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Employment and Performance Effects of Circular Economy Innovations

ZEW

Employment and Performance Effects of Circular Economy Innovations

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Abstract

Circular economy (CE) describes an economic concept that aims at saving resources by minimizing the use of material and energy over the entire life-cycle or products, including repair, reuse and recycling. CE innovations help to realize the goals of a sustainable development and target both the environmental, economic and social dimensions of sustainability. This paper looks at the economic and social dimensions by investigating the performance and employment effects of CE innovations at the firm level. CE innovations such as the reduction of energy and material consumption or the recycling of waste, water or material may lead to cost savings which in turn can increase the competitiveness of the firm and raise demand for a firm's products. Our econometric analysis uses data of two waves of the German part of the Community Innovation Survey (CIS). The performance effects of CE innovations measured by the financial standing of a firm and by turnover growth tend to be positive. The results of quantile regressions show that this is also the case for employment effects.

JEL-Classification: C21, Q01, Q55

Key words: Circular economy, Community Innovation Survey, eco-innovation, quantile regression

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1. Introduction

Circular economy (CE) describes an economic approach to minimize the use of resources over the entire life-time of products. CE focuses both on saving material and energy input in the production process, and the repair, reuse and recycling of products. The CE approach is a key element in greening the economy and is therefore in the focus of the environmental policy debate. Some authors claim that the CE helps realizing all three dimensions of a sustainable development, namely environmental, economic and social aspects. While environmental impacts of CE have been widely studied (see e.g. Domenech, Bahn-Walkowiak 2019), rather little is known about the effects of circular economy activities on firm performance and employment, representing the economic and social dimensions of a sustainable development. The Community Innovation Survey (CIS) 2014 allows such an analysis because it includes a module on eco-innovation with detailed information about CE innovations. The CIS data contains information on energy and material savings, recycling, recyclability of products, increase of the product-lifetime, replacing fossil energy sources by renewables, and substituting dangerous substances. Our econometric analysis focuses on the performance and employment effects of CE innovations at the firm level. Do CE innovations not only reduce environmental impacts but also improve a firm´s performance measured by different indicators such as financial standing and turnover growth? What is the contribution of CE innovation activities to the social dimension of a sustainable development measured by the respective employment effects?

The paper is organized as follows. Section 2 describes the definition and the scope of the CE. In Section 3, the transmission channels of CE innovations on performance and employment at the firm level are developed. Furthermore, the section contains an overview of empirical literature related to these effects. Section 4 discusses the database, descriptive statistics and the econometric estimation strategy. Section 5 presents the estimation results. Section 6 concludes.

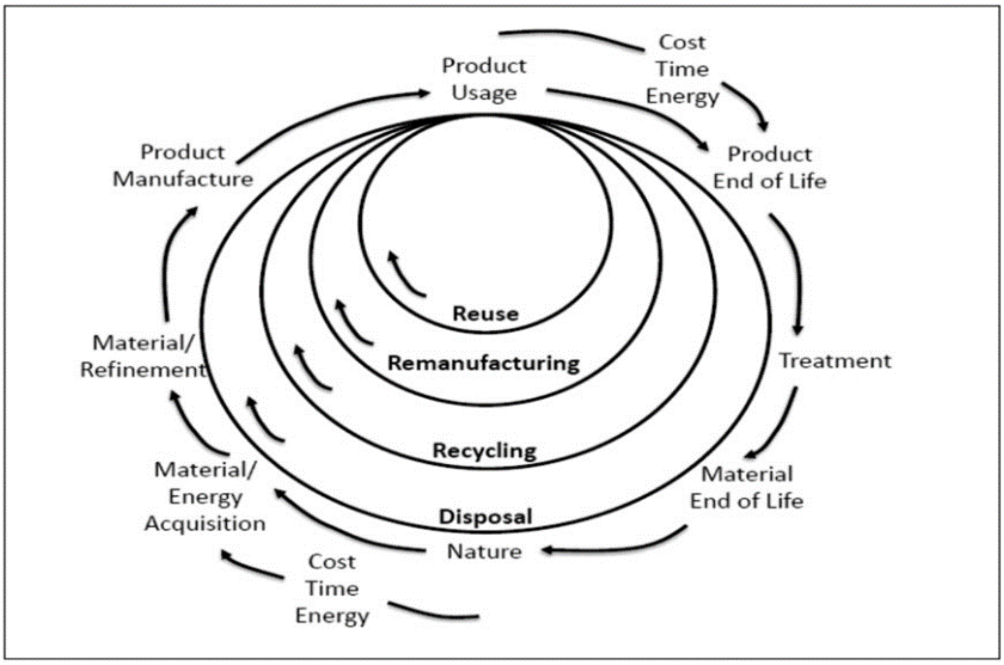
2. Definition and scope of the Circular Economy (CE)

The Circular Economy (CE) is a very broad and heterogeneous concept covering activities such as product-life extension, reuse, repair and recycling, material and energy efficiency, and new modes of socio-technical organization (de Jesus, Mendonça 2018). De Jesus and Mendonça (2018:7) define the CE "as a multidimensional, dynamic, integrative approach, promoting a reformed socio-technical template for carrying out economic development, in an environmentally sustainable way, by re-matching, re-balancing and re-wiring industrial processes and consumption habits into a new usage-production closed-loop system". Korhonen et al. (2018:37) state that "… CE seems to be a collection of vague and separate ideas from several fields and semi-scientific concepts". Kirchherr et al. (2017) identified 114 different definitions of the circular economy concept. The definition of Korhonen et al. (2018:39) is also very broad: "Circular economy is an economy constructed from societal production-consumption systems that maximizes the service produced from the linear nature-society-nature material and energy throughput flow. This is done by using cyclical materials flows, renewable energy sources and cascading1-type energy flows. Successful circular economy contributes to all the three dimensions of sustainable development. Circular economy limits the throughput flow to a level that nature tolerates and utilises ecosystem cycles in economic cycles by respecting their natural reproduction rates." Interestingly, this definition of CE is not restricted to a reduction of material flows but it covers all three dimensions of a sustainable development. A circular economy thus also includes the social dimension such as the effects of CE activities on employment.

The focus of the present contribution lies on the firm perspective of the CE. We concentrate on the innovation activities of firms to adapt firm processes and products leading to a reduction of material and energy consumption or increasing the recyclability or lifetime of products. We call these firm related activities CE innovations. These innovations are a subset of the broader concept of eco-innovations also including the reduction of air pollution or noise emissions.

The framework of Mihelcic (2003, see Figure 1) shows the central role of firms for the realization of the CE. "The CE message is that the inner circles demand less resources and energy and are more economic as well" (Korhonen 2018:37). The optimization of these inner circles including the reduction of material and energy flows, recycling, reuse and remanufacturing and the design of products with a longer product life are strongly dependent on respective activities of firms.

Figure 1: A concept of the Circular Economy (CE)



Source: Mihelcic et al. (2003), cited by Korhonen et al. (2018:39).

3. Impacts of CE on firm performance and employment: Transmission channels and existing empirical evidence

The present analysis focuses on the economic performance effects of CE innovations. In addition, we analyze the social sustainability dimension of CE innovations using the respective employment effects of these innovations as indicator.

Why does it pay off for firms to introduce CE innovations? From a theoretical perspective, there are different transmission channels from CE innovation to a higher firm performance. First, CE innovations such as the reduction of energy and material consumption, the substitution of fossil energy by renewables or the recycling of waste, water or material may lead to cost savings at least in the long run. These cost savings allow the firm to lower product prices which will lead to an increased demand for the firm's products. Nevertheless, in the short run, the introduction of CE innovations may lead to additional costs because of the costs of additional equipment or organizational changes. Such a u-shaped performance effect has been empirically measured by Soltmann et al. (2015).

Secondly, in the light of the Porter-hypothesis (Porter, van der Linde 1995), new products serving a CE (such as energy saving products or products characterized by a higher recyclability or a longer life-time) may lead to first mover advantages that are also accompanied by a higher competitiveness of the innovating firms. Thirdly, this effect may be re-enforced if consumers are willing to pay more for the added ecological value caused by CE improved products with a positive effect on product demand, too. This argument is also discussed in the Corporate Social Responsibility (CSR) literature (see e.g. Ambec, Lanoie 2008; Hart 1997; Margolis, Walsh 2003; Orlitzky et al. 2011). "This literature associates the positive returns of greener production choices to improvements in market's evaluation of the firm, access to new markets or cost reduction driven by increased resource efficiency" (Ghisetti 2018:59). Especially in regions characterized by a high awareness for green issues, CE innovations might also increase the reputation of a firm thus also leading to a positive demand effect (see Horbach, Rammer 2018).

While there are arguments for positive turnover effects of CE innovations, their employment effects remain undetermined from a theoretical point of view, particularly as employment effects may vary by type of CE innovation. CE process innovations (e.g. energy or material savings in the production process) and CE product innovations (e.g. a higher recyclability of products or a longer lifetime of products) are likely to result in very different employment effects. Process oriented CE innovations might have negative effects because the realization of these innovations might result in higher labor productivity (see also Horbach, Rennings 2013). The labor productivity may rise because CE process innovations often require a redesign of the whole production process from the choice of materials to the final design of products. Such a modernization might also lead to a substitution of labor by capital (e.g. an increased use of robots), hence increasing labor productivity.

However, an augmented efficiency of capital may lead to a higher valuation of capital versus labor, thus inducing lower wages which in turn may alleviate the negative employment effects of the substitution by capital. The realization of CE process innovations may also induce direct positive employment effects if they require additional investment or more specialized and better qualified employees.

The employment effects of CE product innovations also remain unclear from a theoretical side of view (see Harrison et al. 2014). Totally new CE related products may induce new demand for the firm inducing a positive employment effect but an increase of net employment only results if the new product does not substitute a more labor-intensive old product of the firm. The increase of the lifetime of products may lead to negative employment effects via a lower product demand, though this may be compensated by a higher demand of consumers for such products.

On the macroeconomic level, which is not the focus of this analysis, the employment effects of CE innovations are also not determined and depend inter alia on the labor intensity of the substituted products. All in all, the employment effects remain an empirical issue because they are undetermined from a theoretical side of view.

Based on these theoretical considerations we formulate the following hypotheses:

H1: Lower production costs induced by CE innovations improve the competitiveness of firms and thus their performance and financial standing.

H2: The positive employment effects of CE innovations via a higher competitiveness dominate the increase of labor productivity and the substitution of more labor-intensive products within firms.

Existing empirical evidence: Performance effects

There is an extensive literature on the performance effects of eco-innovations in general (for an overview see Ghisetti 2018). Ghisetti (2018:59) states that: "As a matter of fact, the meta-analysis of the literature by Horváthová (2010) summarizes that 15% of the studies found a negative return of going green, 55% a positive return, and 30% found no significant effect." Concerning the special case of CE innovations there is only rare evidence at the firm-level. In the following, we restrict our literature review to studies that at least include separate results for CE innovations.

Based on a macroeconomic analysis, the European Commission is very optimistic about the potential gains of the transition to a CE. Recent estimations predict that these transitions might create significant economic gains in the EU manufacturing sector (Korhonen et al. 2018). Technical change that drives theses gains is strongly related to CE innovation activities at the firm-level. Unfortunately, the empirical literature on these specific innovation activities is quite small up to now. An exception is the study of Flachenecker and Kornejew (2019) which analyzes the impact of material productivity on microeconomic competitiveness and environmental performance in the European Union. The study uses data from the Community Innovation Survey (CIS) 2008, comprising over 52,000 firms across 23 sectors and 12 European countries. Using an instrumental variable approach, the authors find evidence "for a positive and causal effect of material productivity improvements on microeconomic competitiveness for those firms that received targeted public financial support to realise eco-innovations" (Flachenecker, Kornejew 2019:87). Nevertheless, the authors show that the positive effects are limited to certain sectors and countries. In a further recent CE oriented analysis of resource efficiency measures and performance, Horbach (2018) shows that an increased use of renewables leads to a higher performance whereas measures to reduce water consumption are negatively correlated to turnover development.

Ghisetti and Rennings (2014) analyze the relationship between environmental innovations and profitability for different fields of eco-innovation. Using two waves of the German CIS (2008 and 2010) the authors find that especially innovations leading to a reduction in the use of energy or materials improve the competitiveness of firms whereas other, more end-of-pipe oriented eco-innovations might even hamper firms' competitiveness. Rexhäuser and Rammer (2014) also use the CIS 2008 to analyze the profitability effects of different types of eco-innovation. The authors find "that innovations which do not improve firms' resource efficiency do not provide positive returns to profitability. However, innovations that increase a firm's resource efficiency in terms of material or energy consumption per unit of output have positive impacts on profitability" (Rexhäuser, Rammer 2014:145).

Antonietti and Marzucchi (2014) analyze two types of environmental investment, those aimed at reducing the environmental impact of production and those that reduce the use of raw materials. Their analysis is based on a firm-level dataset of Italian manufacturing. Using a quantile regression approach, the authors show a positive productivity effect for medium-high performing firms of investments that help reducing raw materials.

Soltmann et al. (2015) point to the problem that eco-innovations had a u-shaped performance effect over the analyzed time period. The authors use industry-level panel data including 12 OECD countries from 1983 to 2009. They argue that "in early periods of green inventions, the costs of invention were relatively greater and, at the same time, the demand for green inventions was limited. The marginal costs of green inventions should have decreased over time. Furthermore, increasing political pressure may also have stimulated the demand for such inventions in the recent years. We thus expect that the negative impact of green inventions on performance has declined over time" (Soltmann et al. 2015:469). Based on a patent analysis of Italian firms, Lotti and Marin (2017) observe a lower return of eco-innovations compared with other innovations in the short run.

Eco-Innovation and employment

While there are several studies analyzing the employment effects of the CE at the macroeconomic level (see Horbach et al. 2015 for an overview), the empirical literature on firm-level employment effects of eco-innovation and, more specifically, CE innovations is quite rare. In general, early studies find positive effects of eco-innovations on employment (Bijman, Nijkamp 1988; Pfeiffer, Rennings 2001; Rennings, Zwick 2002). Pfeiffer and Rennings (2001) show that cleaner production is more likely to increase employment compared to end-of-pipe technologies. Horbach (2010) finds a positive and significant influence of eco-product innovations on employment. The positive effects of eco-innovation appear to be greater compared to other non-environmental innovation fields.

Horbach and Rennings (2013) use German CIS 2008 data which allow the analysis of employment effects in specific technology fields, such as recycling, energy and resource efficiency which are all highly relevant for the CE. The econometric analysis shows that eco-innovative firms are in general characterized by a significantly more dynamic employment development. Especially the introduction of cleaner technologies as process innovations cause higher employment within the firm. Especially material and energy savings are positively correlated to employment as they help to increase the profitability and competitiveness of the company. On the other hand, air and water process innovations that are still dominated by end-of-pipe technologies have a negative impact on employment. Hence, the results of this study confirm positive employment potentials of a circular economy.

Licht and Peters (2014) also use the CIS 2008 data to analyze employment effects of product and process innovations for different European countries and for Germany. The authors find that both environmental and non-environmental product innovations trigger employment growth, but that still non-environmental product innovations are more likely to increase employment. Following their estimation results, the displacement effect of process innovations seems to be rather small.

The study of Gagliardi et al. (2016) analyzes the link between eco-innovation and job creation at the firm level for 4,507 Italian firm matched with patent records for the period 2001 to 2008. Their results show a strong positive impact of eco-innovation on the creation of long-run jobs. The effects are substantially greater than the effects of other innovations. Kunapatarawong and Martínez-Ros (2016) analyze the relationship between eco-innovation and employment on the basis of data from the Spanish Technological Innovation Panel (PITEC) for 2007 to 2011. The authors find a positive relationship between eco-innovation and employment. The employment effects seem to be stronger for firms in the so-called ‘dirty’ industries.

The paper of Burger et al. (2019) analyzes the skill requirements within the CE. The authors differ between core CE activities focusing on renewable energy, repair, reuse of materials and the sharing economy and enabling activities focusing on management, design, and ICT-applicability of the CE. The authors conclude: "While core CE-activities generally require more manual and technological skills, enabling activities, in contrast, require more complex cognitive skills. […] Part of the education and skills demand is identifiably driven by 'circularity', particularly with regard to technical skills for the core of the CE" (Burger et al. 2019:248).

4. Data and definition of variables

Data

For our analysis, we use panel data of two waves of the German Community Innovation Survey (CIS) 2014 and 2016. The CIS wave of 2014 contains a special module on eco-innovation allowing a detailed analysis of CE innovations (introduced during 2012 to 2014). The data of the performance effects stem from the 2016 survey. The CIS 2016 provides data on turnover and employment development from 2014 to 2016. The combination of the two databases allows the use of lags between regressors and dependent variables thus reducing endogeneity and causality problems. The German CIS data is matched with data on turnover (2014 to 2016) and financial standing (2016) provided by *Creditreform*, which is the largest credit rating agency in Germany. CIS data and *Creditreform* data are matched via the Mannheim Enterprise Panel (see Bersch et al. 2014) which also serves as the drawing base for the German CIS. Furthermore, we match patent data at the NUTS 3 level (German districts). For more information on the data base, see Peters and Rammer (2013) and Behrens et al. (2017).

Definition of CE innovation

For our empirical analysis, *CE innovations* are defined as innovations that led to significant positive environmental effects in any of the following fields: energy and material savings per unit of output, substitution of fossil energy sources by renewables, substitution of dangerous substances, recycling of waste, waste water and material within the firm, products leading to a reduced energy use, improvement of the recyclability of products and an increase of the lifetime of products. We consider all types CE innovations that have been introduced during 2012 to 2014.

Table 1 shows the different CE innovation fields that are captured by the CIS 2014. The question on eco-innovation includes CE innovations related to processes and products. The most important CE innovations focus on energy and material savings.

Table 1: Share of firms by different types of CE innovation

CE innovations	**Share of firms with significant[1)] CE innovations (%)**
CE process-related innovations	
Reduced energy use per unit of output	24.0
Reduced material use / use of water per unit of output	17.7
Replaced fossil energy sources by renewable energy sources	6.6
Replaced materials by less hazardous substitutes	9.3
Recycled waste, water, or materials for own use or sale	13.8
CE product-related innovations	
Reduced energy use	14.6
Improved recycling of product after use	9.8
Extended product life through longer-lasting/more durable products	8.5
All CE innovations	**41.3**

1) Firms reporting that the CE innovation had a significant positive impact on the environment.
Source: German CIS 2014, own calculations (sample mean).

Table 2: Determinants of CE innovations

Factors[1)]	**Share in all firms with significant CE innovations (%)**
Increasing cost of energy, water or materials	50.2
Existing environmental regulations	39.1
Improving the enterprise's reputation	31.5
Voluntary actions or standards for environmental good practice	30.3
Environmental regulations or taxes expected in the future	29.0
Existing environmental taxes, charges or fees	21.2
Current or expected market demand for environmental innovations	19.4
Government grants, subsidies etc. for environmental innovations	15.6

1) Firms rating a factor as highly or medium important.
Source: German CIS 2014, own calculations (sample mean).

The CIS 2014 also contained a question on the factors that drove a firm's decision to introduce a CE innovation (or other types of eco-innovation). The results show that increasing costs of energy, water or materials are the most important drivers for firms having introduced CE innovations (Table 2). Existing regulations take the second place. The analysis also shows that reputation issues (31.5%) are very important factors for introducing CE innovations whereas subsidies are less decisive.

Definition of dependent variables

For measuring firm performance and employment, we use the following indicators:

- Growth rate of turnover from 2014 to 2016 *(Turnover1416*);
- Financial standing of the questioned firm 2016 measured by *Creditreform*'s credit rating index (*Finstanding*) which ranges from 100 (best) to 600 (worst) (see Czarnitzki, Kraft 2007 for more details on this measure);
- Growth rate of employment from 2014 to 2016 (*Emp1416*).

For the econometric analysis, a set of control variables is used (see the Appendix for a more detailed description of the variables). The dummy variables *Productinno* and *Processinno* get the value one if the firm introduced product or process innovations from 2012 to 2014. *Turnover12-14* gets the value one if the growth rate of turnover from 2012 to 2014 (2014-2016) was greater than 10% and zero otherwise. The variable *Export* captures firms selling to customers abroad. *Highqual* describes the share of employees with university degree, *Family* denotes firms that are dominated (at least 50% of firm shares) by a family. The competitive situation is indicated by the variables *Compabroad* (measuring the relevance of competition by firms from outside the home country), *Pricecomp* (measuring whether price increase leads to an immediate loss of customers) and *Competitors* (measuring the number of competitors). *Size* represents the number of employees of the firm, *West* gets the value one if the firm is located in Western Germany. The variable *Wage1314* denotes the growth rate of per capita wages from 2013 to 2014. The variable *Patreg0812* captures the growth rates of the number of patents per capita from 2008 to 2012 in the German district (NUTS 3 level) the firm belongs to. This indicator thus describes the regional innovation dynamics. Firms located in a dynamic region might profit from positive spill-over effects. Furthermore, sector dummies and four variables (*Event1-Event4*) that help to explain outliers of the dependent variables are included. *Event1* takes the value one if the questioned firm merged with another firm or firms, *Event2* describes the sale or closure of parts of the firm, *Event3* captures the outsourcing of firm activities to other firms whereas *Event4* denotes the foundation of subsidiaries. All control variables (except *Patreg0812*) are taken from the CIS survey and are either based on the financial reporting of firms (quantitative variables) or on statements by the management.

Estimation strategy

For our three dependent variables, we use different econometric models according to the data structure and quality of the respective variables. For the variable on financial standing we apply an OLS estimator with robust standard errors. As the employment variable shows many outliers, we use OLS only as baseline estimation. A better solution is the application of quantile regressions. This estimation method is more robust against outliers and there are no assumptions about the parametric distribution of the error term (Cameron, Trivedi 2009). Besides a median regression where the objective is an estimation of the median of the dependent variable, conditional on the values of the independent variables, we also estimate regressions for the 25% and 75% quantile.

The qth ($0 < q < 1$) quantile regression estimator minimizes the objective function over β_q (Cameron, Trivedi 2009:207):

$$Q(\beta_q) = \sum_{i:y_i \geq x_i'\beta}^{N} q|y_i - x_i'\beta_q| + \sum_{i:y_i < x_i'\beta}^{N} (1-q)|y_i - x_i'\beta_q|$$

β_q instead of β is used showing that different choices of q lead to different values of β. As the objective function is not differentiable, the simplex method is used for a solution.

Unfortunately, the turnover variable (turnover growth 2014-2016) contains many outliers, zeros and not explainable jumps so that we reduced the variable to a dummy level. This dummy variable gets the value 1 if the growth rate of turnover was greater than 10% from 2014-2016. We then estimate the probability *prob (Turnover14-16 = 1| **x**) = F (**x**, β)* within a probit model and calculate marginal effects.

5. Estimation results

The econometric analysis (Table 3) shows that firms having introduced CE innovations from 2012 to 2014 are characterized by a significantly better performance measured by the turnover development from 2014 to 2016 compared to other firms. Furthermore, the CE firms show a significantly better financial standing in 2016. Both results support our Hypothesis H1. In terms of financial standing and turnover development process innovators perform better. Firms with a strong increasing turnover from 2014 to 2016 show a significantly better financial standing in 2016. The regional innovative capacity of the district (NUTS 3) where the firm is located measured by the lagged patent dynamics from 2008 to 2012 (*Patreg0812*) seems to be also relevant for the financial standing of a firm via positive regional spill-over effects.

Table 3: Performance effects of circular economy innovations in German firms

Regressors	Dependent variables	
	Finstanding	*Turnover1416*[1)]
CE Innovation	6.00 (3.53)**	0.03 (2.04)*
Processinno	6.68 (3.31)**	0.03 (1.73)$^{+}$
Productinno	-0.83 (-0.44)	0.03 (1.64)$^{+}$
Patreg0812	0.04 (2.09)*	0.00 (0.51)
Turnover14-16	6.18 (3.83)**	-
Export	5.13 (2.61)**	0.02 (1.17)
Highqual	-15.3 (-3.97)**	0.06 (1.94)*
Family	-7.53 (-4.09)**	-0.02 (-1.29)
Compabroad	-0.50 (-0.26)	-0.03 (-2.11)*
Competitors	-5.57 (-2.80)**	-
Size	1.01 (2.95)**	-0.002 (-1.34)
West	-0.36 (-0.19)	0.03 (2.23)*
Event1 (merger or acquisition)	6.42 (1.65)$^{+}$	0.00 (0.03)
Event2 (sale or closure)	-14.9 (-2.50)**	-0.08 (-2.59)**
Event3 (outsourcing)	-9.00 (-1.85)$^{+}$	-0.06 (-1.94)*
Event4 (new subsidiaries)	13.2 (3.59)**	0.03 (0.95)
Type of regression	OLS, robust standard errors	Probit, robust standard errors
No. of observations	4,163	4,287
R^2 / Pseudo R^2	0.07	0.02

t, z-statistics shown in parentheses. +,*, ** denote significance at the 10%, 5% and 1% level, respectively. Sector dummies are included but not reported.

1) The model shows the results for a growth rate of turnover greater than 10% from 2012 to 2014. As robustness checks, we also estimated models for turnover growth rates greater than 5% and 20%, respectively. The 5% model shows a slightly lower significance level of the CE Innovation variable whereas the 20% model shows nearly no significant regressors because of a too low number of observations in this turnover growth category.

Source: German Community Innovation Survey (CIS) 2014, 2016, Eurostat 2018, *Creditreform*, own estimations.

Family dominated firms are characterized by a lower financial standing, the shareholder value seems to be less important for these firms. A high competition pressure is correlated to a lower financial standing and turnover development. Sale, closure of parts of the firm or outsourcing of firm activities to other firms is negatively correlated to both financial standing and turnover development whereas the foundation of subsidiaries seems to improve the financial standing of the firm.

Positive effects of CE innovations are also confirmed for the employment indicator. CE innovative firms show a positive employment development from 2014 to 2016 (Table 4) supporting the Hypothesis H2. This is especially true for the results of the 25% quantile regression capturing moderate employment changes whereas there is no significant influence of CE innovations on the big employment changes (75% quantile regression). Not surprisingly, the employment development is also triggered by a growing product demand in the past (*Turnover1214*) whereas a high price competition leads to a lower employment. Only for the 25% quantile regression, the international orientation of a firm is significantly important for a firm´s employment development.

Table 4: Employment effects of circular economy innovations in German firms: OLS and Quantile Regressions

Regressors	Dependent variable: *Emp1416*			
	OLS	25% quantile	Median	75% quantile
CE Innovation	1.86 (2.09)*	2.62 (2.77)**	0.51 (2.15)*	-0.16 (-0.18)
Patreg0812	-0.02 (-1.61)	-0.02 (-0.97)	-0.00 (-0.91)	-0.02 (-5.04)**
Turnover12-14	4.69 (5.09)**	5.01 (5.27)**	2.48 (4.02)**	7.25 (7.05)**
Wage1314	0.13 (2.92)**	0.09 (2.83)**	0.06 (4.76)**	0.22 (7.58)**
Export	1.21 (1.14)	2.20 (2.06)*	0.33 (0.87)	-0.92 (-0.86)
Highqual	2.71 (1.14)	-1.26 (-0.59)	1.47 (1.60)	10.2 (5.44)**
Family	0.97 (1.02)	-2.00 (-2.10)*	0.31 (1.00)	3.52 (3.62)**
Pricecomp	-2.34 (-2.60)**	-1.60 (-1.76)+	-1.07 (-3.42)**	-2.08 (-2.30)*
Size	-0.35 (-1.52)	-0.75 (-0.60)	-0.03 (-0.03)	-0.14 (-0.40)
West	-0.17 (-0.17)	0.06 (0.06)	0.06 (0.32)	0.60 (0.62)
Event1 (M&A)	1.27 (0.66)	-0.13 (-0.09)	0.42 (0.89)	-2.03 (-0.62)
Event2 (sale or closure)	-6.18 (-2.83)**	-3.70 (-1.92)*	-2.72 (-5.91)**	-0.51 (-0.31)
Event3 (outsourcing)	-5.00 (-2.37)*	-3.77 (-1.74)+	-1.86 (-1.61)	-0.34 (-0.19)
Event4 (new subsidiaries)	3.24 (1.47)	2.96 (1.35)	1.37 (1.29)	4.77 (1.99)*
Type of regression	OLS, robust standard errors	Quantile, robust standard errors.	Quantile, robust standard errors	Quantile, robust standard errors
No. of observations	3,136	3,210	3,210	3,210
R^2 / Pseudo R^2	0.044	0.010	0.002	0.010
t-statistics shown in parentheses. +,*, ** denote significance at the 10%, 5% and 1% level, respectively. Sector dummies are included but not reported.				

Source: German Community Innovation Survey (CIS) 2014, 2016, Eurostat 2018, *Creditreform*, own estimations.

At first glance, the positive effect of the wage dynamics (*Wage1314)* on employment growth seems to be counter-intuitive but against the background of a growing lack of qualified personnel in Germany especially dynamic and expanding firms are forced to (and able to) pay higher wages. In the light of the efficiency wage theory only firms that are able to raise wages can attract and retain the required qualified personnel. Rising wages are thus a pre-condition for an expansion of employment in a firm. Not surprisingly, the sale or closure of parts of the firm or outsourcing of firm activities evokes a decline of employment.

6. Summary and conclusions

Circular Economy (CE) innovations aim at maximizing the output of the nature-society-nature material and energy throughput flow by a reduction of energy and material use, a substitution of fossil fuels by renewables, or a higher recyclability and lifetime of products. Besides positive environmental effects, these innovations may also induce a higher economic performance and higher employment levels within firms. The positive performance effects of CE innovations may result from cost savings of a lower energy and material consumption or the recycling of waste or water. These cost savings may induce a higher competitiveness of the firm by inducing additional demand. This effect may be re-enforced if consumers are willing to pay more for the added ecological value of CE improved products. Especially in regions characterized by a high awareness for green issues, CE innovations might also increase the reputation of a firm thus also leading to a positive demand effect.

The employment effects of CE innovations remain undetermined from a theoretical point of view. Process oriented CE innovations might have negative effects because the realization of these innovations might be accompanied by higher labor productivity leading to a lower employment level. The labor productivity may rise because CE process innovations often require a re-design of the whole production process from the choice of materials to the final design of products. On the other hand, the realization of CE innovations may also induce direct positive employment effects because of the increased product demand and the additional investment for the introduction of CE measures requiring more specialized and high qualified employees.

The employment effects of CE product innovations also remain unclear from a theoretical perspective: Entirely new CE-related products may induce new demand for the firm inducing a positive employment effect but an increase of net employment only results if the new product does not substitute a more labor-intensive product of the firm. The econometric analysis uses panel data of two waves of the Community Innovation Survey (CIS) 2014 and 2016. The combination of the two databases allows the use of lags between regressors and dependent variables thus reducing endogeneity and causality problems. The CIS data is matched with data on turnover (2014 to 2016) and financial standing (2016) provided by *Creditreform*, Germany's largest credit rating agency.

Econometric estimations show that firms having introduced CE innovations from 2012 to 2014 are characterized by a significantly better performance measured by the turnover development from 2014 to 2016 compared to other firms. Furthermore, the CE firms show a significantly better financial standing in 2016. The results of quantile regressions show that the employment development of CE innovative firms is also positive. CE innovations seem thus having positive effects on the social dimension of a sustainable development. All in all, it seems to pay to be circular at the firm level. A political promotion of CE related activities seem to have positive performance and employment effects. Lower taxes for labor and higher taxes on resources use would strengthen the estimated positive effects.

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Appendix: Definition of variables and descriptive statistics

Name of variable	Definition	Mean	SD
Performance			
Finstanding	Index from -600 (low) to -100 (highest)	-229.6	54.9
Empl1416	Change of employment 2014-2016 (%)	50.5	1972
Turnover1416	1: Turnover growth 2014-2016 >10%, 0: otherwise	0.23	0.42
Innovation capacity			
CE Innovation	1: Significant CE innovation, 0: otherwise	0.41	0.49
Highqual	Share of employees with university degree 2013	0.22	0.28
Patreg0812	Change in number of patents 2008-2012 at NUTS3 (%)	-14.2	34.7
Processinno	1: Introduced process innovation 2012-2014, 0: otherwise	0.28	0.45
Productinno	1: Introduced product innovation 2012-2014, 0:otherwise	0.38	0.49
Control variables			
Compabroad	1: Strong competition by foreign firms; 0: otherwise	0.32	0.47
Competitors	1: More than 15 main competitors, 0: otherwise	0.28	0.45
Event 1	1: Take-over or merging with other firm(s), 0: otherwise	0.08	0.27
Event 2	1: Sale or closure of parts of the firm, 0: otherwise	0.06	0.24
Event 3	1: Outsourcing of activities, 0: otherwise	0.06	0.23
Event 4	1: Foundation of subsidiaries, 0: otherwise	0.06	0.24
Family	1: At least 50% of firm shares owned by family, 0: otherwise	0.56	0.50
Pricecomp	1: Price changes induce a loss of customers, 0: otherwise	0.49	0.50
Export	1: Selling products on international markets, 0: otherwise	0.44	0.50
Size	Number of employees 2012 (in 1,000)	0.34	3.87
Turnover1214	1: Turnover growth 2012-2014 >10%, 0: otherwise	0.37	0.48
Wage1314	Growth rate of per capita wages 2013-2014 (%)	4.78	42.3
West	1: Firm located in Western Germany, 0: otherwise	0.67	0.47
Sector dummies			
Sec1	Food products and beverages, tobacco	0.04	0.20
Sec2	Textiles, clothing, leather products	0.03	0.17
Sec3	Wood and paper products, printing	0.03	0.16
Sec4	Chemical and pharmaceutical industry	0.03	0.16
Sec5	Rubber and plastic products	0.02	0.15
Sec6	Glass, ceramics and concrete products	0.02	0.14
Sec7	Basic metals and fabricated metals	0.07	0.25
Sec8	Electrical machinery, electronics, instruments	0.05	0.21
Sec9	Machinery	0.07	0.25
Sec10	Motor vehicles, other transport equipment	0.02	0.14
Sec11	Medial products, furniture and other products	0.06	0.23
Sec12	Energy and water supply, mining, mineral industry	0.03	0.17
Sec13	Recycling, waste and waste water removal	0.05	0.21
Sec14	Wholesale trade	0.04	0.19
Sec15	Transport and logistics	0.07	0.26
Sec16	Media services	0.04	0.20
Sec17	Computer programming, data processing, telecommunication	0.04	0.19
Sec18	Financial services	0.05	0.21
Sec19	Technical and R&D services	0.08	0.27
Sec20	Business consulting and advertising	0.06	0.24
Sec21	Other business services	0.12	0.33

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