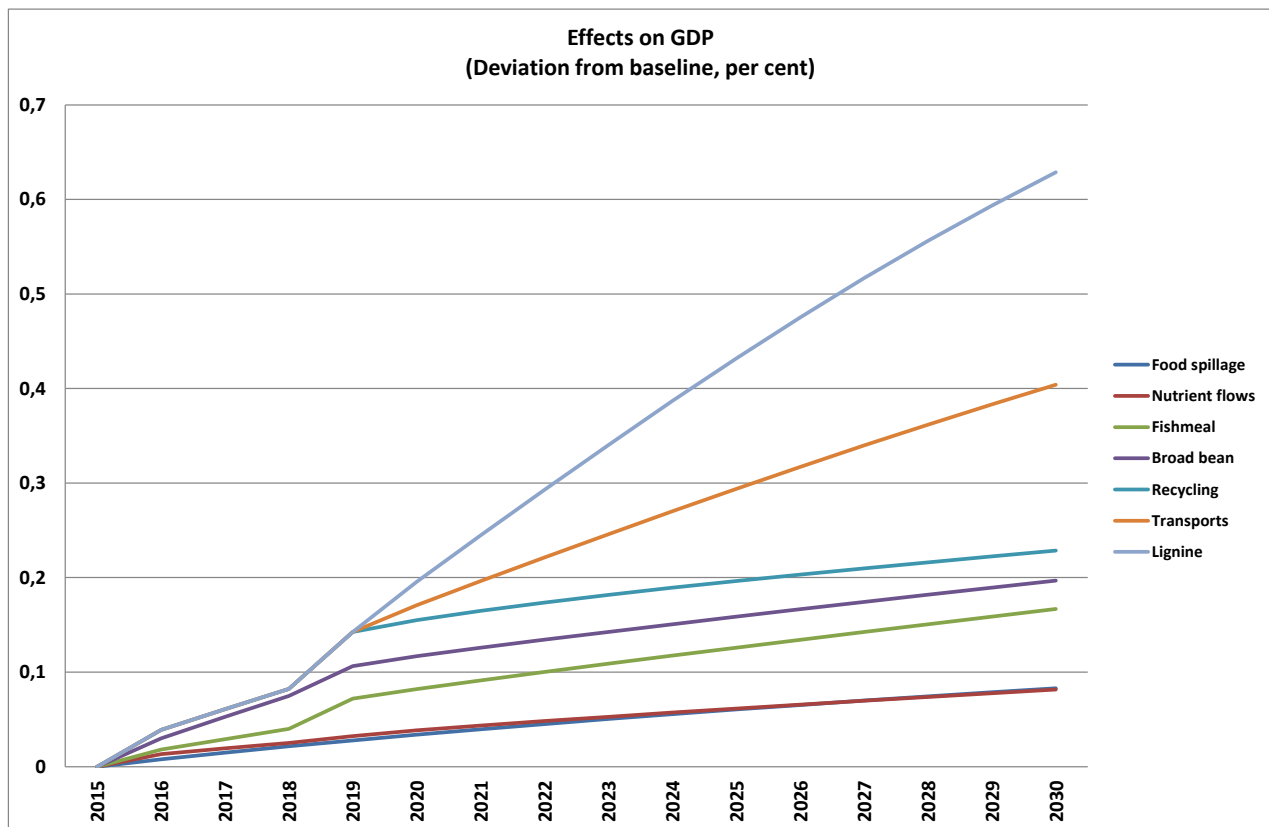


Figure 2



**Figure 3**



There is also a similarity between our cases: they all affect via technology's contribution to GDP. Figure 4 shows the supply-side decomposition of the GDP effects by 2030. It is clear that most of the growth is due to the contribution of technological change, with capital deepening accompanying technology, and with employment improving slightly because we have allowed the labour market to tolerate this. In most of the cases, we introduce new material flows that utilise or recycle previously under or un-utilised material flows, and this improvement in material efficiency is recorded in the decomposition as a positive contribution to GDP of technology. In other words, the circular economy increases GDP because it makes economic sense.

In pecuniary terms, the different cases contribute to 2030 GDP in the following way;

1) Food spillage	226 million €
2) Nutrient flows	-4 million €
3) Fishmeal	233 million €
4) Broad bean	82 million €
5) Recycling	87 million €
6) Transport sector	479 million €
7) Lignine	613 million €
Total	1 715 million €

The monetary estimates make it clear that the largest and most lasting potentials stem from the transport sector and the forest cluster, whereas in the nutrient flow scenario, the initial GDP gains have vanished by 2030. Since in most of the other cases new technologies are introduced at the cost of investment in new plants, we have also estimated how large public investment subsidies would have to be to induce the required investments. We estimate about 400 million in investment subsidies in the agriculture, food industry and

waste and recycling sectors would suffice. Since these cases together can be something like 600+ million euros, the societal cost-benefit ratio would likely be positive.

**Figure 4**

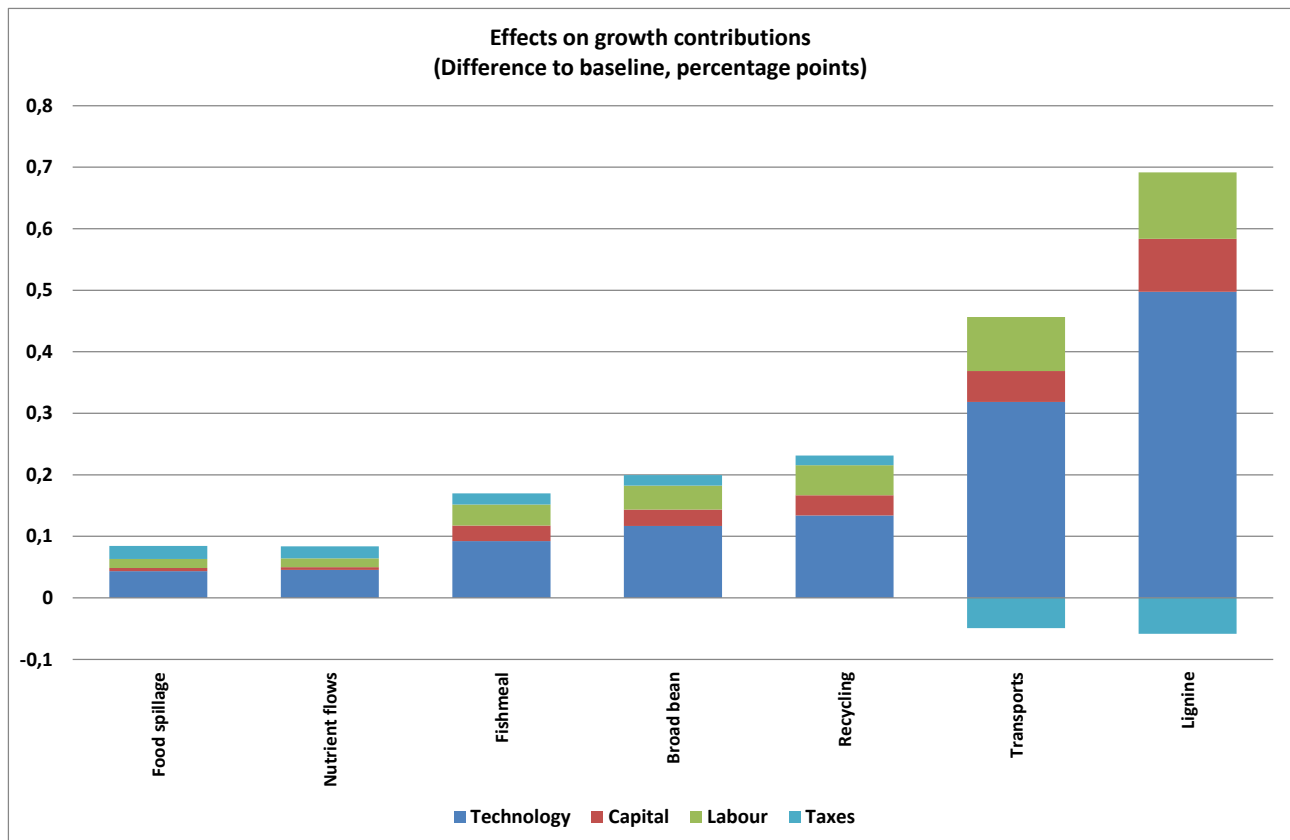
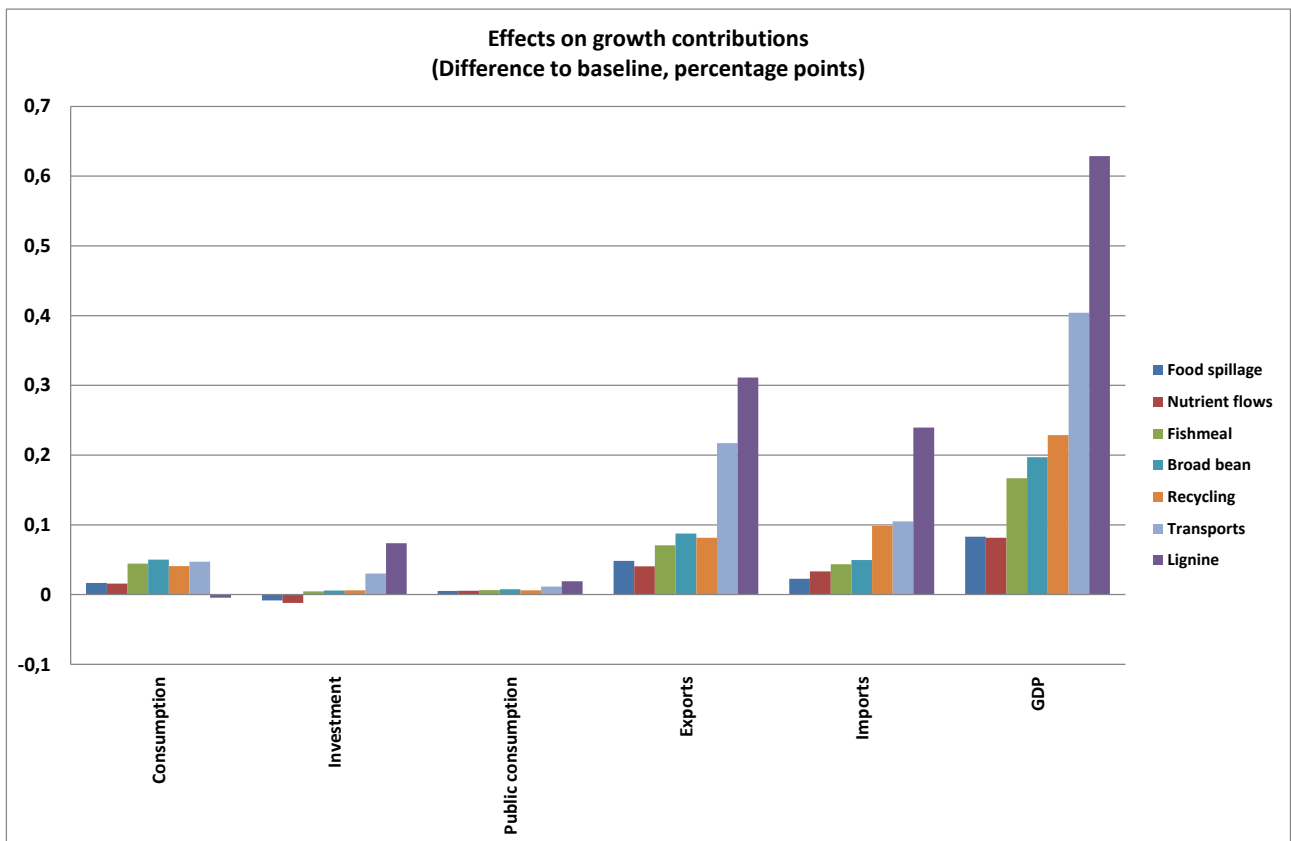


Figure 5 shows the contributions to GDP by expenditure component in 2030. The figure shows how the effects due to household consumption are fairly small, whereas the import-replacement effect in many of the cases is relatively more important, with especially the recycling-scenario demonstrating the importance of this channel. In the transport and lignine scenarios, in contrast, the effect on volumes dominates and the replacement effect is relatively small.

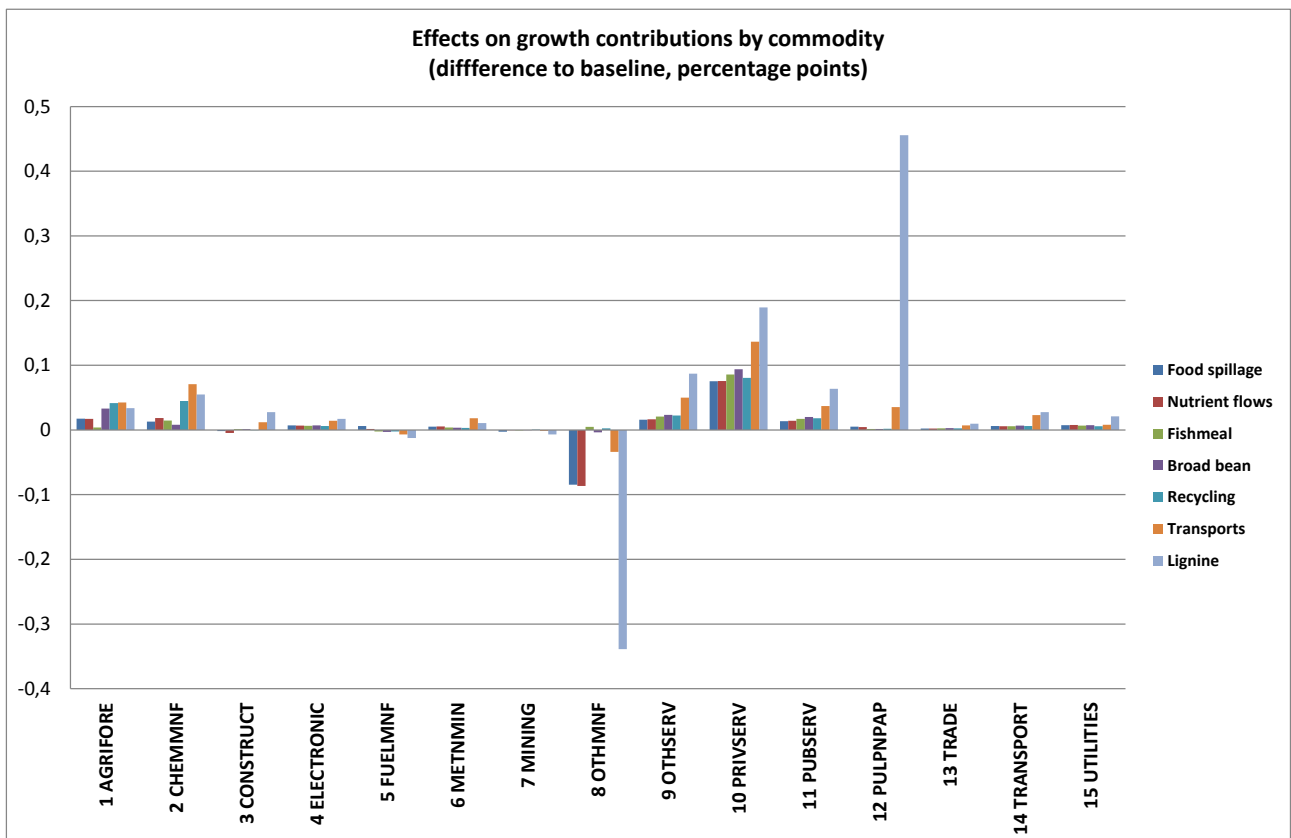
It is clear that the cases induce changes in the structure of the economy. Figure 6 shows the growth contributions at the level of 15 commodity groups by 2030. The figure shows how primary production and chemical industries contribute positively to growth as a consequence of the more efficient nutrient flows and the increase in domestic fishmeal production and broad bean cultivation. Construction also boosts GDP for reasons already explained, whereas oil refining slightly reduces GDP as domestic demand decreases in relation to baseline. Other industries mostly reflect changes in food industries, which decline as a result of the decrease in food spillage, but this effect is reversed by the growing domestic fodder production in the broad bean scenario. The most remarkable change is the growth of service sectors which is largely due to increased household consumption. Since the service sectors are relatively labour intensive, the shift in domestic demand towards them is actually hurting labour-intensive exports.

Figure 7, finally, shows the effects in terms of growth contributions of 15 industries. The aggregation is not exactly the same between commodities and industries, but by and large, the value-added effects follow the pattern of the commodity contributions.

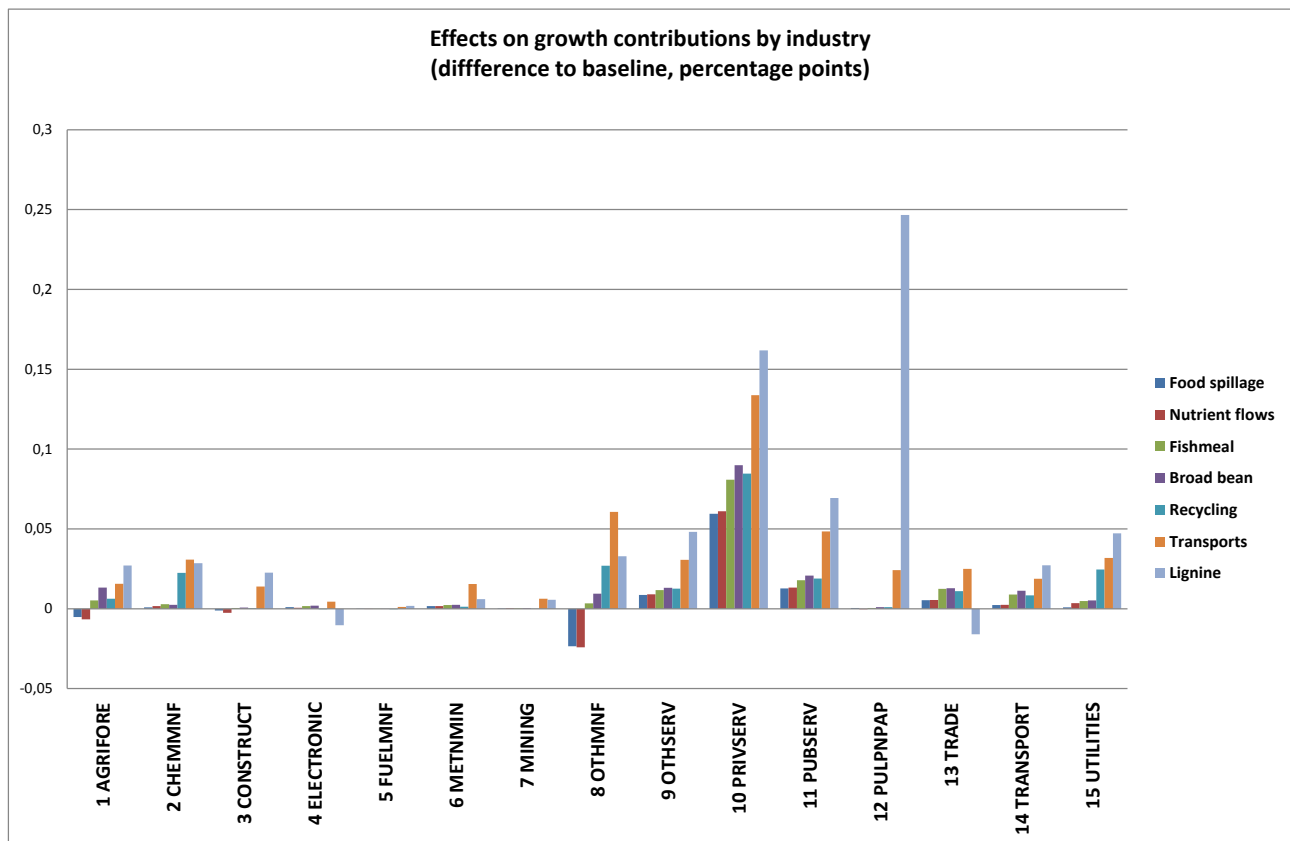
### Figure 5



### Figure 6



**Figure 7**



#### 4. Conclusion

The study is part of a larger study of the potential of Circular Economy in Finland. The paper analyses the potential of Circular Economy in the light of several, recent case studies covering the flow of food from agriculture to food industries to retailing to consumption; the role of recycling; the possibilities of radically different new technologies; and the emergence of a new kind of consumerism. We integrate each of these cases into the FINAGE CGE model of the Finnish economy to assess the economic potential of these new technologies. At first glance, there seems to be precious little in common between our technology cases. This seems to imply that convenient top-down policies are unlikely to achieve very much. Indeed, the new technologies and markets need to be analysed in much more detail than customary, to see where and how new markets are forming, and where the economic incentives are. But in most of the cases covered, we do find that the new technologies contribute to economic growth via technology-induced productivity gains that can be modelled, and that lend to cost-efficiency comparisons that are directly policy relevant. We find that it is not unrealistic to expect significant gains from the Circular Economy. Even with conservative estimates of the effects in our cases, the gains from increased material efficiency outweigh the investment costs. To put the magnitude of the effects in perspective, the gains outweigh the estimated costs of climate policies.

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