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LABOUR MARKET CONSEQUENCES OF A TRANSITION TO A CIRCULAR ECONOMY: A REVIEW PAPER – ENVIRONMENT WORKING PAPER N°162

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Abstract

Resource efficiency and circular economy policies aim at reducing resource intensity and use throughout the economy, thereby decreasing environmental impacts. Besides the environmental benefits expected from these policies, potential employment benefits are often emphasised, which would follow the anticipated structural changes in the economy from material-intensive to more labour-intensive activities. However, the size of the employment effect is still unclear and difficult to quantify. To date, the quantitative literature on the employment impacts of the circular economy is still scarce. This study is the first of its kind to review the available studies on this increasingly important policy issue.

An analysis of global sectoral economic data in 2011 reveals that just four material-intensive sectors (i.e. construction, food products, primary metals and non-metallic minerals and power generation and distribution) account for almost 90% of global material use, while relying on only 15% of the workforce. This suggests that overall job losses resulting from policies that tackle materials consumption might be modest. This loss could potentially be more than compensated by job creations in more labour intensive sectors, most notably services.

There is a limited, but growing body of work that employs quantitative models to assess the employment implications of the circular economy transition. This paper reviewed 47 scenarios from 15 modelling studies. Many of them are regional and only four are global assessments. The review suggests that the employment gains of resource efficient and circular economy policies range between 0 and 2%, with one study predicting employment gains up to 7%. Only three scenarios find slightly negative employment results. The scenario design among the studies varies widely, but in general, most simulations revolve around material taxes aimed at reducing virgin material consumption and increasing resource efficiency. In some simulations, the generated tax revenues are redistributed to reduce distortionary labour taxes, which is commonly referred to as an environmental tax reform. In such scenarios, the positive employment effect is found to be stronger by around 2 percentage points.

Generally, the existing literature on the macroeconomic impacts of the resource efficiency and circular economy transition indicates that the transition is likely to lead to a net improvement in employment rates, albeit small. However, these modelling results should be seen in the context of rather stylised policy scenario designs, the geographical coverage and assumptions around revenue recycling. Furthermore, the net employment gains should be considered in the context of the quality, duration and gender aspects of the jobs created, and of the potential distributional effects of changes in the labour market. These aspects, as well as those concerning potential skills requirements for a resource efficient and circular economy, will need to be further explored.

Keywords:

Circular economy, resource efficiency, natural resources, employment & redistributive effects, labour markets, macro-economic modelling

JEL codes: O14, Q52, Q53, J4, C68

Résumé

Les politiques publiques pour la transition vers l'utilisation efficace des ressources et l'économie circulaire visent à réduire l'intensité et l'utilisation des ressources dans l'ensemble de l'économie, et de ce fait les impacts sur l'environnement. Outre les avantages environnementaux attendus de ces politiques, les gains potentiels pour l'emploi sont souvent mis en évidence. Les impacts sur l'emploie suivraient les changements structurels de l'économie, passant d'activités à forte intensité de matériaux à des activités à plus forte intensité de main-d'œuvre. Cependant, l'ampleur de l'effet sur l'emploi n'est pas encore claire et demeure difficile à quantifier. À ce jour, la littérature quantitative sur les effets de l'économie circulaire sur l'emploi est encore limitée. Cette étude est la première à passer en revue les études disponibles sur cette question politique qui prend de plus en plus d'importance.

Une analyse des données économiques sectorielles mondiales en 2011 révèle que seulement quatre secteurs à forte intensité matérielle (notamment secteur de la construction, produits alimentaires, production de métaux primaires et de minéraux non métalliques, ou encore génération d'électricité) représentent près de 90% de l'utilisation mondiale de matières, tout en n'employant que 15% de la main-d'œuvre. Cela suggère que les pertes totales d'emploi résultant de la mise en places de politiques de réduction de la consommation de matériaux pourraient être modestes. Ces pertes d'emploi pourraient être plus que compensées par des créations d'emploi dans des secteurs à plus forte intensité de main-d'œuvre, notamment les services.

Des études, en nombre assez restreint mais croissant, basées sur l'utilisation de modèles numériques évaluent les implications sur l'emploi de politiques de transition vers une économie circulaire. Ce document de travail explore 47 scénarios de transition extraits de 15 études de modélisation. La majorité de ces études a une portée régionale, seules quatre d'entre elles sont des évaluations mondiales. L'analyse des résultats de ces travaux suggère que les gains d'emploi, qui découlent de la mise en place de politiques publiques visant à promouvoir une meilleure efficacité des ressources, se situent entre 0 et 2% de l'emploi total. Une seule étude prévoit des gains d'emploi allant jusqu'à 7% et seuls trois scénarios présentent des résultats d'emploi légèrement négatifs. L'architecture des scénarios varie considérablement entre les études, mais, en général, la plupart des simulations incluent des taxes sur les matériaux visant à réduire la consommation de matériaux primaires et à augmenter l'efficacité des ressources. Dans certaines simulations, les recettes fiscales générées sont utilisées pour réduire les impôts sur le travail, ce qui est communément appelé une réforme fiscale environnementale. Il est important de noter que l'effet positif sur l'emploi se révèle plus important d'environ 2 points de pourcentage lorsque les recettes provenant des impôts sur les matières sont redistribuées afin de réduire les impôts sur le travail.

En conclusion, la littérature sur les impacts macroéconomiques de la transition vers l'utilisation efficace des ressources et l'économie circulaire indique que la transition est susceptible de conduire à une nette amélioration des taux d'emploi, bien que restant faible. Cependant, ces résultats restent basés sur des scénarios politiques stylisés, de par leur couverture géographique et dans le cadre des hypothèses retenues concernant l'utilisation de des recettes fiscales supplémentaires. En outre, les questions de la qualité, de la durée et de la distribution par sexe de ces gains d'emploi méritent d'être examinées, de même que les effets potentiels sur la distribution des revenus résultant de ces changements sur le marché du travail. Ces aspects, ainsi que ceux concernant les types de qualification nécessaires pour assurer une transition efficace vers une économie circulaire, devront être approfondis.

Keywords:

Économie circulaire, efficacité des ressources, ressources naturelles, emploie et effets distributif, marchés du travail, modélisation macroéconomique

JEL codes: O14, Q52, Q53, J4, C68

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Abbreviations and acronyms

BAU	Business as usual
BC	British Columbia, Canada
BRIC	BRIC-countries: Brazil, Russia, India, China
CAD	Canadian Dollars
CGE	Computable general equilibrium
DSGE	Dynamic stochastic general equilibrium
RECE	Resource Efficient and Circular Economy
CO_2e	CO_2 equivalents
DMC	Domestic Material Consumption
EC	European Commission
EEA	European Environment Agency
EFR	Environmental Fiscal Reform
EOL	End-Of-Life
EPR	Extended Producer Responsibility
ETR	Environmental Tax Reform
EU	European Union
GDP	Gross Domestic Product
GFR	Green Fiscal Reform
GHG	Greenhouse Gas Emissions
GTS	Green Tax Swaps
IRP	UNEP's International Resource Panel
ISCO08	International Standard Classification of Occupations
ISIC Rev.4	International Standard Industrial Classification of All Economic Activities
LCA	Lifecycle Assessment
ME	Macro econometric
MI	Material Intensity
MRIO	Multiregional input-output
PSS	Product-service systems
RE-CE	Resource Efficiency and Circular Economy
R&D	Research and Development
SSC	Social Security Contributions
TMC	Total Material Consumption
UNEP	United Nations Environment Program

Executive Summary

Resource efficiency and circular economy policies aim at reducing resource intensity and use throughout the economy. While a more resource efficient and circular economy is necessary to fulfil key environmental targets, the transition process will determine changes in labour markets that may pose challenges in the social domain, especially in the short term. The present report provides a state-of-the-art review of existing literature on the labour market, employment and skills implications of the transition to a more resource-efficient and circular economy.

Overall, four mechanisms are likely to affect the labour market: changes in production modes, in demand patterns, in aggregate income and macroeconomic conditions, and changes in trade and competitiveness. Through these mechanisms, the circular economy transition can induce a variety of effects on labour markets, including job creations, job substitutions, job losses and job redefinitions. The interplay of these drivers determines the net aggregate effect of circular economy policies on the labour market.

As different economic sectors are likely to be affected differently by resource efficiency policies, the structure of the economy is likely to change because of their implementation. In particular, the transition is likely to boost economic activity in more labour-intensive sectors – such as those related to product life extension (e.g. repairing, re-manufacturing and recycling) and certain services sectors – while job destructions are expected to take place in more material-intensive sectors. An analysis of sectoral data at the global level reveals that, in 2011, only four material-intensive sectors (i.e. construction, food products, primary metals and non-metallic minerals and power generation and distribution) accounted for almost 90% of global material use, while employing only 15% of the global workforce. This suggests that the job losses resulting from circular economy policies are likely to be modest and more than compensated by job creations in other sectors.

Economic models provide important quantitative insights into the complex dynamics between resource efficiency policies and labour markets. There is a limited, but growing body of work that employs quantitative models to assess the macroeconmic consequences and employment implications of the circular economy and resource efficiency transition. This report reviews 47 scenarios from 15 economic modelling studies, thus providing an overview of the current stand of existing literature in this field.

The modelling studies reviewed suggest that employment gains range between 0 and 2%, with one study predicting employment gains up to 7%. Only three scenarios out of the 47 reviewed find a slightly negative employment outcome. Yet, employment implications vary widely across sectors and regions.

Importantly, the allocation of revenues from taxes on materials use can substantially influence the final employment outcomes of modelling simulations. In the modelling studies reviewed, the employment effect is stronger by around 2 percentage points when revenues from material taxes are redistributed to reduce distortionary labour taxes.

The labour impacts described are likely to be asymmetric within and across countries, and the specialisation and composition of local economies plays an important role in determining how the transition will play out in different areas. When regions and sectors experience a strong gap between job gains and job losses, the mobility of workers becomes

particularly important. To ensure a just transition, it is also essential to consider elements such as job quality, job duration, health impacts and gender inequalities.

Additionally, the impacts of the circular economy transition on labour markets depend on the transferability of skills from declining to growing sectors. Recent studies suggest that most "green jobs" require an upskilling of the labour force, rather than a complete re-skilling. Nonetheless, to date, the literature on skill shifts and skill demand in a circular economy is still scarce and involves large uncertainties, due to the lack of sufficiently detailed data. In order to strengthen the quantitative evidence on the subject, more research is needed.

The conclusions of this review should be considered in the context of an emerging but still limited literature on the topic. The lack of a comprehensive and common definition of the circular economy and the variety of indicators and assumptions used by different studies limit the comparison of modelling results. In addition, the scenario design in most modelling studies is still rather stylised and revolves predominantly around materials taxes. To date, only few studies have addressed the emergence of new business models and socio-technological trends such as digitalisation and automation. Future macroeconomic modelling studies in this field could therefore explore additional dimensions in their scenarios and further elaborate on the skills aspect of the circular economy transition.

1. Introduction

Resource efficiency and the circular economy[1] are becoming important elements of environmental policy. If current socio-economic trends continue, the demand for natural resources is projected to more than double by 2060 with potentially severe environmental consequences (OECD, 2019[1]). The environmental issues related to resource extraction include water and soil degradations and biodiversity loss as well as pollution, if dismantling and disposal of end-of-life products is handled improperly. Limiting resource use and increasing resource efficiency and material recovery is thus crucial to address these environmental challenges.

Multilateral initiatives at the G7 (2015[2]), the G20 (2017[3]) or the European Union (European Commission, 2015[4]) have started to address the issue of the transition to a more resource efficient and circular economy and several countries, such as China, Finland, France, and The Netherlands, have implemented circular economy roadmaps, legislative frameworks or strategies (Thieriot, 2015[5]; Ministry of the Environment Finland, 2017[6]; French Ministry of Environment, 2017[7]; Dutch Ministry of Infrastructure and the Environment & Ministry of Economic Affairs, 2016[8]). At subnational level, cities and regions, such as in Paris or Oslo (Mairie de Paris, 2017[9]; Oslo Municipality, 2017[10]), also set up roadmaps and strategies.

Besides environmental motives for such a transition, governments also emphasise the employment benefits it can generate. For instance, the "Circular Economy Package" of the European Commission anticipates to create over 170,000 direct jobs in the EU by 2035 (European Commission, 2016[11]), the French "50 measures for a circular economy" expects to generate up to 300,000 new jobs in France if the proposed policies are implemented (French Ministry of Environment, 2017[7]) and the Finnish "roadmap to circular economy" mentions a potential gain of 75,000 jobs for Finland (Ministry of the Environment Finland, 2017[6]; Wijkman and Skånberg, 2015[12]).

Policies that help steer the transition to a more resource efficient and circular economy – hereafter referred to as RE-CE policies – imply a transformation of the structure of the economy towards less-polluting and more resource-efficient economic activities. Like any structural change in the economy, this transition process will have impacts on employment, economic growth and income distribution at aggregate and sectoral level, involving multiple interactions between different sectors and countries. In parallel, additional sources of structural change can be expected. Examples are changes in consumption patterns, driven by increased living standards, or changes in technology and production modes, such as digitalisation and servitisation.

Impacts can therefore expected to be complex and while RE-CE policies will likely bring about job gains in some sectors and some regions, they may also lead to job losses in others. Comprehensive evidence of overall and sectoral employment effects is still scarce. Quantitative models can be used to obtain a better understanding of this complexity and to calculate net employment effects. Such models describe the relation between different sectors and countries through production structures and international trade flows.

[1] See Box 1 for a discussion of the definition of circular economy.

Box 1. What is the circular economy?

Various definitions and interpretations of the circular economy (CE) exist. Generally, these share a common conceptual basis but may differ in scope. The definition from the Ellen MacArthur (2013[13]) is the most commonly cited. In essence, the circular economy seeks to keep products, components and materials in the economy for as long as possible, trying to eliminate waste and virgin resource inputs. There are two main strategies to increase circularity, (1) through regeneration of biotic materials and (2) through maintaining the value of abiotic materials for as long as possible.

Ongoing OECD work on the circular economy considers a range of processes to achieve circularity, which have been conceptualised along three different elements (McCarthy, Bibas and Dellink, 2018[14]):

- *Closing resource loops* aims at minimising raw material extraction and waste output through improved end-of-life sorting, treatment and increased material recycling.
- *Slowing resource loops* stresses the need for fundamental changes in the economic system towards more durable products and extended lifespans through reuse, repair and remanufacture services.
- *Narrowing resource flows* aims at a more efficient use of natural resources, materials, and products along all phases of the value chain. This third part addresses the significant "structural" waste in current consumption patterns and underutilisation of assets (e.g. office space or private vehicles).

All CE concepts share common concerns of increased resource efficiency, waste management and decoupling resource extraction from economic output. However, the scope, processes, actors and main underlying motivations of the transition to a circular economy can vary. Several "schools of thought" share a common theme but differ in their main focus, their intended outcomes and optimal implementations (Ghisellini, Cialani and Ulgiati, 2016[15]). Some prioritise minimising waste and resource extraction (Ekins et al., 2017[16]), others economic growth potential and job gains (Ellen MacArthur Foundation, 2016[17]; Groothuis et al., 2016[18]; Gower and Schröder, 2016[19]) and again others environmental impact reductions (OECD, 2019[20]).

The circular economy still lacks a clear, commonly accepted definition and consequently the policies associated with a circular economy transition can also differ substantially (Kirchherr, Reike and Hekkert, 2017[21]). Due to the lack of a clear definition, there are also no comprehensive parameters and indicators established yet that capture all aspects of a circular economy and allow for a standardised monitoring and comparison of the RE-CE transition progress and its effects on environment, economy and employment between countries and regions.

This report provides an overview of the state-of-the-art economic modelling literature on the labour market implications of RE-CE policies. It reviews the current stand of research on the dynamics of employment gains, losses and shifts that may follow a transition to a circular economy. The literature review is also useful to highlight limitations and research needs in this field. The review focuses in particular on modelling studies on the impacts of RE-CE policies on the labour market, skills and potential skill-shifts. Employment and resource efficiency outcomes of the 47 policy scenarios of the 15 reviewed modelling studies are compared, in order to gain an overview of labour dynamics. A brief review of relevant work on green growth impacts on labour markets is also included in order to capture synergies of both fields of studies.

The analysis of the existing modelling literature about employment impacts of the RE-CE transition suggests that well-implemented policies may lead to a slight net-increase in employment (Ekins et al., 2012[22]; Green Alliance, 2015[23]; Bosello et al., 2016[24]; Groothuis et al., 2016[18]). However, the effects appear complex and heterogeneous across sectors and geographical regions. Importantly, the way tax revenues from fiscal instruments (e.g. materials taxes) are recycled may significantly affect economic and employment outcomes of a RE-CE transition.

This paper is structured as follows. Section 2 explores the underlying drivers and dynamics that influence the labour market during a transition. Using this conceptual framework, Section 3 looks at the current economic structures and discusses in what sectors and regions employment effects of RE-CE could be expected. Given the importance of modelling to understand the complex changes of the economy and labour markets in the RE-CE transition, Section 4 critically reviews the current macroeconomic modelling literature on the employment effects of the circular economy transition. Sections 5 elaborates on the types of jobs and skills that are needed for the transition. Finally, Section 6 concludes with a discussion on limitations and ideas for further research opportunities.

2. Potential employment impacts of circular economy policies

2.1. Mechanisms and drivers of labour implications of the resource efficiency and circular economy transition

Resource efficiency and circular economy (RE-CE) policies aim to reduce resource-intensity throughout the economy and provoke a paradigm shift away from the current linear "take, make and dispose" consumption model. Whilst a resource efficient economy is clearly beneficial in many aspects, becoming resource efficient will have distributional consequences and may pose challenges in the social domain, especially in the short term. Thus, it is important to carefully study the dynamics and acknowledge positive as well as negative labour implications that may arise during the transition, in order to highlight how additional policies and reforms may reduce possible short-term issues.

In principle, there is nothing inherently different about the job turnover associated with a circular economy transition than that associated with any other transition that industrialised societies have experienced in the past. The composition of change will be different, but the underlying dynamics and the trend of creative destruction has been around for a long time (Davis and Haltiwanger, 1999[25]). Thus, much can be learned from the broader literature on the green growth and low carbon transition and their effect on labour markets (UNEP et al., 2008[26]; OECD, 2012[27]; OECD, 2017[28]; Chateau, Bibas and Lanzi, 2018[29]). Although this literature predominantly explored climate policies, similarities exist between the effects of climate policies on carbon-intensive sectors and the effects of RE-CE policies on material-intensive sectors. For instance, the labour implications of a carbon tax on carbon-intensive sectors could be similar to the effects of a material tax on material-intensive sectors.

Based on the green growth literature this section identifies the drivers of changes in labour markets induced by RE-CE policies and the different effects that determine the overall aggregate changes in labour markets. This section proposes a conceptual framework that will be applied in the remaining paper.

2.2. Drivers of policy-induced changes in labour markets

A variety of macroeconomic trends can drive the change in labour markets. Previous OECD work identified four main drivers, through which market-based policies can affect economic sectors and labour markets (Chateau, Bibas and Lanzi, 2018[29]). RE-CE policies could influence markets through changes in (i) production modes, (ii) demand patterns, (iii) aggregate income and macroeconomic conditions, and (iv) trade and competitiveness.

When adapting to RE-CE regulations or fiscal incentives, firms will change their *production modes* using fewer raw and refined resource inputs. For instance, governments could promote metal production based on recycling input rather than raw metal ores, which would induce firms to switch between the different technologies. With less material-intensive production processes, each sector will need to adjust its labour demand accordingly, which can then lead to job creation and job destructions.

Changes in *demand patterns* can lead to the expansion and the contraction of certain economic sectors and industries, which then lead to employment adjustments. Changes in demand patterns can be the result of policy-induced changes in the relative price of goods or service, or they could occur when agents change their preferences (due to e.g. increased consumer awareness) and react by investing and purchasing durable goods that reduce their own material footprint. For instance, a materials tax can change the incentive structure for businesses and consumers towards limiting their material footprint and opt for more resource efficient products in final and intermediate demand. With increased prominence of the circular economy topics in the public debate, awareness of material consumption and their environmental consequences may further change consumer demand (a recent example is the negative association of single-use plastics, causing a shift to more durable substitutes).

The implementation of RE-CE policies also influences *aggregate income and macroeconomic conditions*, including aggregate supply, demand, and employment. For instance, in short run additional fiscal revenues from RE-CE policies can be used to stimulate employment or to mitigate direct adverse employment effects of the policies. In long run, these policies also affect capital accumulation and therefore the potential GDP of economies. Importantly, RE-CE fiscal policies implemented as part of a tax reform may achieve multiple dividends and may result in improved environmental quality, better health and wellbeing of citizens as well as reduce distortionary labour market taxation and concurrently lead to a more efficient economy (see Box 2). Reversely, country-specific macroeconomic conditions also influence the effects of RE-CE policies and their effects on labour markets. During economic upturns, consumer and firms' confidence is high and thus demand increases in anticipation of future benefits. Such increase in demand could mitigate some of the transitional costs of RE-CE policies in the short-term, more so than during economic downturns. Vice versa, economic downturns could complicate a smooth RE-CE transition.

Finally, RE-CE policies can change the production structure and prices unevenly in different regions, thus leading to changes in *international trade and competitiveness*. Since natural resources are not uniformly allocated across regions, policies that promote secondary materials use and recycling to reduce the use of these resources will likely have asymmetrical effects on different regions. Furthermore, in a world where policy stringency and ambition to move towards a circular economy vary, this can lead to significant discrepancies between countries. Trade policies in itself can also affect the transition to a circular economy; export restrictions, tariffs and subsidies could hamper or stimulate resource efficiency, especially if secondary materials are treated differently than primary materials. Extractive and material intensive industries in regions with strict policies on material consumption can suffer from a loss in competitiveness and decrease in labour demand, whereas clean production sectors may expand their exports and boost production and labour in the same jurisdiction. Fragmentations in the policy landscape can also lead to shifts of material-intensive practices from one jurisdiction with stringent regulations to others with less stringent regulation, resulting in geographical shifts in employment. Besides natural resource endowments and stringency of policy enforcement, there are other factors that affect the competitiveness impacts of RE-CE policies, such as average skill levels, labour costs or demographics. Countries and regions with low wages can attract labour-intensive circular activities, where labour costs account for a large share of the overall costs. Dismantling, refurbishing and repair processes, for instance, tend to have high labour intensities (Vellinga, Berkhout and Gupta, 1998[30]).

Box 2. Environmental Tax Reform (ETR) and the Double Dividend hypothesis

While the primary aim of environmental taxation is to improve environmental quality, it can at the same time achieve improvements in health and wellbeing of citizens, and give the government budgetary flexibility to reduce harmful labour market taxation, which improves the overall efficiency of the economy (Chateau, Saint-Martin and Manfredi, 2011[31]).

The concept of shifting taxation form socially desired 'goods' (e.g. employment) to environmental 'bads' (e.g. natural resource use and consumption) has been known under various terms, such as Green Fiscal Reform (GFR), Environmental Tax Reform (ETR), Environmental Fiscal Reform (EFR) or Green Tax Swaps (GTS). The underlying rationale is the same in all definitions and can be defined as "a reform of the national tax system where there is a shift of the burden of taxes from conventional taxes such as labour to environmentally damaging activities, such as resource use or pollution" (EEA, 2005, p. 83[32]). In the following report it will be referred to as Environmental Tax Reform (ETR), in order to maintain coherence with previous OECD work on this topic (OECD, 2012[27]).

Environmental tax reforms – shifting tax burdens from what is socially desirable (e.g. labour) to something that is socially undesirable (e.g. environmentally damaging activities) – can reduce the risk that the structural change required by mitigation policies will lower employment rates. Indeed, a 'double dividend' can sometimes be achieved, where an ETR can lead to two kinds of benefits in both environmental outcomes and employment (Goulder, 1995[33]; Ekins, 1997[34]). This positive substitution effect on labour can dominate in the short and medium run but as the capital stock adjusts over time, the double dividend may become a single dividend in the long run (Chateau, Saint-Martin and Manfredi, 2011[35]).

2.3. Partial and aggregate effects of policy-induced changes in the labour market

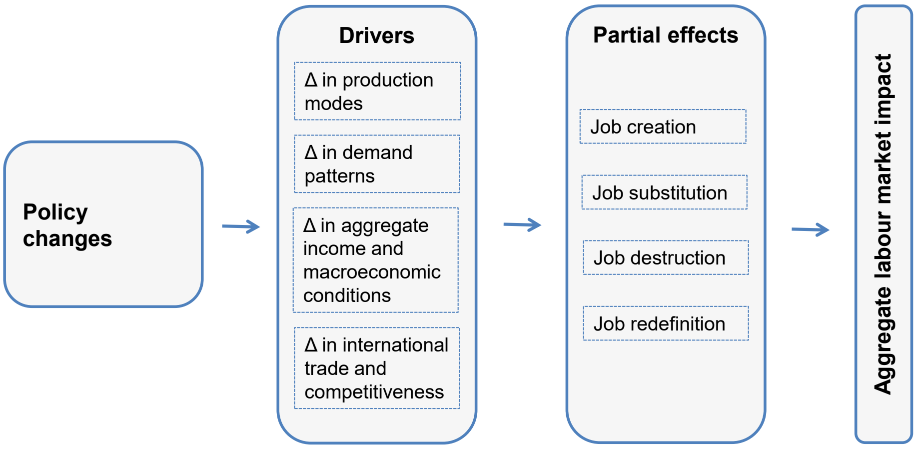
While the abovementioned drivers describe *why* changes in labour markets occur and provide information on the underlying mechanisms and dynamics, they do not lay out the mechanism *how* labour markets are impacted. Several partial effects can bring about labour market changes, which can be grouped in four main categories:

- *Job creation* can be expected in the group of 'green' sectors and activities that are stimulated through RE-CE policies as these intend to reduce environmental pressures or increase resource efficiency. The development of new circular business models also creates new jobs.
- *Job substitution* takes place where a shift in economic activity occurs either within or across sectors from resource-intensive activities to more circular activities. Substitution in this context are considered instances where one labour activity is directly replaced by another (e.g. from landfilling and waste incineration to recycling).
- *Job destruction* takes place when labour activity is lost without direct replacement by another. Job losses can occur in sectors with large environmental and materials footprints, where these are not directly replaced with another activity (e.g. products or practices that are banned, or discouraged, and their production is discontinued).

- *Job redefinition* includes all situations where existing jobs change their day-to-day skillsets, work methods, and profiles as part of an overall socio-technological transition towards more resource efficiency and circularity.

A combination of these effects is at play during a transition and the aggregate labour market impact depends on an interplay of different partial effects and their drivers (see Figure 1). Increased material circularity likely *creates* jobs in recycling and reuse sectors, but these may partly *substitute* jobs from other waste management and end-of-life activities (e.g. incineration and landfilling). Similarly, the emergence of new business models such as product-service systems or the sharing economy can *create* new jobs, but may also displace and *destruct* economic activity and labour demand in other sectors.

Figure 1. Flowchart of policy induced changes in labour markets



Uncertainties revolve around any of these steps, for individual sectors as well as their aggregate. While empirical assessments of past trends can reveal labour market implications of past transitions, quantitative economic modelling analysis, in particular Computable General Equilibrium (CGE) or Macroeconometric modelling (ME), is useful to assess future dynamics, as these can provide more insight into the different effects and interlinkages across and within economies and quantify the aggregate labour market impact. This enables to trace policy's impact across the economy, and to understand how labour and resource allocations change from one sector to another, as well as between regions and countries.

3. The resource efficiency and circular economy transition: learning from current data

The previous discussion elaborated the different dynamics that drive labour market changes and made a case for quantitative modelling to assess future implications of the circular economy transition. However, looking at the current structure of the economy can already give a first indication on what effects can be expected when moving to a more resource efficient and circular economy.

3.1. Expected structural changes at the sectoral level

With a transition to a more resource efficient and circular economy, the sectoral composition of the economy is likely to change with consequent implications for the labour market. Different sectors (and their labour force) will be affected differently by RE-CE policies.

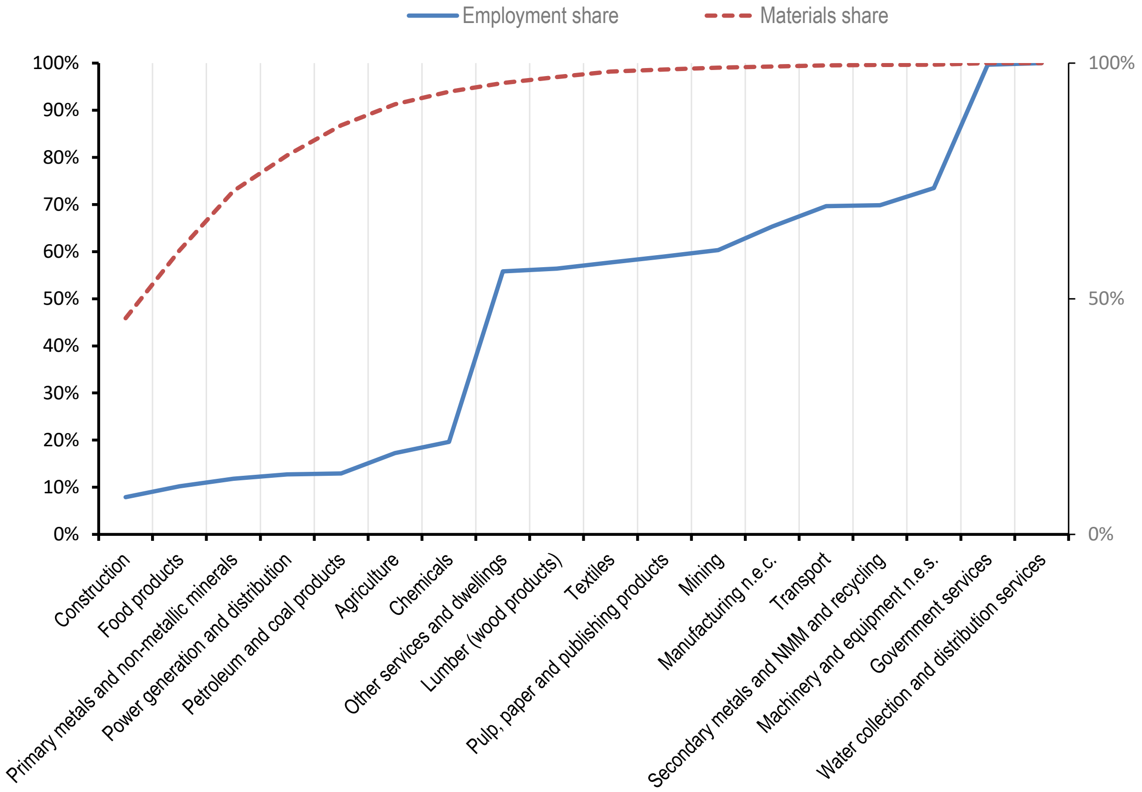
A shift towards a more resource efficient and circular economy would change economic activity and then employment from materials-intensive activities (sectors on the left of Figure 2) towards sectors with less materials use, such as services (on the right). For instance, jobs in primary metal production may be *substituted* by ones in recycling and secondary metal production. The shift to new business models and increase in servitisation of the economy more generally, can also lead to job *destruction* in primary production and job *creation* in services sectors (e.g. repair services, sharing business models or product service systems).

Whereas most job destructions can generally be expected to take place in material-intensive sectors, most of these sectors tend to be relatively less labour-intensive. For example, in 2011 at the global level, the four sectors with the highest materials footprint (construction, food production, primary-based metal production and electricity) accounted for almost 90% of overall material use, but employed only 15% of the total workforce (see Figure 2). The largest bulk of materials (in weight) in the economy is used by the construction sector (46%), which only contributes to 8% of total employment. Other industrial sectors are likely to be even less labour intensive than construction. This suggests that the potential total job destructions from implementing RE-CE policies might be modest and more than compensated by job creations in other sectors. Nevertheless, uncertainty remains about the potential size of knock-on jobs destruction effects in sectors that provide inputs to industries with high materials use or to sectors that used the refined-materials as inputs (e.g. machinery).

While the RE-CE transition may lead to a reduction of output of material-intensive sectors, it is expected to boost economic activity in other sectors, such as product-life extension activities (e.g. re-use, repair and remanufacturing), which tend to be more labour-intensive in comparison with primary processes, as the potential for economies of scale and automation is limited. Some processes can be automated, but batch sizes will likely be smaller and more heterogeneous than for primary production (Stahel, 1986[36]; van Beukering and Bouman, 2001[37]; Stahel and Clift, 2016[38]). This may consequently lead to an increase of economic activity in services sectors. Services sectors already provide a large share of employment (see “other services and dwellings” (36%) and “governmental services” (26%) in Figure 2) and have a relatively small materials footprint. As the RE-CE transition shifts economic activity towards more services, this may lead to a net employment increase.

Figure 2. Cumulative shares of materials use and employment per sector in 2011

Sectors sorted by total materials use in 2011



Note: The individual sectors in the figure are sorted by materials use, showing the sectors with the highest materials footprint on the left and sectors with small materials footprint on the right. The figure illustrates the cumulative shares of materials and employment per sector in a 0-100% scale.

Source: Author calculation, based on GTAP database (2018[39]) and UNEP-IRP global material flows database.

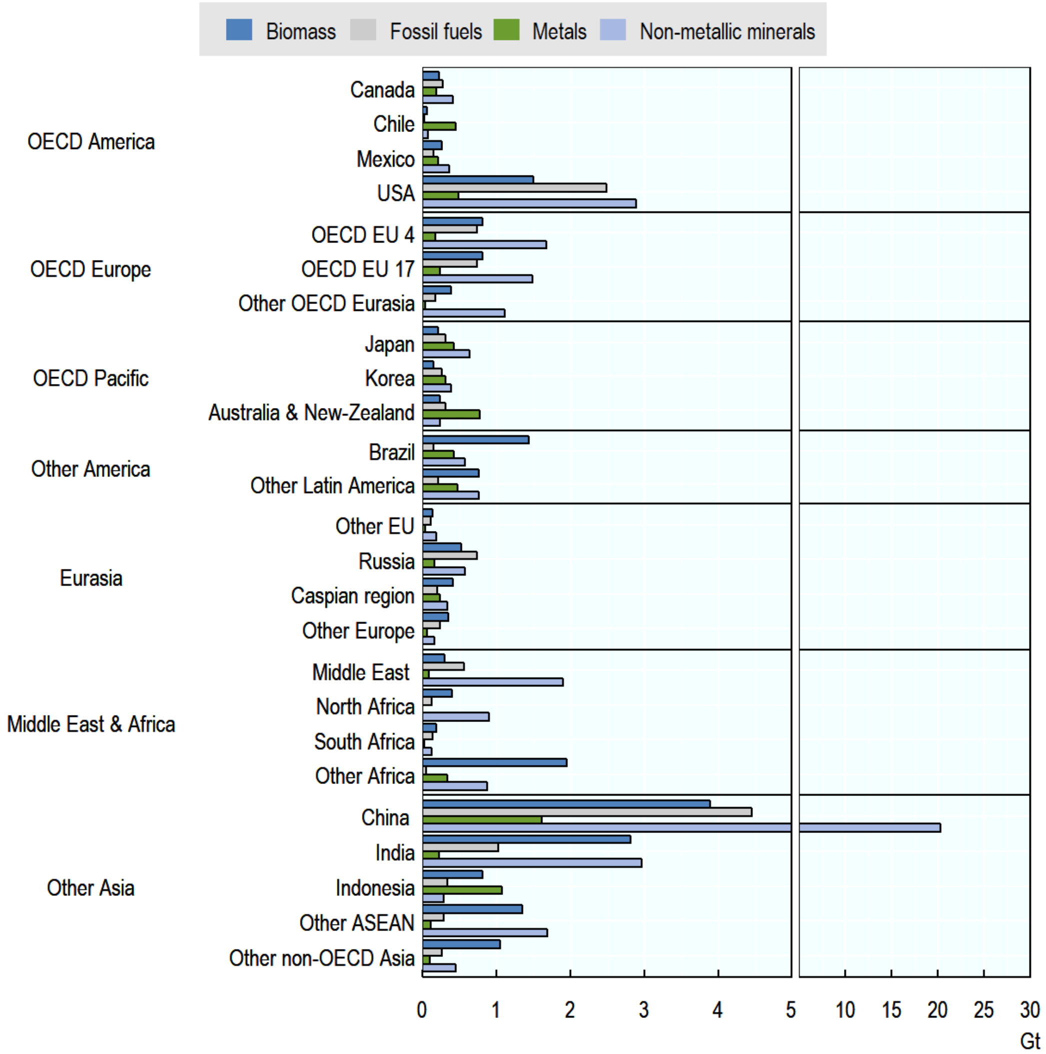
3.2. The geographic dimension of employment effects

RE-CE policies will not only have asymmetric effects on sectors, but also on different regions. Earlier modelling work of green growth strategies conducted at the OECD found significant differences in labour market implications of climate and energy policies depending on regional characteristics (Chateau, Bibas and Lanzi, 2018[29]). The economic structure of countries differs because countries are at different stages of development and have different international specialisation and sectoral composition. The presence of natural resources and other local specificities also contribute to the heterogeneous specialisations of economies. Countries or regions where the local economy is relatively more dominated by material-intensive sectors may experience larger effects by a shift to a circular economy (e.g. demand changes and necessary shifts in production modes) than those countries, which economies are less centred around materials extraction and processing.

Material use varies across regions, reflecting different development levels and specialisations of the countries (Figure 3). Resource rich regions also often rely on the extraction and processing of their domestic materials for economic growth; for example fossil fuels for Russia; biomass for Sub-Saharan Africa (labelled in the figure as “Other Africa”); or metals for “Australia and New Zealand” and Chile.

Figure 3. Materials use is heterogeneous across regions and development levels

Materials use by region and material type in 2011 in Gt



Note: OECD EU 4 includes France, Germany, Italy and the United Kingdom. OECD EU 17 includes the other 17 OECD EU member states. Other OECD Eurasia includes the EFTA countries as well as Israel and Turkey. Other EU includes EU member states that are not OECD members. Other Europe includes non-OECD, non-EU European countries excluding Russia. Other Africa includes all of Sub-Saharan Africa excluding South Africa. Other non-OECD Asia includes non-OECD Asian countries excluding China, India, ASEAN and Caspian countries.
Source: (OECD, 2019[1]).

In most regions, non-metallic minerals are the largest group (in terms of weight), given that these consist of relatively low-value bulk commodities (e.g. sand and gravel) that are expensive to import and thus usually sourced domestically. China dwarfs the other regions, with most of its extraction being non-metallic minerals, largely destined for infrastructure.

At regional level within a country, employment implications can also differ, according to local specificities. Certain circular economy activities may have a higher growth potential in some regions than in others and labour mobility is an important factor, where there are divergences between destructed and created jobs. Aggregated job numbers on national level may hide these regional distinctions, disparities and exceptions between countries or regions. Small or not diversified regional economies may be particularly exposed to large shocks on the labour market.

Some circular economy activities could result in geographically dispersed job creation, whereas others are likely to be more concentrated around urban agglomerations. Low-skilled repair and recycling jobs as well as waste collection and sorting activities are likely to be needed in urban as well as rural areas (Morgan and Mitchell, 2015[40]). On the other hand, some specialised repair jobs are more likely to be concentrated in cities, where there is high population density with sufficient demand. Similarly, jobs associated with the sharing economy (e.g. shared transport or product sharing) may be predominantly located in compact urban agglomerations, as a certain population density is often required for these business models to thrive.

The degree to which a sector or product can be traded also influences the extent to which labour markets are impacted across space. Labour effects can be transboundary, in particular in sectors with highly tradable goods (Ecorys, 2009[41]). Sectors with lower degrees of international trade, on the other hand, will likely impact labour markets more locally. The general trend towards global value chains and increased international trade has contributed to larger transboundary effects (De Backer and Miroudot, 2013[42]).

Overall, heterogeneous effects can be expected across sectors as well as across different regions. With changing economic structures and global trade patterns, in the future it will be even more complex to predict the impacts on the labour market. Modelling labour market implications in global CGE and ME models seems a sensible way to get a comprehensive idea of the overall impact and dynamics.

3.3. Ensuring a "Just Transition" and decent jobs

Labour implications of RE-CE policies, do not only comprise job creation and destruction, but also elements such as job duration, quality of jobs, health impacts and gender inequalities. The UN Sustainable Development Goal (SDG) 8 mentions decoupling economic growth from resource consumption (8.4), alongside with achieving decent work for all (8.5) (UN SDG, 2019[43]) and the International Labour Organisation (ILO) defines ten criteria for decent work and inclusive growth, which include the stability and security of work, safe work environments and social security (ILO, 2013[44]).

Job duration is a critical element to determine the long-term gains to society from RE-CE policies. Any of the mechanisms of change described above and their consequences on the labour market can be temporary or permanent. Some jobs may only the required for the transition period and are thus temporary, whereas others are required in the new 'state' of the economic system. For instance, the transition to a circular economy may trigger an increase in employment in the waste management and recycling sector, which in the long run – as ultimately a circular economy may produce less waste – may again be lost. Parallel trends towards more digitalisation and automation may also affect labour intensities and labour demand in the long-run (European Commission, 2018[45]).

The quality of jobs lost and created is another factor that should be considered. To date, there is little certainty about what the circular economy means for job relocation and skill changes. Modelling exercises could be useful to provide answers to such questions, similarly to previous work done on the green growth transition (Chateau, Bibas and Lanzi, 2018[29]).

It is still rather unsure what environmental and health conditions circular economy occupations are exposed to (EPSU, 2017[46]). Understanding the health impacts of a transition to a circular economy, for instance in relation to exposure to chemicals of concern, electrical and electronic waste, and distributional effects, is essential but still shows significant information gaps. The World Health Organisation (WHO) Regional Office Europe identified several risks to unintended adverse health effects of circular economy activities, particularly related to managing waste and potential exposure to hazardous substances (WHO Regional Office Europe, 2018[47]). It was emphasised that these risks frequently affect vulnerable groups disproportionately, for example, through informal work practices involving children and low-income groups. An example in this context is the export of waste, particularly e-waste to unregulated and informal recycling sites in developing countries where the local population and site workforce is often more deprived and vulnerable than the general population (WHO, 2016[48]).

4. Review of economic modelling literature on the resource efficiency and circular economy transition

As illustrated in the previous section, resource efficiency and circular economy policies can affect employment in different and complex ways. For instance, if the price for minerals is increased through a minerals tax, this can lead to direct employment effects in the construction sector, but also to indirect effects in real estate as construction output decreases. Considering that sectors and economies are increasingly structured along global value chains, labour dynamics often not only extend across different sectors but also across national borders. The way in which tax revenues are spent can also significantly influence employment outcomes.

Economic models are useful to provide quantified results to which mechanism dominates, and to provide insights into the various interactions between RE-CE policies and labour markets. Economy-wide quantitative economic models can help to trace the effects of a policy throughout the complex web of sectors and countries. While the literature is still scarce, several modelling assessment have studied the labour market impacts of RE-CE policies. To obtain an overview of existing results, this section reviews modelling work of resource efficiency and circular economy on aspects of labour and employment.

4.1. An overview of modelling studies on labour implications of RE-CE policies

There is a limited, but growing body of work that employs ex-ante quantitative models to assess the transition dynamics of the circular economy (McCarthy, Dellink and Bibas, 2018[49]). This review comprises 15 different modelling analyses, which together form a set of 47 policy-scenarios of circular economy transitions. Table 1 provides a descriptive summary of the considered studies and their scenarios.[2]

The scenario design among the studies varies widely, but in general, most simulations revolve around economic instruments, as it remains complex to translate 'soft policies' (e.g. R&D funding, education awareness, labelling) and the uptake of new business models (e.g. sharing economy) into quantifiable macroeconomic model configurations. Most studies conducted scenarios around a material tax aimed at reducing virgin material consumption and increasing resource efficiency. By changing the rate for materials taxes some studies aimed at addressing the valuation of environmental externalities/damages (e.g. the Green Fiscal Reform Scenario in (Bosello et al., 2016[24])), while others set arbitrary non-specific tax rates for the scenarios. In addition, the treatment of revenues generated from materials taxes varies (see last column of Table 1). In some cases the revenues were used to reduce distortionary taxes on the labour market (e.g. through a reduction in social security contributions), which is commonly referred to as an environmental tax reform. In other cases, the generated revenues were returned as a lump-sum to households or no information was given about revenue recycling.

[2] See Annex 1 for a more elaborate version of this table.

Table 1. Overview of reviewed modelling studies and scenario

Modelling Group	Key paper	Model name	Model type	Area	Scenario names	Scenario descriptions	Revenue recycling
DYNAMIX	(Bosello et al., 2016[24])	ICES, MEMO II, MEWA	CGE	EU	Green Fiscal reform (GFR): Material tax	material tax	-
			DSGE		GFR: Circular Economy tax trio	Trade & material extraction tax (non-metallic minerals), landfill & incineration tax	*In MEMO II model:* lump-sum
			DSGE		GFR: internalisation of external environmental costs	*Scenario 1:* flat tax-rate of 35% on all sectors, *Scenario 2:* differentiated tax rate on sector-specific externalities	50% of tax-revenue to reduce labour taxation, rest lump-sum to households
World Bank	(Bouzaher, Sahin and Yeldan, 2015[50])		CGE	Turkey	Policy Scenario 1 & 2	tax air emissions (PM10, CO2), solid waste, wastewater	*In Scenario 2:* Promotion of green jobs & earmarked R&D
Cambridge Econometrics	(Cambridge Econometrics, 2014[51])	E3ME	ME	EU	Scenario “modest”, “flexible” and “ambitious”	1, 2 or 3% resource productivity improvement per year *(depending on Scenario)*: 1/3 public investment in resource efficiency, 1/3 privately funded business measures, 1/3 raw material tax	reduced labour taxation
Wuppertal Institute	(Distelkamp and Meyer, 2010[52])	PANTA RHEI	ME	Germany	Economic	change in VAT for transport, material tax for building materials	reduction in income tax
					Information	1.2% of improvement in resource efficiency per year in firms through consulting	-
					Regulation	recycling must increase by a factor of 3 by 2030	-
UCL	(Ekins et al., 2012[22])	E3ME	ME	EU	LS1, HS1, HS2	carbon price; material tax; 15% CO2 reduction (25% for Scenario HS2); low oil price (high oil price for HS1 and HS2)	reduction in social security contributions (SSC) and income tax
ERC	(Hartley, Caetano and Daniels, 2016[53])	SAGE	CGE	South Africa	Scenario 2, 3, 4	share of materials recycled increases to 29%, 47% and 100% respectively (each from 11% baseline)	-
POLFREE	(Meyer, Distelkamp and Beringer, 2015[54])	GINFORS	ME	EU	Sc1: global cooperation	All countries worldwide commit to 2-degree target, (upstream carbon tax, renewable energy production, material tax etc.)	reduction of taxes on production
					Sc2: EU goes ahead	EU meets targets though economic instruments, Non-EU only soft policies	reduction of taxes on production

	(Hu, Moghayer and Reynès, 2015[55])	EXIOMOD	CGE	global	Sc1: global cooperation; SC2: EU goes ahead	*see scenario descriptions above*	*In Sc2 EU goes ahead:* reduction of taxes on production
NIES	(Masui, 2005[56])	AIM	CGE	Japan	Scenario 2, 3	CO2 reduction 2% by 2010 (from 1990), half solid waste by 2010 (from 1996) *In Sc3:* additional countermeasures on environmental preservation	reduction in SSC
CSIRO	(Schandl et al., 2016[57])	GIAM	CGE	global	"medium" and "high" efficiency scenarios	*"Medium":* global carbon price rising from 50 to 120 $/t CO2 (2% increase, hotelling rule); improvements in resource efficiency ca. 3% *"High": carbon price 50 – 236* $/t CO2 (4% increase, hotelling rule), improvements in resource efficiency ca. 4.5%	-
NERA	(Tuladhar, Yuan and Montgomery, 2014[58])	NewERA	CGE	Denmark, EU	DNKMod, DNKOpt, EURMod, EUROpt	Modest or strong circularity effect (*Depending on "Mod" or "Opt" Scenario*), affecting 5 sectors (food&bev, construction, real estate, machinery, plastic packaging and hospitals); Denmark or EU aggregate (*Depending on DNK or EUR Scenario*)	-
Ex'tax	(Groothuis et al., 2016[18])	E3ME	ME	EU	EU Scenario	Tax on gasoline, diesel (0.60/l), aviation fuel (0.30/l), natural gas (7.8/MWh), VAT to 21% across EU, 30e/t CO2 on top of ETS price)	reduce income tax, SSC, innovation
UNEP IRP	(Ekins et al., 2017[16])	GTEM	CGE	global	Sc1: Innovation; Sc2: Resource extraction tax; Sc3: Regulations & New formations	Sc1: efficiency-innovations; Sc2: extraction taxes; Sc3: reducing amount of materials required to meet basic human needs	- Sc2: lump-sum to households -
Cambridge econometrics	(European Commission, 2018[45])	E3ME	ME	EU	Scenario: "ambitious", "moderate"	measures in Circular Economy package & extensive/moderate sectoral transformation (*depending on Scenario*)	-
ILO	(ILO, 2018[59])	Exiobase v3	MRIO	global	Circular Economy Scenario	5% annual increase in recycling & 1% annual growth in the services sector	-

Note: See Annex I for an extended version of this table.
Model abbreviations: Computable equilibrium model (CGE), Dynamic stochastic general equilibrium model (DSGE), Macroeconomic model (ME), Multiregional input-output model (MRIO).
Source: Author's own compilation of literature.

Comparing the results of different modelling studies in a standardised way is challenging, as the design of studies and model type is highly heterogeneous. Models specifications differ in terms of scope, model inputs, assumptions, scenario design and indicators. Some studies conduct scenarios at country-level in e.g. Germany or Denmark (Distelkamp and Meyer, 2010[52]; Tuladhar, Yuan and Montgomery, 2014[58]), whereas others focus on European (Cambridge Econometrics, 2014[51]; Bosello et al., 2016[24]) or global scopes (Schandl et al., 2016[57]; Ekins et al., 2017[16]). In addition, configurations and assumptions on labour markets, such as labour supply, productivity and mobility can also affect the outcomes (see Box 3).

Box 3. Modelling labour markets – specifications and assumptions in macroeconomic modelling of the circular economy

Labour market outcomes can vary strongly depending on the underlying specific configurations and assumptions retained in each model. Three criteria define how the labour market responds to policy changes in the model.

First, a fixed or dynamic *labour supply* define model results significantly. For most computable general equilibrium (CGE) models, the total labour supply is fixed at each period. Workers are assumed to be homogenous and aggregate wages adjust to clear labour markets at each period. A fixed labour supply thus assumes that the demand for labour always equals the supply of labour. Some CGE models include an element of elasticity in labour markets through dynamic unemployment or elastic labour supplies.

Macro-econometric (ME) models present more realistic functioning of labour supply/markets, and generally incorporate wage-setting and price-setting features, and responses of aggregate employment to business cycle shocks. While labour markets in ME models are often considered at the aggregate level, these models can show employment losses and gains in different sectors and enable a projections of net employment gains or losses in different scenarios.

Second, assumptions about how policies will affect *labour productivity* will also affect the modelling results of labour markets. Labour productivity can vary across countries and evolve over time. For instance, technological advancements or education could increase labour productivity. Assumptions on how future labour productivity evolves can thus influence labour markets and over- or underestimate future employment in certain sectors.

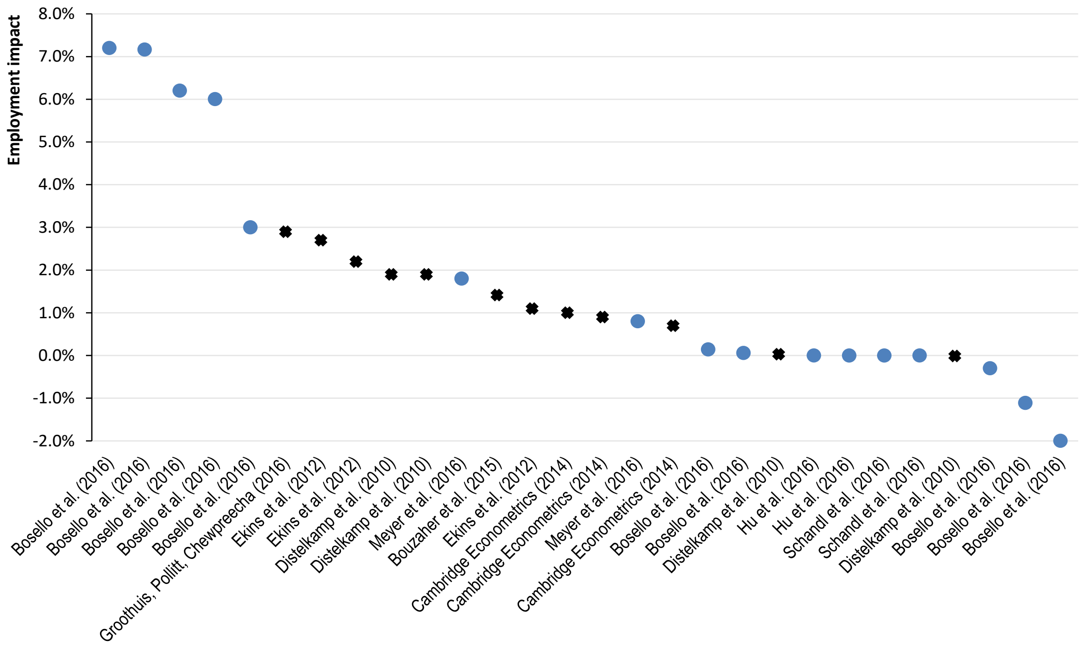
Third, assumptions about the *mobility* of workers can further affect employment projections. Labour mobility defines how flexible and responsive the labour force is to structural changes and how much labour can be transferred. Labour mobility becomes essential where there is a strong divergence between lost and gained jobs either across regions, different sectors or job occupations. Low labour mobility causes friction and can affect the labour market negatively as the transition unfolds.

Finally, the indicators used to analyse results can vary between the studies. In most studies, labour was reported as an increase in employment in respect to the reference scenario, but in one study the absolute increase in jobs was reported (Hartley, Caetano and Daniels, 2016[53]). GDP was commonly chosen as an indicator for economic output and development of the overall economy. However, indicators for the circular economy transition differed including resource productivity, material intensity, domestic material consumption,[3] or total material consumption indicators. To enable a standardised comparison, all environmental indicators were converted into material intensity (MI).[4] When MI is negative, this shows that the use of resources has increased at a lower rate than economic growth over time, compared to the baseline scenario (relative decoupling).

4.2. Aggregate employment impacts of RE-CE policies in macro-modelling analysis

Most of the modelling studies indicate that it is possible to obtain positive outcomes for resource efficiency and employment at the same time in the long run. The change in total employment was used in all studies as an indicator for changes in the labour market. The gross effect of RE-CE policies on the labour market is positive in most of the scenarios that were considered. As presented in Figure 4 most studies predict a positive effect on employment ranging from 0-2%. One study concludes with employment results as high as 7%, whilst three scenarios predict a net-negative employment outcome of the RE-CE transition.

Figure 4. Employment impacts of reviewed modelling scenarios



Note: The blue dots represent scenarios until 2050 and the black scenarios until 2030 or shorter. It is important to keep in mind the substantial heterogeneity between scenarios and studies as pointed out throughout Section 4 and Annex 1.

[3] Note that domestic material consumption (DMC) risks underestimating material footprints and related impacts of a country, especially when domestic production is substituted with imports of processed goods.

[4] Note that material intensity of DMC and TMC is the same only at global level.

Table 2 represents employment results of reviewed scenarios alongside materials intensity and GDP changes. The results show that positive employment outcomes can in most cases be achieved together with significant resource decoupling. Reductions in material intensity range widely from -1% up to -60% by 2050, depending on the policy stringency of the scenario.[5]

Two factors contribute to the increase in employment in most models; a shift of economic activity to sectors with higher labour intensities and the reduction of distortionary labour taxes through tax revenues.[6] For example a large share of the employment gain in the modelling study by the European Commission result from a shift from landfilling to more labour-intensive recycling activity in the waste sector (European Commission, 2018[45]).

The most optimistic results on labour markets originate from simulations of the MEWA and MEMO II models[7] of the DYNAMIX research group with 6.2% and 7.2% employment increase respectively, following the imposition of a gradually increasing materials tax[8] reaching 30% by 2030 and 200% by 2050 (Bosello et al., 2016[24]). In both simulations, the tax revenues are used to decrease labour taxation, following an environmental tax reform scheme as proposed by Ekvall et al. (2016[60]). According to their projections, this policy intervention would boost employment by up to 7.2% until 2050 in Europe and generate a 5.8% increase in GDP growth, whilst at the same time decoupling economic growth from material consumption (-19% decrease in MI).

As caveat, it must be noted that this simulation is built on the assumption that countries can pursue unlimited material efficiency improvements, which ignores lock-in effects or physical limits to material efficiency. In a second scenario (‘Alternative 1’), where R&D efficiency improvements of firms are restricted, outcomes are far less positive; employment benefits drop to almost zero (0.1%), GDP turns negative (-1.8%), and material intensity only decreases by -11%. This scenario shows that the role of R&D is a key condition for maintaining economic growth in a circular economy.

[5] Increases in employment are clearer in ME models, first because these models better reflect employment changes than CGE models and secondly because ME models take into account business cycle macro-economic effects such as activity multipliers.

[6] See section 4.2.1 for a more elaborate discussion of the latter.

[7] The European MEWA (Material Energy Waste and Agriculture) and MEMO II (Macro-Economic Mitigations Options) models are large-scale DSGE model with an extensive productive structure, considering 18 economic sectors.

[8] The materials tax comprised a sales tax of wood, fuels, metal, chemical and non-metallic mineral to all manufacturing sectors and construction.

Table 2. Results of selected circular economy modelling studies

Key Paper	Model Name	Area	Scenario name	ETR	Time frame	Material Intensity (%)	Employment (%)	GDP (%)
Bosello et al. (2016)	ICES	EU	BAU		2018-2050			
			Green Fiscal reform: Material tax	no		-12.0%		-5.0%
			GFR: Circular Economy tax trio	no		-3.7%*		-0.3%
	MEMO II	EU	GFR: material tax	yes	2020-2050	-57.8%*	6.2%	1.9%
			GFR: internalisation of external environmental costs	yes	2030-2050		-2.0%	-5.8%
			GFR: internalisation of external environmental costs	yes	2030-2050		3.0%	-4.5%
			Circular Economy tax trio	no	2020-2050	-14.8%	-0.3%	-0.2%
	MEWA	EU	GFR: Material tax (base case)	yes	2020-2050	-19.0%	7.2%	5.8%
			GFR Material tax (Alternative 1)	yes	2020-2050	-11.0%	0.1%	-1.8%
			GFR Material tax (Alternative 2)	no	2020-2050	-14.0%	-1.1%	-6.6%
			GFR: internalisation of external environmental costs (flat tax)	yes	2020-2050		7.2%	6.5%
			GFR: internalisation (differentiated tax)	yes	2020-2050		6.0%	5.2%
			Circular Economy tax trio	no	2020-2050	-0.1%	0.1%	0.1%
Bouzaher et al. (2015)		Turkey	Policy Scenario 1	no	2010-2030			
			Policy Scenario 2	yes	2010-2030		1.4%	2.4%
Cambridge Econometrics (2014)	E3ME	EU	Scenario 2: modest	yes	2014-2030	-13.0%**	0.7%	0.6%
			Scenario 3: flexible	yes	2014-2030	-23.1%**	1.0%	0.8%
			Scenario 4: ambitious	yes	2014-2030	-33.3%**	0.9%	-0.1%
Distelkamp et al. (2010)	PANTA RHEI	Germany	Economic	yes	2012-2030	-1.4%***	0.0%	-0.1%
			Information	yes	2012-2030	-20.5%***	1.9%	14.2%
			Regulation	no	2012-2030	-8.9%***	0.0%	0.0%
			combined	yes	2012-2030	-29.8%***	1.9%	14.0%
Ekins et al. (2012)	E3ME	EU	LS1	yes	2010-2020	-3.4%*	2.2%	0.6%
			HS1	yes	2010-2020	-2.7%*	1.1%	0.2%
			HS2	yes	2010-2020	-3.0%*	2.7%	0.5%
Meyer et al. (2016)	GINFORS	EU	Sc1: global cooperation	yes	2015-2050	-58.8%*	0.8%	8.0%
			Sc2: EU goes ahead	yes	2015-2050	-58.9%*	1.8%	12.3%
Hu et al. (2016)	EXIOMOD	global	Sc1: global cooperation	yes	2010-2050	-50.7%***		-0.6%
			Sc2: EU goes ahead	yes	2010-2050	-49.8%***		-0.3%
Schandl et al. (2016)	GIAM	global	high efficiency	no	2010-2050	-47.1%*	0.0%	-1.6%
			medium efficiency	no	2010-2050	-29.0%*	0.0%	0.0%
Groothuis, Pollitt, Chewpreecha (2016)	E3ME	EU	EU Scenario	yes	2015-2020	-7.3%*	2.9%	2.0%
UNEP IRP (2017)	GTEM	global	(1) Innovation	-	2020-2050	-9.3%*		8.8%
			(2) Resource extraction tax	no	2020-2050	-4.3%*		-4.2%
			(3) Regulations & New formations	-	2020-2050	-13.7%*		6.2%
			(4) Combined effect	no	2020-2050	-22.4%*		6.2%
European Commission (2018)	E3ME	EU	Moderate	-	2015-2030		0.3%	0.3%
			Ambitious	-	2015-2030		0.3%	0.5%

Note:
* MI approximated with domestic material consumption: MI=DMC/GDP
** MI approximated from resource productivity: MI=1/RP
*** MI approximated with total material consumption: MI=TMC/GDP

4.2.1. The importance of the choices made on revenue recycling from materials taxes

Whilst it is challenging to compare the heterogeneous modelling studies, there appears to be a notable difference between scenarios that recycle revenues from materials taxes to lower labour taxation in form of an environmental tax reform (ETR), and others that do not specifically recycle revenues through interventions in the labour market.

In the reviewed set of modelling studies, the average employment effect of ETR scenarios lies at 2.3%, while the average effect in non-ETR scenarios is marginally negative at -0.07%.[9] If revenues from material taxes are recycled to lower other distortionary taxes, the transition may fall out positive for gross employment. If revenues are returned in lump sum to households, the consequences to overall net employment are negligible or may even be negative.

In the study by Bosello et al. (2016[24]), the way in which tax revenues are spent seems to contribute significantly to the positive outcome of the Green Fiscal Reform (GFR) scenario in the MEWA model. In the base case scenario, revenues are used to lower distortionary labour taxation as part of a green fiscal reform package. The scenario 'Alternative 2' is equivalent to the base case, with the only difference that revenues are returned to households in form of lump-sum transfers. In this scenario, employment decreases -1.1% until 2050 and GDP -6.6%. Also in the MEMO II model simulations, the authors state that the large increase in employment (6.2%) is mainly brought about by the reduction of labour taxes, rather than an increase in economic activity in emerging sectors. Complementary scenarios showed that under the assumption of a normal lump-sum closure, employment is expected to decrease, which again underlines the importance how tax revenues are treated. Overall, the study concludes that the way tax revenues are reinvested can make a drastic impact in how the economy and labour markets react to material taxes.

A similar trend appears in other studies. Cambridge Econometrics (2014[51]) ran two iterations of their "ambitious policy scenario" (Scenario 4) with and without environmental tax reform. They conclude that by 2030, GDP decreases by -1.5% in the non-ETR scenario, whilst in the ETR scenario the negative effect of the materials tax policy on the economy can be largely compensated through lowering other distortionary taxes. Another study by Ekins et al. (2012[22]) also points out the positive effect of ETRs for achieving resource productivity. Their ETR scenarios project an employment increase of 1.1% to 2.7%[10], concluding that ETR may be an "attractive and cost-effective policy for environmental improvement".

Besides promoting employment, environmental tax reforms may also have a positive effect on economic welfare and further contribute to decoupling economic growth from environmental impacts. The review shows a clear difference of GDP growth between scenarios that recycle revenues to lower distortionary labour taxes and non-ETR scenarios. While ETR scenarios have on average a positive effect on GDP (+2.7%), the effect of non-ETR is negative (-1.5%). Recycled tax revenues may also be used to address distributional aspects of environmental policies, leading to additional welfare improvements.

[9] Note that different time scales and regional scopes have been disregarded in this mean calculation and numbers should be treated with caution.

[10] The three scenarios are designed around different international energy prices and levels of ambition on CO_2 reduction, but all revolve around an ETR design.

It should be noted that long-term results of ETR scenarios may be subject to a possible tax base effect, as in a possible erosion of the tax base. By purpose, the increase of the material tax induces agents to substitute material-intensive goods with less material-intensive ones (substitution effect). Consequently, material consumption, as well as the revenues generated from material taxes, might decrease in the long-run. The decline in tax revenues from materials taxes may lead to less budgetary flexibility in the longer term and to reduced labour subsidies and long-term employment effects of ETRs (European Environment Agency, 2016[61]; Chateau, Saint-Martin and Manfredi, 2011[35]).

4.2.2. Impacts on competitiveness and across regions

Besides the choice on how tax revenues from materials taxes are recycled, aspects on competitiveness across regions are also essential to consider in order to achieve an equitable and inclusive transition.

Materials taxes at the national level do not need to come with disadvantages and loss in competitiveness in the global economy. Noteworthy is the design of the taxes in the 'EU goes ahead' scenario of Meyer, Distelkamp and Beringer (2015[54]), which includes a border tax adjustment.[11] The material tax based on TMC is levied to domestic production and imports, whilst exports are exempt from the tax. This design prevents losses in the EU that may be triggered by reduced international competitiveness. On the contrary, in this scenario, the EU continues to improve resource efficiency, whereas non-EU areas remain at current levels, increasing its international competitiveness. The EU achieves a "first-mover advantage" through technological gains, which leads to higher GDP increases than in the "global cooperation" scenario[12] (12% compared to 8% GDP growth until 2050), whilst material intensity within the EU is reduced equally in both scenarios. At the same time, the subsidies on environmentally harmless goods raise the demand for services and other goods, which in most cases have labour intensive technologies. Insofar, the employment increases by 1.8% in the EU, compared to only 0.8% increase in the "global cooperation" scenario.

Overall, the 'EU goes ahead' scenario shows that if trade and international competitiveness issues are overcome through a careful design of material taxes[13], the local economy could benefit from the resource efficiency improvements, as this generates cost-reductions of production and a first-mover advantage on the global market.[14]

Several country case studies also show that a circular economy transition can be beneficial for job creation in advanced economies (see Box 4). The potential for job creation varies across studies, reflecting differences in modelling approaches and in country-specific characteristics of labour markets and the national economy, as well as behavioural responses to RE-CE policies, but they give an initial indication of the potential direction and order of magnitude of positive employment effects in different national contexts. More robust modelling is however required, to place the country studies in the context of the

[11] A border tax adjustment taxes goods based on location of final consumption rather than production.

[12] Note that in the "global cooperation" scenario, RE-CE fiscal policies are levied equally to all countries globally.

[13] Note that this policy design may not be WTO compatible.

[14] The domestic market would need to be sufficiently large to provide sufficient incentives to move towards increased resource efficiency that would not be implemented in the absence of the domestic materials tax.

global economy, to substantiate these findings and to further identify the induced effects on the rest of the world.

Furthermore, while these studies emphasise the potential job gains of the transition to a circular economy, short-term unemployment as a result of the restructuring of the economy and longer-term structural unemployment in declining sectors may also occur in absence of adequate policies to ensure the relocation of workers to new activities related to the circular economy.

Box 4. Employment potential of the circular economy in different OECD countries

On country-level a number of quantitative case studies have focused on the employment potential within the circular economy in different OECD countries.

For **Britain**, the net job potential by 2030 from the circular economy was calculated from an inventory of existing jobs with activities related to the circular economy (reuse, repair, remanufacturing, recycling and servitisation) and their growth projections. The net job creations were estimated between 10,000 (business as usual), 54,000 (advanced scenario) and 102,000 (transformation scenario). These increases have been estimated to result in a decline in the unemployment rate of 0.02%, 0.15% or 0.28% respectively.

In **The Netherlands**, it has been estimated that the circular economy can create an additional 54 thousand jobs (0.6% of overall employment). Using expert judgement about future trends in resource prices, and the increase in reuse, collection, and recycling of products and waste it was concluded that these activities could have a positive effect on GDP of up to 1.2% .

In **Flanders** (a region in Belgium with approximately 6 million inhabitants), the economic benefits from the circular economy have been estimated by combining sector-specific data and predictions about the development of the circular economy by 2020. An added value of 2.3 billion Euro (1.3% growth of Flemish GDP) or approximately 27,000 jobs could be generated in Flanders by 2020 through well-implemented circular economy policies .

For **Denmark**, it was estimated that committed circular economy policies could add between 7,000 and 13,000 jobs and concurrently increase GDP by 0.8-1.4%.

Sources: (TNO, 2013[62]; Dubois and Christis, 2014[63]; Ellen MacArthur Foundation, 2015[64]; Green Alliance, 2015[23]).

4.3. Model results on labour implications of RE-CE policies at the sectoral level

Most of the analyses conducted with macro-economic models reviewed in the previous section, did not explicitly investigate how RE-CE policies affect the sectoral mix of employment. Only two studies – by the European Commission (EC) (2018[45]) and the International Labour Organisation (ILO) (2018[59]) – cover these aspects to some extent, by providing insights on the sectoral reallocations of jobs in a circular economy.

The ILO report 'World employment and social outlook (WESO) 2018: greening with jobs' (ILO, 2018[59]) provides insights into gains and losses of jobs in a circular economy scenario, for different sectors by 2030.[15] According to the simulations, manufacturing and mining are projected to see most job destructions, whereas reprocessing of secondary steel and retail and repair sectors receive most job creations (see Table 3).

Table 3. Sectors most affected by the transition to a circular economy

Demand growth in % by 2030

Industries set to experience the highest job demand growth (percentage)		Industries set to experience the strongest job demand decline (percentage)	
Sector	**Jobs (percentage)**	**Sector**	**Jobs (percentage)**
Reprocessing of secondary lead into new lead, zinc and tin	15	Production of electricity by coal	-0.9
Reprocessing of secondary precious metals into new precious metals	11.2	Extraction of crude petroleum and services related to crude oil extraction, excluding surveying	-0.9
Production of electricity by solar photovoltaics	4.9	Extraction, liquefaction, and regasification of other petroleum and gaseous materials	-0.9
Reprocessing of secondary copper into new copper	4.3	Petroleum refinery	-0.8
Reprocessing of secondary wood material into new wood material	4.2	Manufacture of gas; distribution of gaseous fuels through mains	-0.8
Reprocessing of secondary steel into new steel	3.1	Mining of coal and lignite; peat extraction	-0.8
Reprocessing of secondary aluminium into new aluminium	2.7	Extraction of natural gas and services related to natural gas extraction, excluding surveying	-0.8

Note: ILO calculations based on Exiobase v3.
Source: (ILO, 2018[59])

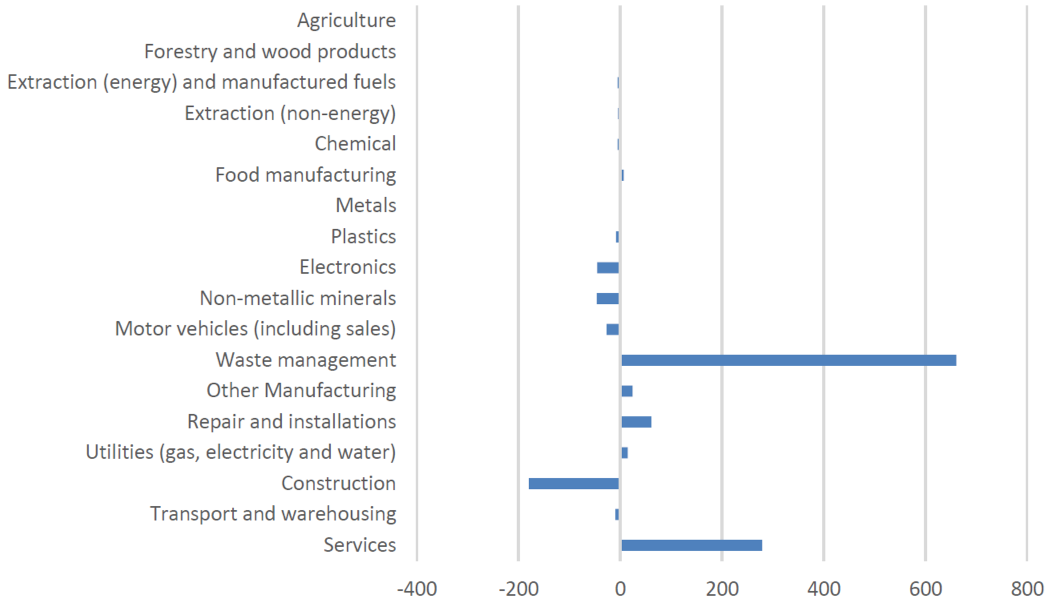
A study by the European Commission (2018[45]) shows similar results for the European economy (Figure 5). The study models a circular economy package with resource efficiency improvements in five key circular economy sectors.[16] Waste management (including recycling) and services sectors are predicted to create jobs, whereas sectors that produce and process raw materials (i.e. construction, non-metallic minerals, electronics and motor vehicles) will experience job destructions. The net employment effect is expected to be positive.

[15] The ILO circular economy scenario explores employment impacts of a 5% annual increase in recycling, replacing extraction of primary resources and a 1% annual growth in the services sector (through rental, repair and reduced ownership and replacement of goods). See Appendix 2.1 of ILO (2018[59]) for more details.

[16] The moderate and ambitious scenarios in the study model ‘circular economy activities’ of different levels in five sectors: the food and beverages (NACE A, C10 & 11), construction (NACE F 41&43), motor vehicles (NACE 29), electronics and electrical equipment (NACE 26 & 27) and waste sector (NACE 38 & 39). See Annex C of European Commission (2018[45]) for more details.

Figure 5. Circular economy job impacts across the EU28 sectors in 2030

Thousands of jobs



Source: European Commission (2018[45]).

These two analyses give a first indication about plausible changes in sectoral composition of employment for a set of RE-CE policies. However, further analysis with a long-run, global macroeconomic model would provide interesting insights into the long-term effect of RE-CE policies on sectoral employment, as well as global impacts and reallocations across sectors as well as across countries.

5. Skills requirements for a resource efficient and circular economy transition

The transition to a more resource efficient and circular economy will not affect all workers homogenously, since jobs created and destructed are heterogeneous in terms of skill requirements and types of tasks to be performed. How impactful a transition will be for the labour force will strongly depend on the transferability of skills from declining to growing sectors. This section provides an overview of the current stand of knowledge on skills requirements for a resource efficient and circular economy.

A resource efficient and circular economy requires a certain set of skills, knowledge and competencies. Understanding in advance where the skill imbalances may arise is important to be able to 'upskill' concerning occupational groups and to prepare them for the transition. In theory, market forces should help align skills demand and skills supply. Workers can switch between jobs and sectors that require similar skills. Yet, these shifts are constrained by time inconsistencies, rigidities or information gaps. The response of skills supply to changing demand (and vice versa) is inert, which can lead to skill imbalances.

Despite a growing field of modelling literature on the employment implications of a circular economy transition (see previous section), research on skills requirements for a RE-CE transition is still scarce. Most studies only discuss the total employment effects of sectors and countries, rather than the types of jobs that are affected. It is still uncertain how a future skill composition of a circular economy will look like and there is a paucity of quantitative modelling analyses that assess the incidence of skills in a RE-CE transition.

One notable reference is a report by the European Commission (2018[45]), which argues that the skills needs for a circular economy take-up are relatively small in comparison to other drivers of change, such as digitalisation, robotics and a general long-term shift towards more highly-skilled occupations. These drivers cannot be seen in isolation, and an interplay will define future skill requirements. Skills for the digitalisation may therefore also be required by the CE transition and vice versa. Seen in this interconnected context, there is a general increase in demand for cross-cutting competences, driven by the technological change on jobs (e.g. communication and STEM-related skills).

The ILO report 'World employment and social outlook (WESO) 2018: greening with jobs' (ILO, 2018[59]) mentions skills on the margins of their study, emphasising that an increase in services jobs may lead to an increase in the female share of workers and an increase in highly skilled jobs. A more in-depth discussion and modelling of skills requirements can be found in the green growth literature (e.g. (OECD/Cedefop, 2014[65]; ILO, 2011[66]; Botta, 2018[67])). Some circular economy job categories, such as recycling and waste are mentioned alongside other green job categories in some of these studies (Cedefop, 2010[68]).

Chateau, Bibas and Lanzi (2018[29]) modelled the future skills composition of different green growth policy scenarios and found that job creation and destruction tend to involve largely similar categories of skills. While the occupations in the different sectors vary more widely, the broad level of skills required for the different jobs types tend to be more homogeneous.

In general the evidence suggests that most green jobs only require a 'topping up' of existing skill sets rather than the development of completely new skill sets (Cedefop, 2010[68]). For example, construction companies that carry out building and housing retrofitting will require workers with traditional construction skills and up-to-date training in energy efficiency (Martinez-fernandez and Hinojosa, 2010[69]).

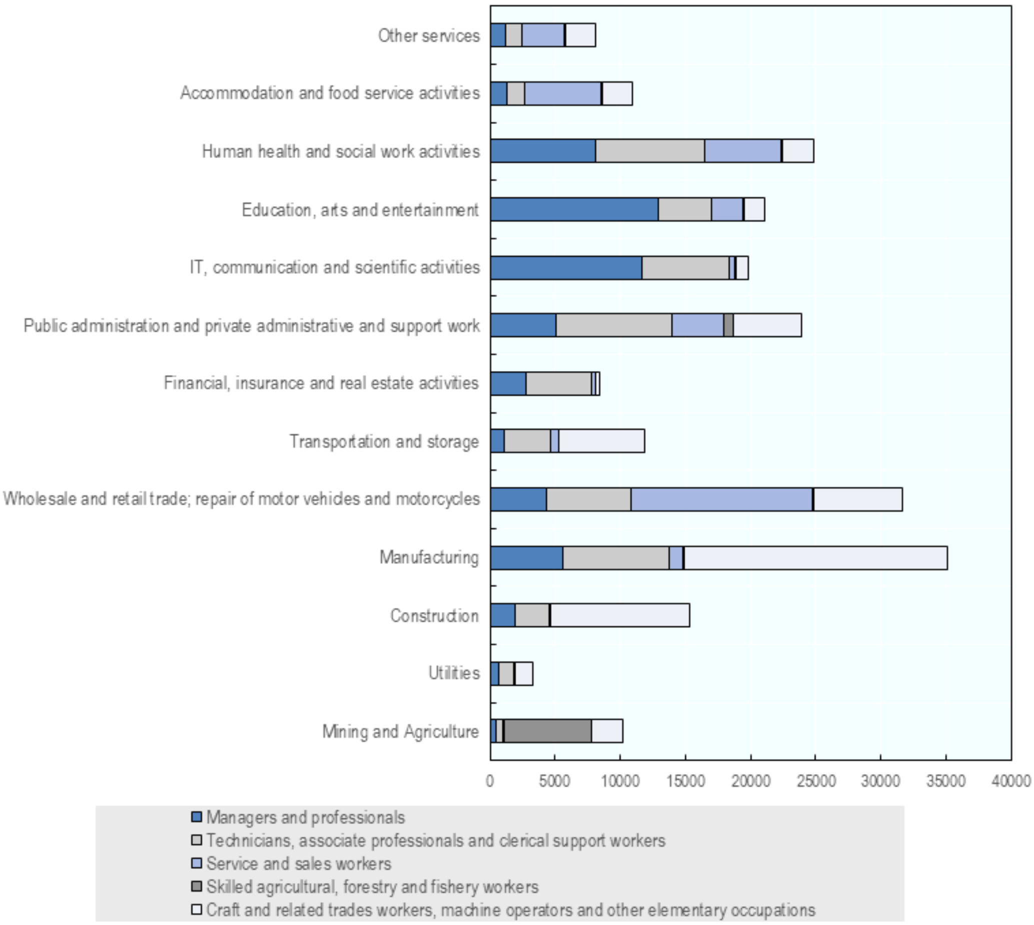
One of the reasons for little quantitative modelling work on this topic is the lack of comprehensive data. Only few international databases exist that provide quantitative information of current skills composition and skills needs of different sectors. The two most prominent are provided by Eurostat and ILOSTAT. The ISCO08 (International Standard Classification of Occupations) occupation classification by the International Labour Organisation (ILO) is commonly used to classify and represent skill distributions (ILO, 2018[70]).

Eurostat provides employment data for the European Union per sector and ISCO08 occupations. However, the data is only available on the broadly aggregated NACE Rev.2 sectoral level containing 21 sectors. Figure 6 depicts a more aggregated version of the available Eurostat data. Overall, it shows that services sectors tend to have higher skilled jobs (i.e. higher share of managers, professionals and associate professionals), compared to the more resource intensive sectors. This could give a first impression that a circular economy would require and sustain higher skilled labour.

While these datasets can provide a general overview of occupational composition in each sector, the large aggregation of sectors limits the possibilities to analyse skills requirements that often happen on a more detailed scale within larger sectors. For instance, wholesale, retail and repair is aggregated in one automotive sector, which makes it difficult to single-out the skills composition with an uptake of solely repair activities in this sector. Similarly, the economic sectors of ILOSTAT are also too aggregated to identify detailed skills shifts.

Figure 6. Employment by occupation and economic activity in the European Union (EU28) in 2018

Number of occupations (Thousands)



Source: (Eurostat, 2018[71]).
Note: Sectors and occupations have been aggregated from 8 ISCO08 occupation groups to 5 occupations and from 21 NACE Rev.2 sectors to 13 sectors.

Several qualitative studies on skills demands of specific countries, regions or sectors have been done. Table 4 provides a summary of different qualitative case studies of sectors that can be associated with the circular economy. Generally, the studies also conclude that green jobs require some upskilling of labour forces, rather than a complete re-skilling. Existing skills can often be used and applied to different sectors to serve functions in the circular economy. While the job composition will likely differ between the sectors, a more circular economy will require a heterogeneous set of job types from low- to high-skilled occupations.

Table 4. Literature on the of employment creation in circular economy activities

Sector	Study	Coverage	Job Types
Recycling	(EEA, 2011[72])	EU	Low skilled work in particular, but also medium and high skilled jobs, ranging from collection, materials handling and processing to manufacturing products
Recycling	(ILO, 2011[66])	Germany	16 per cent low skilled, 47 per cent skilled, 11 per cent technical, 25 per cent university.
Waste Collection	(ECOTEC, 2002[73])	EU	Labour required for waste collection and transport, at relatively low wage rates.
Remanufacturing	(APPSRG, 2014[74])	UK	Skilled, with substantial training needs.
Waste management	(SITA UK, 2012[75])	UK	A range of jobs, but particularly significant numbers of mid-level (supervisors/operators) and low-level (manual) occupations.
Deposit refund scheme (DRS) for packaging	(Eunomia, 2011[76])	UK	A range of skills would be required, including some higher skilled jobs. Jobs would be geographically spread, with counting centres and logistics and regional jobs in retail and collection.
Recycling, Remanufacturing	(Beck, 2001[77])	US	Relatively high skill requirements.
Servitisation & Biorefining	(Morgan and Mitchell, 2015[40])	UK	Mostly low- and medium skilled employment. Some high-skilled jobs in biorefining and servitisation activities.

Source: Based on (Green Alliance, 2015[23])

To sum up, research on skill shifts and demands in a circular economy is scarce and involves large uncertainties. In particular, quantitative (modelling) insights are still lacking. This is largely due to the lack of available data. The coarse sectoral aggregation of datasets do not allow for a detailed investigation on country or international level, nor a comparison of skill composition of declining and emerging sectors in a circular economy transition. Therefore, it is still rather uncertain how a future skill composition of a resource efficient and circular economy may look like.

6. Discussion

The present report provides a review of the state-of-the-art literature on labour market, employment and skill implications of a transition to a circular economy. The review of the economic modelling literature suggests that a transition to a more resource efficient and circular economy can generate a net positive effect on employment. However, the employment implications may differ widely across different sectors and regions and some may experience significant losses. Overall, the conclusions of this study should be considered in the context of the limited existing literature on the topic.

The lack of a comprehensive and common definition of the circular economy circular economy leads to ambiguity regarding the sectors, processes and practices that individual countries or research group consider part of the broader circular economy. No set of indicators currently exists that captures all the main elements of the RE-CE. This is of concern, especially when comparing modelling studies, where the circular economy indicators can vary widely. Future macroeconomic modelling studies would benefit from addressing issues around indicators and a common framework to monitor progress of the circular economy. Furthermore, a set of more detailed indicators on labour markets, such as changes in labour demand, wages, a response by households with regard to willingness to supply labour or their preference of leisure time, could also shed light on interesting impacts of RE-CE policies on labour.

The RE-CE scenarios in the modelling studies assessed are rather stylised and mostly revolve around raw material taxes and assumptions on resource productivity improvements, as these are the instruments that can be assessed most robustly in applied macroeconomic models. Only a few studies have intended to model the effects of newly emerging circular business models (e.g. product-service-systems) or the effect of ‘soft’ policies (e.g. labelling or awareness campaigns). The European Commission (2018[45]) attempts to include car-activities, modular design and higher use of buildings because of teleworking and office sharing. Such policies could also be studied as part of storylines in baseline scenarios, but it is challenging to find sufficient information to make robust assumptions on the future developments of new business models or socio-technical trends such as digitalisation and automation.

Furthermore, analyses of skills shifts and future skills demands in a more circular economy are still a scarce. Yet this is a highly relevant field of research, which would deserve more attention. In particular, quantitative studies assessing and projecting skill compositions in the future are very limited. Most quantitative studies on labour market consequences of the circular economy report the total employment needs of the sector, rather than the specific types of jobs that might be needed. This is largely due to the unavailability of sufficiently detailed datasets, which allow a comparison of skill composition of declining and emerging sectors in a circular economy transition. Some qualitative research and case studies into specific sectors exist but it should be encouraged that future modelling work includes skills and occupations in their projections.

Finally, the distributional effects of resource efficiency and circular economy policies is still underexplored. More empirical case studies on specific sectors and countries as well as regional and global macroeconomic modelling studies would greatly enhance the knowledge of labour market dynamics in a circular economy transition.

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ANNEX 1. Detailed overview of reviewed modelling studies and scenarios

The following information is an extension of Table 1 and provides more detailed information about the model scenarios of the set of modelling studies that were reviewed.

Table A1.1. Detailed description of reviewed modelling studies and scenarios

Modelling Group	Key Paper	Model Name	Model type	Area	Scenario name	Scenario description	Revenue recycling
DYNAMIX	(Bosello et al., 2016[24])	ICES	CGE	EU	Green Fiscal reform (GFR): Material tax	material tax (increases to 200% by 2050)	-
					GFR: Circular Economy tax trio	Trade & extraction tax on virgin materials (non-metallic minerals)	-
		MEMO II	DSGE	EU	GFR: material tax	material tax	50% of tax-revenue to reduce labour taxation
					GFR: internalisation of external environmental costs 1	flat tax-rate of 35% on all sectors	50% of tax-revenue to reduce labour taxation, rest lump-sum to households
					GFR: internalisation of external environmental costs 2	tax differentiated on sector-specific externalities	50% of tax-revenue to reduce labour taxation, rest lump-sum to households
					Circular Economy tax trio	volume based tax on mining and quarrying, tax on exports of non-metallic minerals	lump sum
		MEWA	DSGE	EU	GFR: Material tax	Base case: material tax, companies able to pursue material efficiency improvements	reduced labour taxation
						Alternative 1: material tax, companies NOT able to pursue material efficiency improvements THROUGH R&D	reduced labour taxation
						Alternative 2: similar to base case but lump-sum recycling	lump sum
					GFR: internalisation of external environmental costs	Max. flat tax of 35% on all sectors	reduced labour taxation
						tax differentiated on sector-specific externalities	reduced labour taxation
					Circular Economy tax trio	tax virgin extraction (only within EU), landfilling & incineration (imports are not taxed)	-
World Bank	(Bouzaher, Sahin and Yeldan, 2015[50])		CGE	Turkey	Policy Scenario 1	tax air emissions (PM10, CO2), solid waste, wastewater	-
					Policy Scenario 2	tax air emissions (PM10, CO2), solid waste, wastewater	Promotion of green jobs & earmarked R&D
Cambridge Econometrics	(Cambridge Econometrics, 2014[51])	E3ME	ME	EU	Scenario 2: modest	goal: 1% resource productivity improvement per year, through: 1/3 public investment in resource efficiency, 1/3 privately funded business measures, 1/3 raw material tax	reduced labour taxation
					Scenario 3: flexible	goal: 2% resource productivity improvement per year, through: 1/3 public investment in resource efficiency, 1/3 privately funded business measures, 1/3 raw material tax	reduced labour taxation
					Scenario 4 ambitious	goal: 3% resource productivity improvement per year, through: 1/3 public investment in resource efficiency, 1/3 privately funded business measures, 1/3 raw material tax	reduced labour taxation

Modelling Group	Key Paper	Model Name	Model type	Area	Scenario name	Scenario description	Revenue recycling
Wuppertal Institute	(Distelkamp and Meyer, 2010[52])	PANTA RHEI	ME	Germany	Economic	change in VAT for transport, material tax for building materials	reduction in income tax
					Information	1.2% of improvement in resource efficiency per year in firms through consulting	-
					Regulation	recycling must increase by a factor of 3 by 2030	-
					combined	combination of all above	reduction in income tax
UCL	(Ekins et al., 2012[22])	E3ME	ME	EU	LS1	carbon price, material tax (low oil price), 15% CO2 reduction	reduction in social security contributions (SSC) and income tax
					HS1	carbon price, material tax (high oil price), 15% CO2 reduction	reduction in SSC and income tax
					HS2	carbon price, material tax (high oil price), ambitious (25% CO2 reduction)	reduction in SSC and income tax
ERC	(Hartley, Caetano and Daniels, 2016[53])	SAGE	CGE	South Africa	Scenario 2	share of materials recycled increases to 29% (from 11% baseline)	-
					Scenario 3	share of materials recycled increases to 47%	-
					Scenario 4	share of materials recycled increases to 100%	-
POLFREE	(Meyer, Distelkamp and Beringer, 2015[54])	GINFORS	ME	EU	Sc1: global cooperation	all countries worldwide commit to 2degree target, (upstream carbon tax, renewable energy production, material tax etc.) see p. 42	reduction of taxes on production directly
					Sc2: EU goes ahead	EU meets targets though economic instruments, Non-EU only soft policies	reduction of taxes on production directly
NIES	(Masui, 2005[56])	AIM	CGE	Japan	Scenario 2	CO2 reduction 2% by 2010 (compared to 1990), half solid waste by 2010 (compared to 1996)	reduction in SSC
					Scenario 3	same as 2, with countermeasures on env preservation	reduction in SSC
	(Hu, Moghayer and Reynès, 2015[55])	EXIOMOD	CGE	global	Sc1: global cooperation	all countries worldwide commit to 2degree target, (upstream carbon tax, renewable energy production, material tax etc.) see p. 42	-
					Sc2: EU goes ahead	EU meets targets though economic instruments, Non-EU only soft policies	reduction of taxes on production directly
CSIRO	(Schandl et al., 2016[57])	GIAM	CGE	global	high efficiency	global carbon price rising 50 - 236 $ / t CO2 between 2010 and 2050 (4% increase, hotelling rule), improvements in resource efficiency 4.5% (doubling current efforts)	-
					medium efficiency	global carbon price rising 50 - 120 $ / t CO2 between 2010 and 2050 (2% increase, hotelling rule), improvements in resource efficiency ca. 3%	-
NERA	(Tuladhar, Yuan and Montgomery, 2014[58])	NewERA	CGE	Denmark	DNKMod	modest circularity effect, affecting 5 sectors (food & beverage, construction, real estate, machinery, plastic packaging and hospitals)	-
				Denmark	DNKOpt	strong circularity effect, affecting 5 sectors (food & beverage, construction, real estate, machinery, plastic packaging and hospitals)	-
				EU	EURMod	same modest as above, EU aggregate	-
				EU	EUROpt	same strong as above, EU aggregate	-

Modelling Group	Key Paper	Model Name	Model type	Area	Scenario name	Scenario description	Revenue recycling
Ex'tax	(Groothuis et al., 2016[18])	E3ME	ME	EU	EU Scenario	Tax on gasoline, diesel (0.60/l), aviation fuel (0.30/l), natural gas (7.8/MWh), VAT to 21% across EU, 30e/t CO2 on top of ETS price)	reduce income tax, social contribution, innovation
UNEP IRP	(Ekins et al., 2017[16])	GTEM	CGE	global	(1) Innovation	efficiency-innovations modelled through reduced unit cost of raw and basic materials	-
					(2) Resource extraction tax	Resource extraction tax	lump-sum to households
					(3) Regulations & New formations	Reducing amount of materials required to meet basic human needs	-
					(4) Combined effect	combination of all above	lump-sum to households
Cambridge econometrics	(European Commission, 2018[45])	E3ME		EU	Ambitious scenario	measures in Circular Economy package & extensive sectoral transformation	-
					Moderate scenario	measures in Circular Economy package & moderate sectoral transformation	-
ILO	(ILO, 2018[59])	Exiobase v3		global	Circular Economy Scenario	5% annual increase in recycling & 1% annual growth in the services sector	-