Organisation for Economic Co-operation and Development

ENV/WKP(2020)14

Unclassified **English - Or. English**

26 August 2020

ENVIRONMENT DIRECTORATE

THE JOBS POTENTIAL OF A TRANSITION TOWARDS A RESOURCE EFFICIENT AND CIRCULAR ECONOMY

ENVIRONMENT WORKING PAPER N° 167

By Jean Chateau and Eleonora Mavroeidi (1)

(1) OECD Environment Directorate

Authorised for publication by Rodolfo Lacy, Director, Environment Directorate

Keywords: Circular economy; resource efficiency; employment and environment; general equilibrium model.

JEL Classification: Q53,Q52, O44, C68

OECD Environmental Working Papers are available at www.oecd.org/environment/workingpapers.htm

JT03464648

OECD ENVIRONMENT WORKING PAPERS

OECD Working Papers should not be reported as representing the official views of the OECD or of its member countries. The opinions expressed and arguments employed are those of the author(s). Working Papers describe preliminary results or research in progress by the author(s) and are published to stimulate discussion on a broad range of issues on which the OECD works.

This series is designed to make available to a wider readership selected studies on environmental issues prepared for use within the OECD. Authorship is usually collective, but principal author(s) are named. The papers are generally available only in their original language –English or French- with a summary in the other language.

Comments on Working Papers are welcomed, and may be sent to:
OECD Environment Directorate, 2 rue André-Pascal, 75775 Paris Cedex 16, France
or by email: env.contact@oecd.org

OECD Environment Working Papers are published on
www.oecd.org/environment/workingpapers.htm

Abstract

This paper examines the consequences of a policy-driven transition towards a more resource-efficient and circular economy on employment levels across countries and sectors during the period 2018-2040. The analysis relies on simulations with ENV-Linkages, the global structural computable general equilibrium model of the OECD Environment Directorate. The results suggest that the overall reallocation of jobs due to a fiscal policy package promoting resource efficiency and the transition to a circular economy is limited to 18 million jobs in 2040 and net job creations are marginal, with 1.8 million of jobs. However, there are large variations across economies and sectors. Countries with large extraction sectors - such as Australia, New Zealand and ASEAN countries - face slightly more job destructions than job creations. At the sectoral level, secondary metals and recyclable sectors benefit from large increases in employment - with 350 000 additional jobs in 2040 in OECD countries - while job losses are experienced in sectors heavily dependent on primary materials, such as construction and certain manufacturing sectors, including production of machinery and electronic equipment. Finally, in the case where only OECD countries implement resource efficiency and circular economy policies, these countries would experience employment losses compared to the baseline due to a relative loss of competiveness. This result implies that globally coordinated action to decoupling material use from economic activity is preferable. Overall, the studied transition to a more resource efficient and circular economy proves very effective in fulfilling its environmental objectives along with marginal but positive employment impacts for most countries. Only few countries and sectors will be negatively affected. As such, they are central to ensure the political acceptance of the resource efficiency and circular economy transition.

Keywords: Circular economy, resource efficiency, employment and environment, general equilibrium model.

JEL codes: Q53, Q52, O44, C68.

Résumé

Ce papier étudie les conséquences sur l'emploi d'une politique fiscale stimulant une transition, sur la période 2018-2040, vers une économie circulaire et économe en ressources matérielles, entre les pays et les secteurs d'activité. L'analyse s'appuie sur des simulations numériques de ENV-Linkages, le modèle structurel et global d'équilibre général calculable de la direction de l'Environnement de l'OCDE. Les résultats montrent que la réallocation d'emploi au niveau global résultant de la mise en place d'un ensemble de politiques fiscales demeure limitée à 18 millions d'emploi, et les créations nettes d'emploi restent marginales, de l'ordre de 1.8 million. Cependant les résultats présentent de large différences entre les économies et d'un secteur à l'autre. Ainsi des pays pour lesquels le secteur minier est important, comme l'Australie, la Nouvelle Zélande et les pays de l'ANASE, peuvent subir plus de destructions que de créations d'emploi. Au niveau sectoriel, la production de métaux secondaires ou le secteur du recyclage présentent les plus importantes créations d'emploi, 350 000 en 2040 dans les pays de l'OCDE ; tandis que les secteurs hautement dépendants de matériaux primaires, comme la construction et certains secteurs manufacturiers, y compris la production de machines et d'équipements électroniques, connaissent des pertes d'emploi. Finalement, lorsque les pays non membres de l'OCDE choisissent de ne pas mettre en place cette politique fiscale facilitant la transition vers une économie circulaire, les pays de l'OCDE subiront des pertes d'emploi par rapport à la situation de référence, en raison des pertes de compétitivité qu'ils subissent. Ceci plaidant pour une la mise en place d'une action coordonnée au niveau mondial, des politiques visant à découpler l'utilisation de matériel de l'activité économique. En conclusion, la transition étudiée vers une économie circulaire et plus économe en matériaux remplie parfaitement ses objectifs environnementaux avec des impacts marginaux quoique positifs sur l'emploi dans la plupart des pays. Seulement quelques secteurs et pays seront négativement impactés. Ces derniers doivent donc faire l'objet d'une attention particulière afin d'assurer l'acceptation politique d'une telle transition vers une économie circulaire et économe en matériaux.

Mots clés: Économie circulaire, efficacité des ressources, emploi et environnement, model d'équilibre général calculable.

JEL classification: Q53, Q52, O44, C68.

Acknowledgements

This report presents results of the modelling projections of future trade consequences of a transition to a more resource-efficient, circular economy. It directly builds on the Global Material Resources Outlook to 2060 (OECD, 2019).

Jean Chateau and Eleonora Mavroeidi of the OECD Environment Directorate, under the guidance of Shardul Agrawala, Head of the Economy Environment Integration Division at OECD Environment Directorate, prepared this report.

This report was overseen by the Working Party on Integrating Environmental and Economic Policies and also benefits from comments received by Delegates of the Working Party on Resource Productivity and Waste.

Comments and suggestions from colleagues at the OECD Secretariat, Elisa Lanzi, Marta Arbinolo, Ruben Bibas (who also helped design the figures of the paper), Norbert Monti and Frithjof Laubinger from the Environment Directorate, but also Duncan MacDonald from the Directorate for Employment, Labour and Social Affairs and Dennis Dlugosch from the Economics Department are gratefully acknowledged. Previous version of this paper also benefits for some comments and remarks from presentations in academic conferences (2020 GTAP conferences and 2019 IAM Conference). The authors also thank Katjusha Boffa for providing editorial support.

The German Federal Environment Ministry's (BMU) Programme (REFOPLAN) funded this project. The responsibility for the content of this publication lies with the authors.

Table of Contents

Tables

Figures

Boxes

Executive Summary

Policies to promote resource efficiency and the transition to a circular economy have become important elements of environmental policy making and green growth, especially in light of the ever-increasing demand for natural resources. Besides the environmental benefits of the transition to a more Resource-Efficient and Circular Economy (RE-CE), governments also emphasize potential employment benefits.

This paper examines the consequences on labour markets and employment levels of a policy-driven transition towards a more resource efficient and circular economy, across countries and sectors during the period 2018-2040. The analysis is based on results of numerical simulations of a stylised RE-CE policy package, taking the form of a *material fiscal reform.* The analysis relies on ENV-Linkages, the global structural computable general equilibrium (CGE) model of the OECD Environment Directorate. The choice of the *material fiscal reform* reflects many of the circular economy objectives including the substitution between materials and other production inputs such as capital and labour, the substitution between different types of materials including recycling goods, the substitution between primary and secondary metal production technologies, and, on the demand side, substitution towards services. It also takes into consideration technological changes through the underlying labour productivity projections.

In the absence of RE-CE policies, material use is projected to increase in all regions, rising by 1.6% annually during the period 2018-2040, but with large differences across countries. At the same time, OECD economies are projected to grow by 2% annually on average, with an annual employment growth of 0.3% during this period. Although the increase in total number of jobs is projected to be small, changes in production modes and demand patterns, as well as changes in trade specialization patterns and global value chains, induce significant reallocations of labour across sectors amounting to 0.7% per year of total employment on average during 2018-2040. In particular, such structural changes imply that within OECD, the majority of job creations, in the next two decades, takes place in construction (the most mineral-intensive sector), renewable power generation and services, while manufacturing sectors, agriculture, food production and fossil-fuel based power are expected to record job losses.

The *material fiscal reform* scenario suggests that in 2040, within the OECD[1], employment in secondary-based metal production and recycling sectors will be 27% and 48% higher than in the baseline (business as usual scenario), corresponding to 284,000 and 68,000 additional jobs. The reduction of the relative costs of secondary-based metals, boosts output and in turn demand for labour in these sectors (direct impact) as well as in production sectors that can shift inputs towards more resource-efficient materials (indirect impact) such as chemicals and certain manufacturing sectors (e.g. textiles).

By contrast, the simulation of the *material fiscal reform* scenario record job destructions in sectors highly dependent on the use of primary materials. Among these, primary-based

[1] OECD area refers to 36 member states (Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States) as of December 2019.

metals, non-metallic minerals, construction sectors would experience job destructions of approximately 135,000, 85,000 and 67,000 jobs respectively compared to the baseline levels in 2040 (corresponding to a 2.9%, 1.6% and 0.1% reduction compared to the baseline).

The overall sectoral reallocation of jobs, resulting from implementation of the *material fiscal reform,* within OECD and globally is limited (respectively 1.3 and 18 million jobs), and total net creation of jobs is marginal (0.3 million for OECD, 1.3 globally). But this hides large variations across economies, according to their economic structure (and in particular their degree of dependence on material use) and whether they are net-importers or exports of raw materials. Total job reallocations across sectors are lower than 0.5% of total employment in most regions of the world, corresponding to a rotation of 18 million jobs compared to the global baseline in 2040. Countries with large extraction sectors (ASEAN countries, OECD Oceania) face slightly more job destructions than job creations, mostly because their economic structure is more material intensive both in terms of sectoral composition of GDP and in terms of production structure. On the other end of the spectrum, material-importers show larger number of job creations relative to job destruction (Korea, Japan, China, USA, EU countries).

In the case where non-OECD economies do not implement this RE-CE policy package, importers of raw materials benefit from lower input prices and thus experience employment gains compared to the baseline across both OECD and non-OECD countries. However, the drop in demand for primary metals by OECD economies, induces a drop in output and employment for certain non-OECD economies (Other ASEAN, Other non-OECD Asia and South Africa). Overall, for both regions, the projected employment gains are smaller than it would have been in the case of a global implementation of the policies.

Structural changes of a transition to a more resource efficient and circular economy will not affect all workers homogenously. Although, the modelling framework does not account explicitly for worker heterogeneity in terms of skills, drawing from the empirical literature on skills projections at the sectoral level, the results suggest an increased demand for medium and high skills as a result of the RE-CE policies in the long-term.

Sensitivity analysis shows that as material taxes increase, net wages rise, gross output decreases marginally and net employment follows a similar pattern. In addition, the use of extra tax revenues matters, suggesting that recycling through labour taxation is the more efficient option compared to lump-sum transfers recycling.

There are certain limitations to the current analysis and thus the results should be interpreted with care. First, the model is designed for analysing long term structural effects of policies, abstracting from the short run transition costs. Second, although reallocations across sectors would have distributional consequences, in the current analysis, distributional impacts are mostly focused on the wage income distribution and abstract from other sources of non-wage income and capital, while consumption and saving patterns are identical across workers. Third, the analysis accounts for changes in the sectoral composition of production, driven by changes in production and demand patterns, but it does not incorporate changes resulting from other factors, such as climate-induced migration from rural towards urban areas or across countries.

These limitations notwithstanding, this report clearly highlights that the transition to a more resource efficient and circular economy, proves very effective in fulfilling its environmental objectives along with marginal but positive employment impacts for most countries.

1. Introduction

Policies to promote resource efficiency and the transition to a circular economy[2] have become important elements of green growth, especially in light of the ever-increasing demand for natural resources and of the negative environmental impacts that it causes.

The environmental damages linked to the full lifecycle of raw materials range from large energy-related emissions of greenhouse gases and air pollutants, to toxic effects on humans, water, land and ecosystems. More policies need to be put in place to curb future material uses. Indeed, raw material use has more than tripled in the last 50 years, reaching almost 90 billion tonnes per year in 2017. If existing population and economic development trends are to continue, material use is projected to more than double by 2060 (OECD, 2019[1]). While primary materials extraction and processing has strong negative consequences on the environment, the environmental impacts of secondary materials use are estimated to be an order of magnitude lower than those of primary materials (OECD, 2019[1]) Thus, policies promoting the shift towards resource efficiency, the use of secondary materials and circularity will lead to an overall reduction in environmental impacts.

Multilateral initiatives under the G7 (2015[2]), the G20 (2017[3]) and the European Union (2018[4]) have started to address this topic. At the same time, several countries have implemented circular economy roadmaps; such as the People's Republic of China (here after China), Finland, France and the Netherlands (Thieriot, 2015[5]; Ministry of the Environment Finland, 2017[6]; Dutch Ministry of Infrastructure and the Environment & Ministry of Economic Affairs, 2016[7]).

Besides the environmental benefits, governments also emphasize the employment benefits that could result from the transition to a more resource-efficient and circular economy. For instance, the "Circular Economy Package" of the European Commission is projected to create over 170,000 jobs in the EU by 2035 (European Commission, 2016[8]). Similarly, the French policy package "50 measures for a circular economy" is expected to generate up to 300,000 new jobs in France (Plan Climat, 2017[9]), and the Finnish "roadmap to circular economy" envisages the gain of 75,000 new jobs in Finland (Ministry of the Environment Finland, 2017[6]; Wijkman and Skånberg, 2015[10]).

The objective of this paper is to examine the consequences of a policy-driven transition towards a more resource-efficient and circular economy – hereafter referred to as RE-CE – on labour markets and employment levels across countries and sectors in the coming decades. The transition process comes along with changes in demand patterns and in production processes, which in turn are likely to reshape labour markets.

A review of the macro-economic models used to assess the impact of various environmental polices (Laubinger, Lanzi and Chateau, 2020[11]) suggests that well-implemented policies may lead to a slight net increase in employment (Ekins et al., 2012[12]; Morgan and Mitchell, 2015[13]; Bosello et al., 2016[14]; Groothuis et al., 2016[15]). However, the effects are complex and vary across sectors and geographical regions. Importantly, the

[2] (OECD, 2020[15]) defines circular economy as seeking to maximise the value of materials and products in the economy, minimise material consumption and their environmental impacts, prevent waste and reduce hazardous components in waste and products.

way tax revenues from fiscal instruments (e.g. materials taxes) are used may also significantly affect the economic and employment outcomes of the RE-CE transition.

While the literature on this subject is still scarce, several modelling studies have focused on GDP and total employment impacts of RE-CE policies. However, most of the economic modelling studies reviewed by Laubinger, Lanzi and Chateau (2020[11]) do not explicitly investigate the impact of RE-CE policies on the sectoral employment mix. On average, scenarios that include some fiscal stimulus to wage income have a positive effect on GDP. Only two studies – by the European Commission (EC) (2018[16]) and the International Labour Organisation (ILO) (2018[17]) - cover these aspects to some extent, providing insights on the sectoral reallocations of jobs in a circular economy. Both studies conclude that RE-CE policies are likely to lead to relatively modest (and generally positive) impacts on aggregate employment levels. These two quantitative studies provide a first indication of the plausible changes in sectoral employment that could follow the introduction of RE-CE policies. However, in line with previous OECD (2012[18]) work on green growth policies, such aggregate net effects are likely to hide significant employment impacts on a subset of sectors. Taking into consideration the job reallocation impacts across sectors is of key importance to ensure a just transition and maintain political support for RE-CE policy measures. Moreover, methodologically, these studies share common features that limit their scope: they do not rely explicitly on structural behavioural mechanisms and they are not designed for long-run analysis. A structural Computational General Equilibrium (CGE) model could address both of these issues.

The modelling tool used in this report to assess the impacts of RE-CE policies is the OECD's global CGE model ENV-Linkages (Chateau, Dellink and Lanzi, 2014[19]). Considering the complexity of the interactions across different sectors and labour markets, ENV-Linkages by taking into account the inter-sectoral, inter-regional, and international trade interdependences, provides an integrated and coherent framework for understanding the underlying economic drivers of material use changes. The model has been used for a large body of OECD work, notably the latest "Global Material Resources Outlook to 2060" (OECD, 2019[1]) as well as two publications on the labour impacts of green growth policies (Chateau, Bibas and Lanzi, 2018[20]; Chateau, Saint-Martin and Manfredi, 2011[21]).

The modelling exercise studies the implementation of a stylised RE-CE policy package, aiming at progressively shifting the structure of the economy towards less material-intensive economic activities. The choice of the policy package was motivated by its ability to capture the relevant aspects of circularity as proposed by the modelling literature (see (OECD, 2020, forthcoming[22]) for a detailed description of this package). Two incremental scenarios are considered: (i) the *material tax only* scenario, in which only taxes on primary materials are implemented, and (ii) the *material fiscal reform* scenario (central scenario), which includes subsidies to the use of recycling goods and subsidies to production of secondary metals, financed by the extra revenues from the material taxes. These reforms are adopted gradually between 2018 and 2040, across all OECD and non-OECD countries.

The implementation of RE-CE policies will take place in parallel to other conventional dynamics of structural change. Such structural changes include shifts in future consumption patterns, changes in technology and production modes, such as digitalisation and "servitisation", and changes in trade specialization patterns, as discussed in the OECD's "Global Material Resources Outlook to 2060" (2019[1]). Understanding how these trends will affect material use and the sectoral composition of output and employment in the absence of RE-CE policies, is therefore a pre-requisite to RE-CE policy assessment.

The success of RE-CE policies depends on the capacity of firms and workers to adapt to the new economic structures. While a resource-efficient economy is beneficial in mitigating environmental impacts and has limited overall macroeconomic effects in the long run (OECD, 2020, forthcoming[22]), the transition towards more RE-CE economies, like any economic structural changes, will imply differentiated changes on industries and workers. Structural change are long-time processes that will have complex impacts on employment, GDP decomposition and in turn on income distribution. In order to maintain political support throughout the transition process, it is crucial to carefully study such dynamics, to acknowledge the positive and negative implications that may arise on workers' income and employment. Furthermore it is important to highlight how additional policies and measures may mitigate some of these side effects; for example implementing training policies to help workers in material intensive sectors to move to new jobs.

In line with the literature, simulations of the stylised RE-CE policy package using ENV-Linkages, suggest, overall, small net employment impacts but with large disparities across countries and sectors. Such disparities depend heavily on material intensity of individual sectors and the economic structure of the different economies studied. Moreover, how impactful a transition will be for the labour force will strongly depend on the transferability of skills from declining to growing sectors. Drawing from empirical projections on occupation and skills by (Cedefop, 2018[23]), their analysis suggests a potential rise in the demand of medium and high skills. In the case where non-OECD economies do not implement the resource efficiency and circular economy policies, importers of raw materials benefit from lower input prices and thus experience employment gains compared to the baseline across both OECD and non-OECD countries. The projected employment gains, however, are smaller than it would have been in the case of a global implementation of the policies.

The remainder of this paper is organised as follows. Section 2 provides an overview of the underlying mechanisms and dynamics that influence labour markets during a transition towards a more resource efficient and circular economy. Section 3 describes macroeconomic trends and employment changes across sectors until 2040 under a business-as-usual baseline projection, in line with OECD (2019[1]). Section 4 investigates how the stylised RE-CE policy package affects labour markets, using illustrative simulations exercises conducted with the OECD ENV-Linkages model. Besides the global implementation of RE-CE policies, this section explores scenarios where non-OECD countries opt out of applying RE-CE policies. Section 5 presents empirical results on projected changes in skills demand, and Section 6 concludes and discusses potential extensions of the analysis. Finally, the Annexes provide background information on the modelling framework and relevant results for the baseline projection and the stylised RE-CE policy package simulations.

2. Overview of the mechanisms driving sectoral labour impacts of the resource efficient and circular economy transition

This section examines the channels through which the implementation of the *RE-CE policies* may affect the structure of the economy and of the labour market. In principle, there is nothing inherently different between the job turnover associated with a circular economy transition and any other transitions occurred in the past within industrialised societies. The composition of change will be different, but the underlying dynamics and the trend of creative destruction have been around for a long time (Davis and Haltiwanger, 1999[24]). Thus, much can be learned from the broader literature on the green growth transition and labour markets (UNEP et al., 2008[25]; OECD, 2012[18]; Chateau, Bibas and Lanzi, 2018[20]). Although this literature predominantly explored climate policies, similarities exist between the dynamics and mechanisms of climate policies on carbon-intensive sectors and RE-CE policies on material-intensive sectors.

Based on existing literature on green growth and on the modelling literature review about employment impacts of RE-CE policies provided by Laubinger et al. (2020[11]), this section identifies the effects and mechanisms through which RE-CE policies can lead to structural change and reshape labour markets. In addition, it conceptualizes the analytical framework that will be used in the present analysis, focusing on the channels taken into consideration within the OECD's global Computational General Equilibrium (CGE) model ENV-Linkages.

2.1. Drivers of policy-induced changes in the labour market

The transition towards a more resource-efficient and circular economy implies permanent macroeconomic and sectoral structural changes, which in turn affect employment. Previous OECD work (Chateau, Bibas and Lanzi, 2018[20]) identified four main channels through which environmental policies generate structural adjustment pressures on good and labour markets: changes in (i) production modes (ii) demand patterns, (iii) macroeconomic conditions, and (iv) trade-specialization and competitiveness. Table 1 summarises the various mechanisms through which RE-CE policies may affect labour markets along with relevant examples.

When adapting to RE-CE regulations or fiscal incentives, firms will change their *production modes* by using fewer raw and refined resource inputs and/or shifting towards secondary materials and recyclables. Consequently, with the implementation of RE-CE policies, economic activity in primary metals sectors, for example, is likely to decline, affecting employment in these sectors accordingly. The opposite effect is expected for secondary metals production. However, sectoral employment is not only determined by the level of activity within each industry, but also by the substitution possibilities between (i) primary and other forms of materials, and between (ii) labour and other inputs, both of which result from changes in their relative prices.

Changes in demand patterns lead to the expansion and the contraction of certain economic activities, which in turn determine employment adjustments. Demand patterns can change as a result of policy-induced variations in the relative price of goods or services, or when preferences evolve to adapt to the new economic environment (due to e.g. increased

consumer awareness), leading consumers to invest and purchase durable goods with lower material footprint.

Table 1. Selected impacts of RE-CE policies on sectoral activity and employment

Channel	Macroeconomic impact	Plausible labour impact	Examples of policies
Changes in production modes	Shift away from production processes using primary materials to processes using secondary materials	Changes in labour according to the degree of complementarity between primary materials and secondary materials and/or recyclables	Promotion of recyclable metal production. Taxation of material-extraction sectors / Royalties
	Intensification of recycling-good uses in manufacture production	Increase employment in recycling-good sectors	Subsidy to recycling good uses in manufacturing sectors
Changes in demand patterns	Reduced final and intermediate demand of primary metals by firms or consumers, due to the increase in their relative price	Job destructions in extraction sectors and sectors heavily dependent on primary metals	Taxation of primary material uses.
	Increase in final and intermediate demand for secondary metals and recyclables by firms or consumers, due to changes in preferences	Job creations in recyclables and secondary metals, and job destructions in primary metals that are replaced by greener activities.	Increased consumer awareness shifts demand towards recyclables and/or goods produced by secondary materials and recyclables
Changes in macroeconomic conditions	Multiplier on final demand associated with stimulus from RE-CE policies	Positive impact on labour	Subsidies on secondary materials and recyclables
	Crowding out of investments in other sectors not included in the stimulus	Decrease in employment in sectors not associated with the stimulated sectors	Reduced resources for primary metals
	Increased taxation	Decrease in employment in sectors affected by the increased tax	Increase in primary materials taxes
	Use of additional fiscal revenues to decrease other types of taxation, or to increase government spending	Increase in employment within all sectors affected by the increased government spending or decreased taxation	Subsidies on secondary materials and recyclables.
Changes in international trade	Changes in exports and imports due to changes in relative competitive position	Decrease in employment in sectors producing these commodities	Reduced exports of material-intensive products
	Changes in trade balances and in real exchange rates induced by changes in exports and imports (terms of trade effect)	Labour changes in all sectors	Increase in recyclables exports

As RE-CE policies alter overall economic activity, they also imply *changes in macroeconomic conditions*, including GDP, aggregate employment, aggregate income and government budget balance. For example, changes in wages and thus households' income are likely to alter not only demand patterns but also savings choices or overall labour force participation rate. Moreover, government spending on resource-efficient sectors may 'crowd out' private investments in other sectors, negatively affecting output and employment within these sectors. Therefore, the overall impact of RE-CE policies on employment depends on the interplay between *Keynesian* multipliers and crowding-out effects.

In addition to the income effects, RE-CE policies also encompass budget adjustments that also imply some *changes in macroeconomic conditions*. For instance, RE-CE policies such as the implementation of taxes on primary materials could be coupled with changes in government spending or in tax rates to mitigate the adverse overall employment effects or offset negative impacts on some specific sectors. Such changes could include the provision of subsidies on alternative inputs such as recycling goods, or a reduction of labour income tax rates. Therefore, fiscal policies implemented as part of a RE-CE reform, can also achieve a double dividend: on the one hand, RE-CE policies can improve environmental quality, ensuring better health and wellbeing of citizens through the reduction of primary material use, and on the other hand, they can give the government the budgetary flexibility to reduce distortionary labour market taxation that consequently leads to a more efficient economy.

Finally, the impact of RE-CE policies on prices and the production structure varies greatly across regions thus affecting relative country competitiveness and, in turn, international trade specialisations. In particular, the policy impact depends primarily on the economic structure and the initial endowments of natural resources (e.g. raw materials) of each country. For instance, extractive and material-intensive industries in regions with strict policies on material consumption can experience competitiveness losses and a decrease in labour demand. On the other hand, the production and exports of less material- intensive goods is likely to increase in these regions. Fragmentations in the policy landscape can also encourage the transfer of material-intensive practices from regions with stringent regulations to regions with less stringent regulations, thus leading to geographical shifts in employment.

2.2. Dynamic effects of policy-induced changes in the labour market

Whilst the above mentioned drivers describe *why* changes in labour markets occur and provide information on the underlying mechanisms and dynamics, they do not lay out the mechanism of *how* labour markets are impacted. The analytical framework incorporates two major dynamic effects that determine potential changes in the structure of employment resulting from the implementation of RE-CE policies:[3]

- *job creation* occurs in 'green' sectors that are stimulated through RE-CE policies and that reduce the use of primary materials or support the development of circular business models;
- *job destruction* occurs in sectors characterised by large environmental and materials footprints without direct replacement (e.g. mining and extraction).

In most instances, these effects do not happen in isolation, but occur in an interplay of different labour changes associated to non-policy driven structural changes. For example, the emergence of new circular business models, such as product-service systems and the sharing economy, contributes to create new jobs, but it can also destruct existing jobs in other sectors that are heavily dependent on raw materials. For this reason, before assessing

[3] The existing literature on green growth (UNEP et al., 2008[25]) identifies four partial effects that determine potential changes in the structure of employment, that could equally apply in the case of RE-CE policies. In particular, such effects include: job creation and destruction, as well as substitution and redefinition of jobs. As the latter two effects are not standard features of CGE modelling, they are not included in this analysis. The companion review paper by Laubinger et al. (2020[11]), discusses in more detail these underlying labour changes.

the potential impacts of policies aimed at reducing material use, it is important to evaluate future labour markets and structural changes that may occur in the absence of any RE-CE policy.

Overall, labour market dynamics are complex and comprise multiple adjustment pressures, which have different effects on employment. Uncertainties revolve around the net impact of RE-CE policies on employment, as well as on job destructions and creations across regions. Applied economic models, such as ENV-Linkages, can help understand the interactions between these different effects and quantify the net effects of RE-CE on both aggregate and sectoral employment.

3. Baseline employment projections to 2040

Before assessing the employment impacts of the transition towards a more resource efficient and circular economy (RE-CE), it is worth understanding how economic trends (such as technological change and changes in production modes) are likely to reshape labour markets in the coming decades, even in the absence of any new policy-driven changes. The reference baseline projections are characterised by the continuation of current policies and by plausible socio-economic developments, including demographic, urbanisation, and globalisation trends (see Annex B). This baseline projection will then serve as the reference point to analyse the long-term consequences of RE-CE policies.

3.1. Aggregate socio-economic projections

This section presents the projected macroeconomic and labour trends in 2017 and 2040 and discusses the underlying drivers of economic growth (labour, capital and total factor productivity) across OECD countries and the rest of the world.

Macroeconomic and employment projected changes

At the global level, living standards - measured as real GDP per capita - are projected to improve by 2040 (Table 2).[4] Income levels will rise in all regions but, due to the underlying economic convergence assumptions, the increase will be higher in emerging and developing countries than in more mature OECD countries.

Labour supply is a key determinant of this increase in economic activity (potential real GDP in the long run). While the contribution of capital to production can be increased through investments, labour inputs are largely restricted by the amount of people available in the labour market.

In the long run, population growth and labour participation drive labour supply (employment). Figure 1 shows the historical and projected trends of population and employment growth in individual countries and aggregate regions. Changes in employment patterns vary widely across countries, depending on specific demographic trends and labour market characteristics (including participation rates by age and gender). While in most countries population growth is projected to contribute to employment growth until 2017 (the last year before the implementation of the RE-CE policies), demographic changes and the increasing share of retired people are projected to reduce labour participation rates and employment by the middle of the century despite an increasing participation of women.[5] This ageing trend would slow down employment growth and may even lead to an overall decline in employment in some countries and regions especially in Japan, Korea, China and many European countries. Overall, the results suggest that employment growth in OECD

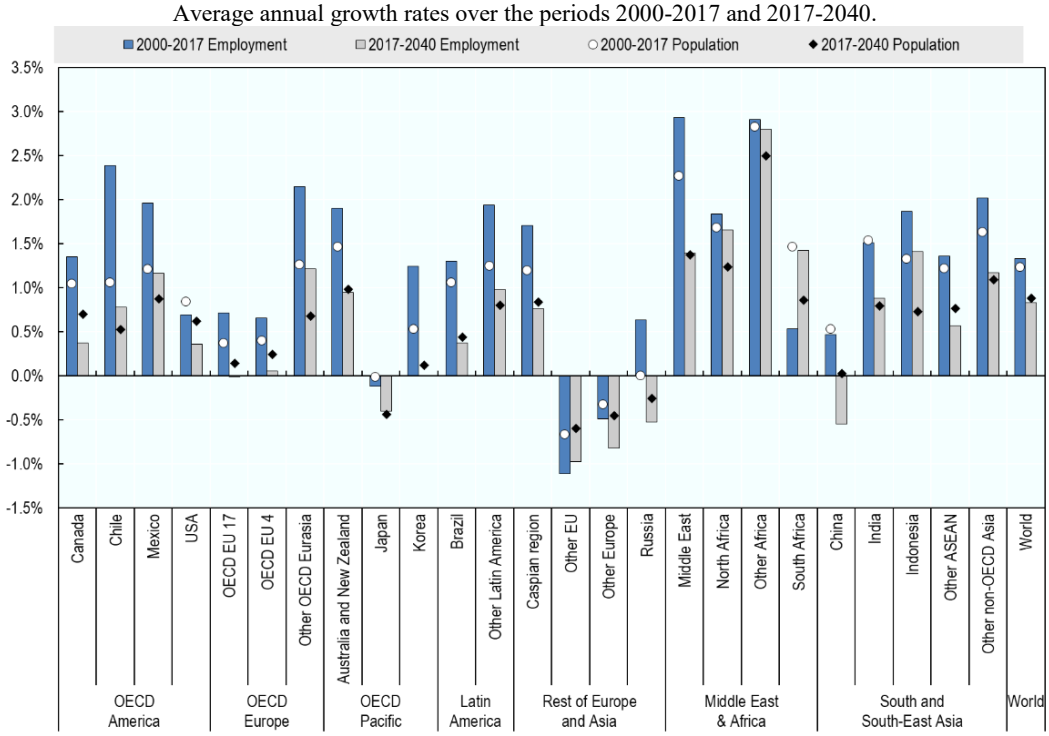
[4] The projections presented do not account for the health crisis caused by COVID-19. Thus, can be considered as relatively optimistic.

[5] Migration could also drive economic growth. The underlying assumptions on migration flows in the current projections are those of the UN population prospects (UN, 2017[34]).

and BRIICS countries is less dynamic than within developing countries where labour is still an important driver of GDP growth.[6]

Figure 1. Employment and population growth by region, Baseline scenario

Average annual growth rates over the periods 2000-2017 and 2017-2040.



Source: OECD ENV-Growth model, central baseline scenario of the Global Material Resources Outlook to 2060 (OECD, 2019). Population projections are based on UN (2017) and Eurostat.

Labour productivity growth is the second driver of the increase in economic activity. In more detail, labour productivity is projected to increase on average by 1.7% per year in OECD countries and by over 3.1% in BRIICS countries by 2040 (Table 2). In turn, at the aggregate level, labour productivity is driven by two main components: capital stock installed by unit of worker and total factor productivity. The underlying projections on total factor productivity (Guillemette and Turner, 2018[26]), take into consideration the projected improvements in productivity resulting from technological advances (such as Artificial Intelligence and ICTs), as well as improvements in human capital or capital efficiency (e.g. robotisation). A detailed analysis of the model baseline, discussed in OECD (2019[1]), shows that labour productivity improvements are mostly driven by increases in total factor productivity in mature economies, like OECD countries, while the main driver in emerging economies is the increase of capital stock installed per worker.

Historically, rapid and sustained productivity growth has lifted OECD countries to high standards of living. However, technological innovations and capital-intensive investments can also lead to job destructions. Overall, the net effect on employment varies greatly across

[6] Economic growth in developing countries is often associated with the expansion of sectors that are highly dependent on labour such as agriculture and light manufacturing.

economies, depending on their economic structure and their level of economic growth. In particular, countries specialising in sectors and skills that match the needs of the growing economic sectors will most likely benefit from increases in labour productivity (OECD, 2018[27]).

Table 2. Aggregate socio-economic indicators by aggregate region, Baseline scenario

	OECD		BRIICS		Rest of the World		WORLD	
	2017	2040	2017	2040	2017	2040	2017	2040
GDP growth [a]		1.9%		3.9%		3.7%		3.0%
Share in world GDP	44%	34%	35%	42%	21%	24%	100%	100%
GDP per capita [b]		1.5%		3.5%		2.1%		2.1%
Employment growth [c]		0.3%		0.2%		1.7%		0.8%
Population growth [d]		0.4%		0.4%		1.6%		0.9%
Labour productivity growth [e]		1.7%		3.1%		1.9%		1.7%
Material use growth [f]		1.2%		1.4%		2.7%		1.6%
Services share [g]	72%	74%	54%	57%	49%	53%	64%	66%
Material intensity [h]	0.47	0.41	1.21	0.68	0.77	0.62	0.79	0.57

Notes:
- a Average annual growth rate of real GDP at 2011 PPPs exchange rate (percentages)
- b Average annual growth rate (over the period) of the real GDP in PPP per habitant (percentages)
- c Average annual employment growth rate (over the period) (percentages)
- d Average annual population growth rate (percentages)
- e Average annual growth rate of labour productivity (percentages)
- f Average annual growth rate of all material use (percentages)
- g Gross value added of services at basic prices in percentage of GDP
- h Material uses per unit of real GDP at 2011 PPPs exchange rates

Source: OECD ENV-Linkages model.

Structural changes and job reallocations across sectors

The share of services in total GDP is projected to rise together with growing income per capita, (Table 2). Economic growth, whether driven by primary-factor growth (e.g. labour, capital) or by overall technical progress, is historically spread unequally across economic sectors and, in the long run, it is thus characterised by changes in the sectoral composition of economies (i.e. by structural change) (Ngai and Pissarides, 2007[28]).

Many factors explain why growth rates are not uniform across economic sectors and commodities. First, changes in *demand patterns* imply that, as income rises, households spend less on necessary goods like food products, and more on services (Fisher-Clark-Kuznets thesis). However, other trends - such as an accelerated "servitisation" of the economy (i.e. increase of service inputs in production processes), population ageing and urbanization - can also induce changes in demand patterns. In particular, changes in *production modes*, such as the uptake of technological progress across sectors (e.g. ICTs) imply an increase of services use in production modes, while ageing societies may cause an increased demand in health expenditures.

The changes in production modes and demand patterns, as well as changes in trade specialization patterns and global value chains, induce reallocations of labour across sectors. Although the increase in the total number of jobs over the period 2017-2040 is projected to be small across OECD countries (Figure 1), it is accompanied by significant job reallocations s across sectors. As suggested in Table 3, the total job reallocation (i.e.

sum of job destructions and jobs creations) is larger than the projected net-employment growth rates for all country groups in 2040. It is worth highlighting that the job reallocations reported account for across sector reallocations but abstract from within sector reallocations.[7]

Job reallocations vary across regions depending on their degree of economic maturity and on the extent to which their economic activity is focused on labour intensive sectors. The results suggest that OECD and BRIICS are less dynamic in terms of job rotation than the "Rest of the world". Large job creations coupled with few job destructions, are projected in the "Rest of the world" by 2040, driven primarily by population growth and the economies' dependence on labour-intensive sectors. In parallel, BRIICS experience larger job reallocations compared to OECD countries reflecting more pronounced structural changes currently underway. Overall, job reallocations progressively decrease in all regions as economies increasingly transition to a service-based economy with less structural change involved (Figure C.1 in the annex).

Table 3. Job reallocations across sectors by aggregate region, Baseline scenario

Percentages of total employment – Average rates over the periods, 2017-2040

	Net employment growth	Excess worker reallocation	Job creations	Job destructions	Total job reallocation
OECD	0.3%	0.4%	0.5%	0.2%	0.7%
BRIICS	0.2%	0.8%	0.6%	0.4%	1.0%
Rest of the world	1.6%	0.1%	1.7%	0.1%	1.8%

Note: Definitions: Total job reallocation = sum of job creation and job destruction; Net employment growth = absolute value of net employment growth (defined as the difference between job creation and job destruction); Excess worker reallocation = difference between total job reallocation and net employment growth.
For each X in {Net employment growth, Excess worker reallocation, Job creations, Job destructions, Total job reallocation}:

$$X = \sum_{t=2017}^{2040} X_t / \sum_{t=2017}^{2040} Total\ Employment_t$$

Source: OECD ENV-Linkages model.

3.2. Projected changes in sectoral composition of employment and output

Although the magnitude of total job reallocations between sectors is projected to be limited as percent of total employment, the projected changes in sectoral composition of employment and output reveals interesting patterns (Figure 2). In OECD countries, structural changes imply that the majority of job creations, in the next two decades, takes place in construction (the most mineral-intensive sector), renewable power generation and

[7] Job reallocations, creation and destruction presented in this report should be taken as illustrative indicators of changes occurring in labour market in various situations. They are not comparable in magnitude to numbers obtained from cross-sectoral employment calculated in labour market statistics. Indeed, the numbers reported account only for job changes across sectors, and not for changes within the same sector. Moreover, the measurement of job reallocation between sectors is sensitive to the industry classification retained for the analysis (see sectoral details in Table A2 in Annex A).

services.[8] Jobs destructions, on the other hand, materialise in some manufacturing sectors, agriculture, food production and fossil-fuel based power. In non-OECD countries, the growth rates of employment are still higher in most manufacturing sectors compared to services sectors, while employment in food and agriculture production sectors are projected to grow less rapidly or even decline for certain countries.

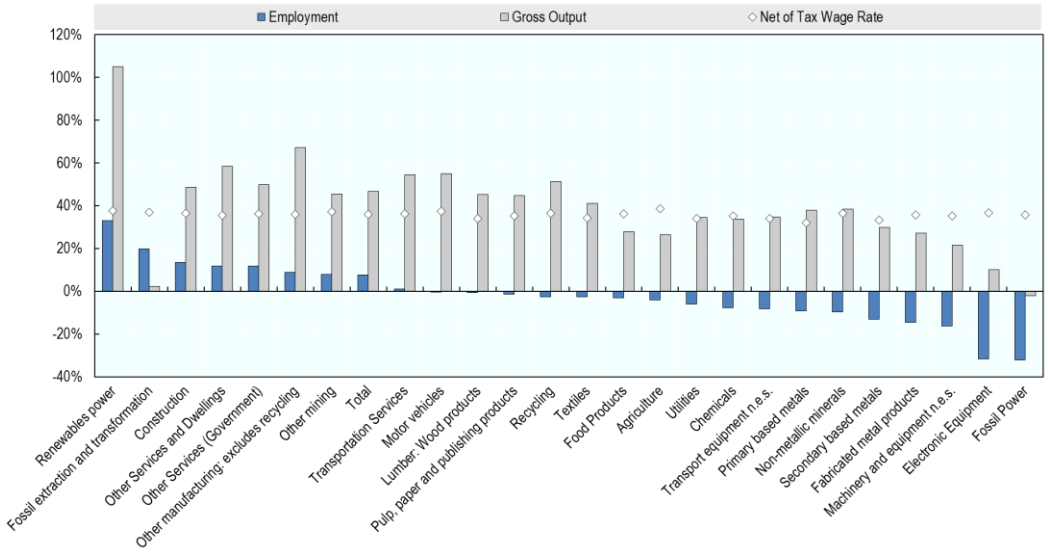
While employment generally follows production, the growth of sectoral employment is always lower than the production growth of the corresponding sector. Two main drivers explain this trend. First, at aggregate level total employment growth is lower than GDP, and second, improvements in labour productivity tend to decrease labour demand by firms.

In OECD countries, on average, the gap between production and employment growth tend to be larger in sectors with relatively high labour productivity, such as fossil-fuel power or heavy industries[9] (Figure 2). On the contrary, sectors with lower labour productivity such as construction and part of manufacturing would show a lower wage increase but a higher employment growth, relative to production growth. In non-OECD countries, output and employment grows across sectors at varying degrees, with transport, electronics and machinery and equipment among the top performers. Overall, across both country groups, secondary-based metal production and recycling sectors exhibit an increase in projected employment reflecting changes in production modes.

Figure 2. Sectoral composition of employment and output, Baseline scenario

Percentage changes in 2040 baseline projection relative to 2017 values.

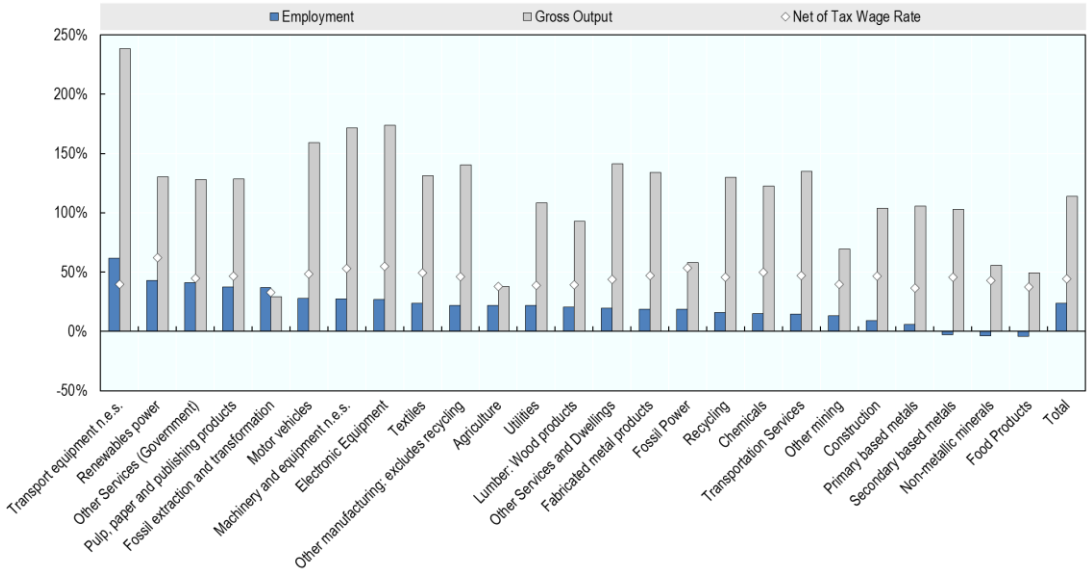
Panel A. OECD countries



[8] Employment in fossil extraction and transformation is also projected to increase and this result is primarily driven by the USA.

[9] Annex Table C.1 depicts the labour productivity per sector in 2017 and 2040.

Panel B. Non-OECD countries



Note: In this figure for sake of simplicity sectors have been aggregated to 25 sectors. The complete list of sectors in the model is reported in Table A.1 in Annex A. Sectors are ordered from greater to lower employment change.
Source: OECD ENV-Linkages model.

3.3. Projected changes in material use

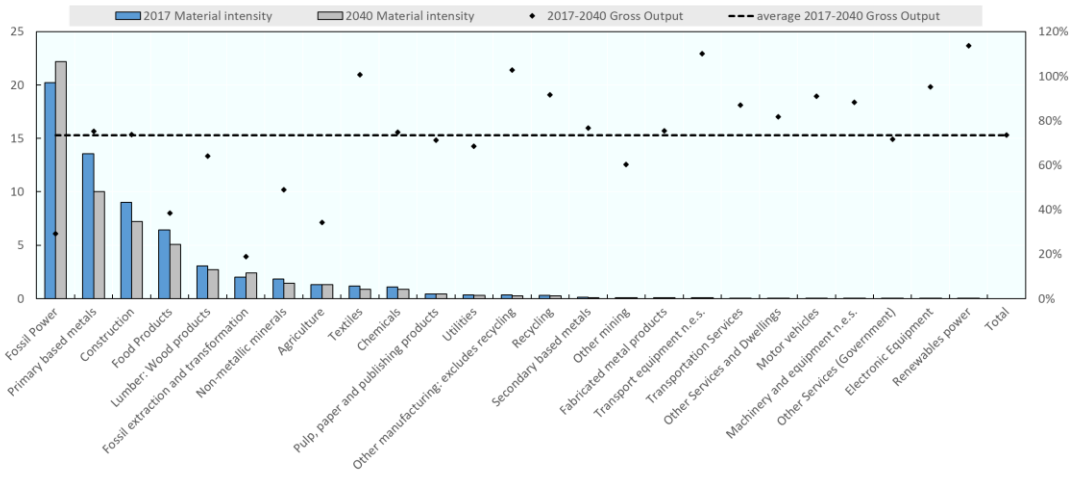
The material intensity (primary materials use per unit of output) is projected to gradually decrease globally by 2040 (bars in Figure 3). This relative decoupling between economic growth and material uses in the next two decades is explained by the projected shift towards more services (diamonds in Figure 3), along with technological changes and other long-run trends such as slowing down of construction and infrastructure sectors. While material use declines across sectors at varying rates, material intensive sectors such as non-metallic minerals and fossil power and extraction sectors are projected to grow below average. Overall, it should be highlighted, that while material intensity is expected to decrease the total material use is still projected to increase (Table 2).

Moreover, material intensive sectors tend also to be less labour intensive[10] compared to sectors with lower material intensity such as services. Based on 2017 data, construction accounts for the largest share of materials use (48%) in total production but only employs 8% of the total employment globally. Other services and government services are the major employers (41% and 27% respectively) with limited material use (1.8% and 0.3% respectively) (Figure C.2). Thus, the projected acceleration of servitisation is likely to lead to overall job creation. However, job losses within material intensive sectors are projected to take place even in the absence of any new policies, and therefore workers in those sectors may face some adverse impacts that should not be neglected.

[10] Annex Figure C.3 depicts the capital to labour ratios per sector in 2017 and 2040 for OECD and non-OECD countries. The results show that primary-based metal production sectors are more capital intensive than secondary-based metal production and recycling sectors.

Figure 3. Material intensity and output growth by sector, Baseline scenario

Left axis: Ratio of primary materials use in tonnes over sectoral output in thousands of constant USD.
Right axis: Percentage growth of gross output between 2017 and 2040 (diamonds)



Note: In this figure diamonds (right axis) show sectoral growth rates of output while the dashed line shows average growth rate of output - any sector above (below) this line increase more (less) rapidly than the economy on average.
Source: OECD ENV-Linkages model.

4. Dynamic employment impacts of a *material fiscal reform* to promote resources efficiency and circularity

This section presents the employment impacts of a set of stylised policies aimed at facilitating the transition to a more resource efficient and circular economy.[11] The analysis of RE-CE policies in this report focuses on a stylized *material fiscal reform* scenario that promotes the RE-CE transition through a policy package that includes excise taxes on metal and non-metallic mineral ores, subsidies to recycling and support to secondary based metal productions (see Box 1 for details).

The objective of the *material fiscal reform* is to reduce raw material use and therefore induce a permanent structural change in the sectoral composition of the economies shifting production from material-intensive sectors towards less material-intensive sectors or sectors using secondary materials and recyclables. Consequently, by curbing material use, the policy package will lead to an overall reduction in environmental impacts (OECD, 2020, forthcoming[22]).

Simulation exercises have been conducted using a version of the ENV-Linkages model that assumes perfectly flexible labour markets. Under the assumption of full flexibility of workers across sectors, labour markets clear at each period such that, after any policy implementation, the average wage adjusts to equalize labour supply and labour demand at the aggregate level. At the sectoral level, differences in wages reflect labour productivity differences across sectors (see Annex A for more details). In the following analysis, the outputs of the policy simulations are compared to the baseline scenario described in Section 3.

Box 1. The design of the *material fiscal reform* scenario

For this analysis, a stylized RE-CE policy package is considered based on a material tax reform that aims at shifting consumption away from primary material use towards secondary materials and recyclables. For a complete investigation of potential RE-CE policy packages and their macroeconomic consequences, please refer to OECD (2020, forthcoming[22]).

The policy packages considered in this analysis

The details regarding the central *material fiscal reform* scenario along with two alternative scenarios are presented in Table 4. In all RE-CE scenarios, the policies are gradually implemented between 2018 and 2040. The central scenario consists of the *material fiscal reform* that implements a tax on primary materials use for all metals and non-metallic minerals, with tax rates varying between 5 and 50 USD/tonne on average at the world level. Tax rates on each mineral uses are adjusted proportionally across countries to take into account existing taxation on

[11] A more detailed analysis of the macroeconomic and environmental impacts of RE-CE policies is presented in OECD (2020, forthcoming[22]).

mining production sectors (including royalties). As a result, the fiscal burden of the sum of implemented material taxes and extraction taxation is smoothed across countries (i.e. imply the same share of fiscal revenues in total fiscal revenues). In turn, the extra revenues from these material taxes finance subsidies aimed at promoting the use of recycled goods as well as subsidies on secondary-metals productions, such that overall the reform is budget neutral.

Two alternative scenarios are also discussed in this report to examine the issue of incomplete coverage of RE-CE policies. First, the *material tax only* scenario, where the scope is limited and only includes material taxes, and where extra revenues from these taxes are lump-sum rebated to households. This scenario is used for comparison to the *material fiscal reform* scenario, in order to show the additional benefits of the subsidies implemented in the central scenario. Second, the *OECD-only material fiscal reform* scenario includes the same fiscal reform as the central scenario but adopted only by OECD countries. This scenario is used as a robustness check to test for potential (or not) co-operation benefits.

Table 4. Policy Packages

	Policies	Global Target (2040)	Countries implementing the package	Time period
Material Tax Only	• A tax on primary materials use for all metals and non-metallic minerals, with tax rates varying between 5 and 50 USD/tonne; Tax rates adjusted at country level to take into account existing extraction taxes and royalties (see details in Table A.3. of the Annex)	• 10 USD/tonne of iron ores, • 50 USD/tonnes of aluminum ores, • 20 USD/tonnes of copper ores, • 15 USD/tonnes of other non-ferrous metals ores • 5 USD/tonne of non-metallic minerals	All OECD and non-OECD countries	Gradually implemented between 2018-2040
Material Fiscal Reform	• *Material Tax* • Subsidy to recycling goods. • Production subsidy to secondary metals at level that ensures the full package is revenue-neutral.	• *Material Tax* targets, and • A 75% subsidy rate on the purchasing price of the recycling commodity for firms, • A subsidy rate on the producer (selling) price of secondary metal production.	All OECD and non-OECD countries	Gradually implemented between 2018-2040
OECD-only Material Fiscal Reform	As in *Material Fiscal Reform*	As in *material Fiscal Reform but restricted to OECD countries only*	All OECD only	Gradually implemented between 2018-2040

Reasons behind the package choice

The choice of the policy package was motivated by its ability to capture the relevant aspects of circularity as proposed by the modelling literature. There is no single commonly accepted definition of the term "circular economy". Despite the wide range of actions proposed by the current roadmaps, they all tend to share the basic concept of decoupling of natural resource extraction and increased resource efficiency as outcome (McCarthy, A., 2018[29]). Recent literature that studies the macroeconomic impact of circular economy has modelled circular economy policies by focusing on such decoupling mechanisms. In particular, within economy-wide quantitative models: such as macro-econometric and Computation General Equilibrium models, circular economy policies are modelled as policies that promote:

- substitution between particular material and other production inputs such as capital and labour or substitution between different types of materials including between primary and secondary materials (e.g. via changes in I-O coefficients, imposition of taxes, exogenous changes in production costs),
- demand side substitution towards services (e.g. exogenous decrease in demand of certain material-intensive sectors),
- technological changes (e.g. via exogenous technological shocks and investment surge in certain sectors), and
- policies that affect the longevity of products (usually via price increases of specific products).

The policy scenario applied in this analysis touches upon the first three aspects (for a detailed description, see (OECD, 2020, forthcoming[22]). Primarily, the package focuses: first, on reducing the use of primary materials by increasing recycling and the use of secondary materials - *closing the resource loop* – and, second on expanding the sharing and service economy - *narrowing the resource flow*. In more detail, the stylised policy package incorporates taxes on primary materials and subsidies on secondary materials and recyclables that aim at progressively shifting the structure of the economy towards less material-intensive economic activities, promote the substitution of primary materials by secondary materials and recyclables, and consequently increase the amount of time materials stay within the economy. In addition to the fiscal scenario imposed, the modelling framework, takes into account the substitutability between primary and secondary materials or recyclables, and incorporates technological advances and shifts in consumer preferences towards services as an economy matures (OECD, 2020, forthcoming[22]).

4.1. Macroeconomic impacts of the *material fiscal reform scenario*

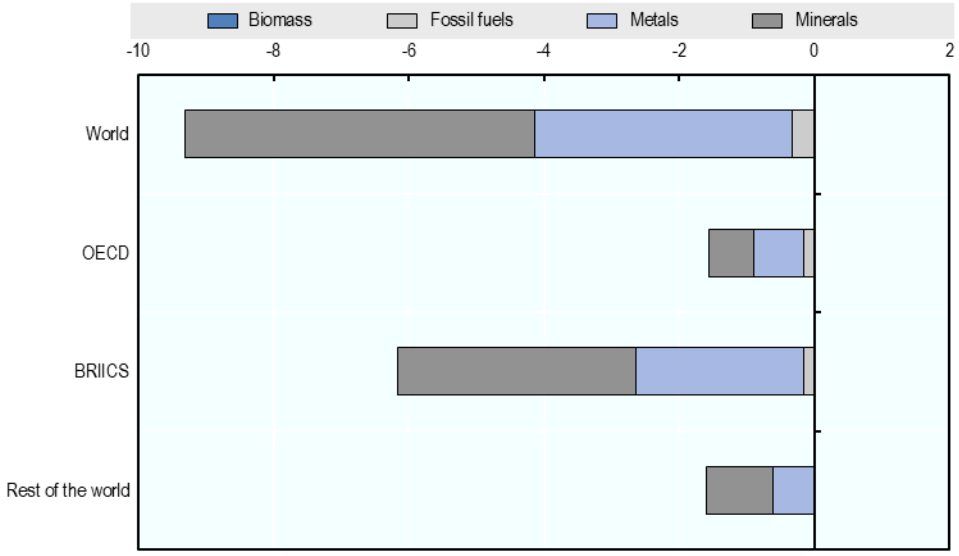
This section discusses the macroeconomic and aggregate employment consequences of the *material fiscal reform* scenario at the regional and global level.

The implementation of the *material fiscal reform* will curb primary material uses. In particular, following the introduction of the reform, agents react by adapting their production and consumption patterns, which influence the overall use of materials. As

illustrated in Figure 4, the policy package results in a substantial 27 % (4 Gt) reduction in metals use and a 8% (5.2 Gt) reduction in non-metallic minerals with respect to the baseline scenario by 2040 globally with larger drops drawn within BRIICS.[12] The reduction of total material use is about 7.2% with respect to the baseline scenario, since fossil fuel and biomass are only slightly affected indirectly by the tax reform (Table 5). Overall, the fall in materials use, including metals and non-metallic minerals, will be accompanied by a series will be accompanied by a series of positive environmental impacts including acidification, climate change, eutrophication, land use, as well as water, human and terrestrial ecotoxicity (discussed in details in (OECD, 2020, forthcoming[22]).

Figure 4. Primary material use changes, *material fiscal reform* scenario

Materials use in Gt – change w.r.t. central baseline scenario in 2040.



Source: OECD ENV-Linkages model.

The macroeconomic impacts of the *material fiscal reform* scenario are limited, mainly because primary-based metal production sectors represent a small share of the economy (about 3% of total value added), and because the ambition of the reform remains limited. Compared to the baseline, GDP and GDP per capita decrease by 0.0-0.4% across regions (-0.2% at the global level) (Table 5). Moreover, the overall aggregate impact of the fiscal reform on employment across regions is almost neutral (+0.03%), as in addition to the limited ambition of the reform, the policy package is budget neutral.

.

[12] This is particularly the case for metals in Indonesia and for non-metallic minerals in China (see Figure C.6 in the Annex).

Table 5. Aggregate indicators by aggregate region, *material fiscal reform* scenario

Percent change in 2040 w.r.t. central baseline scenario.

	OECD	BRIICS	Rest of the world	World
GDP [a]	0.0%	-0.3%	-0.4%	-0.2%
GDP per capita [b]	0.0%	-0.3%	-0.4%	-0.2%
Employment [c]	0.05%	0.05%	0.01%	0.03%
Services share [d]	0.0%	-0.1%	0.1%	0.0%
Material use [e]	-5.0%	-9.5%	-4.8%	-7.2%
Material intensity [f]	-5.0%	-9.2%	-4.4%	-7.0%

Notes:
a GDP at 2011 PPPs exchange rate
b real GDP in PPP per habitant
c Employment in persons
d All material uses in Gt
e Gross value added of services at basic prices in percentage of GDP
f Material uses per unit of real GDP at 2011 PPPs exchange rates
Source: OECD ENV-Linkages model.

The policy package affects economic activity through two main channels: through the induced increases in the relative cost of primary resources, and through the changes in consumer prices of secondary based metal and recycling goods (both are now subsidised). In particular, the tax on primary materials increases the relative production costs of firms, which in response reduce their use of and dependence on primary materials and, where possible, substitute them by secondary materials. Indirectly, the overall increase in production costs is passed on to consumers via higher prices of final goods, thus affecting their demand patterns. Conversely, the subsidies for recycling and secondary materials have the opposite effect on the production costs for firms using the subsidised materials as inputs.

In response to the relative changes in material prices, agents react by adapting their production and consumption patterns, which subsequently affect output and employment. Employment growth generally follows production growth and demand, while improved labour productivity tends to increase capital to labour substitution and to offset the employment gains. A shift from capital to labour[13] induces employment gains. Moreover, the role of wages in the model is twofold. At the aggregate level, the real wage rate adjusts to equilibrate labour demand and supply, while at the sectoral level, the relative real wages across two sectors reflect their relative labour productivity adjustments.

Regarding the government budget in the central scenario, the fiscal revenues from the material taxes accrue to national budgets and serve to finance the subsidies that stimulate demands for recycled goods and secondary metal production. Overall, the *material fiscal reform* is budget neutral and as such would limit the impact on total labour supply that results only from structural changes in the sectoral composition of employment due to changes in relative wages across sectors. Despite the implementation of non-negligible taxes on materials use, the imposed taxes do not change substantially the composition of government budgets. Indeed, the total amount of material taxes reaches around 0.9% of

[13] See Figure C.3 in the annex for more details about labour intensive sectors.

total tax revenues in 2040 at the global level, and only 0.3% for OECD countries[14] (OECD, 2020, forthcoming[22]).

Decomposition of the material tax reform by fiscal tools

The comparison of two incremental scenarios helps illustrate the mechanisms underlying these results: (i) the *material tax only* scenario, in which only taxes on primary materials are implemented and extra revenues are distributed to households as lump sum transfers, and (ii) the *material fiscal reform* scenario, which includes subsides for recycling and secondary materials, financed by the extra revenues from the material taxes. Table 6 shows a comparison of the results for employment indicators from these two scenarios.

The *material tax only* scenario induces a negative effect on employment across regions – more jobs are destroyed in material-intensive sectors than created in less material-intensive sectors and secondary material production. This effect is driven by the direct impact on material intensive sectors that face a large increase in their production costs, coupled with extra costs of switching to alternative sources of production. Subsidies on recycling and on reprocessing of recycled metals mitigate the negative employment effect of taxes on primary materials under the *material fiscal reform* scenario (Table 6), leading to a slightly positive employment growth.

Table 6. Net employment effects by aggregate region, for two material tax scenarios

Difference to baseline, as a percentage of total employment, 2040

		Net employment growth	Excess worker reallocation	Job creations	Job destructions	Total job reallocation
OECD	Material tax only	-0.1%	0.1%	0.0%	0.1%	0.1%
	Material fiscal reform	0.0%	0.1%	0.1%	0.1%	0.2%
BRIICS	Material tax only	-0.2%	0.1%	0.1%	0.2%	0.3%
	Material fiscal reform	0.1%	0.4%	0.3%	0.3%	0.6%
Rest of the world	Material tax only	-0.1%	0.1%	0.1%	0.2%	0.2%
	Material fiscal reform	0.0%	0.4%	0.2%	0.2%	0.4%
WORLD	Material tax only	-0.1%	0.1%	0.1%	0.2%	0.2%
	Material fiscal reform	0.0%	0.4%	0.2%	0.2%	0.4%

Notes: This table reports the difference with respect to the baseline in 2040 as a percentage of total employment. In particular, for each X in {Net employment growth, Excess worker reallocation, Job creations, Job destructions, Total job reallocation}:

$$X = \frac{X(MFR)_{2040} - X(BAU)_{2040}}{Total\ Employment(MFR)_{2040}}$$

Thus, the reported numbers are not directly comparable to the average growth rates over the period 2017-2040 presented in Table 3.
Source: ENV-Linkages model.

[14] Moreover, the subsidies to secondary metals in the *material fiscal reform* accelerate the substitution away from primary-based metals and therefore reduce the tax base of primary metal use.

Job reallocation induced by implementation of the material tax reform scenario

Although the overall impact on employment is neutral or slightly positive compared to the baseline across regions under the *material fiscal reform*, it is accompanied by job creations and destructions across sectors. For all regions, the total job reallocation is always much larger than the projected net-employment growth rates. Moreover, under this scenario more jobs are created than destroyed, with job creations ranging from 0.1% 0.3% and 0.2% of total employment in 2040 compared to baseline, corresponding to 0.8, 5.2 and 3.7 million of jobs in OECD countries, BRIICS and Rest of the World economies respectively. However, this trend is coupled with a significant number of jobs destructions.

The implementation of the *material tax reform* scenario provide extra incentives to shift output towards secondary metals and recycling sectors relative to the case of the *material tax only* scenario, and therefore boost jobs creation in these sectors. As a result, total job reallocations are higher in the former scenario than in the latter. A close study of the employment impact across sectors and countries is necessary to draw a complete picture and design targeted policies depending on country-specific economic structures.

4.2. Sectoral implications of the *material fiscal reform* scenario

At the aggregate level, the consequences of the implementation of *material fiscal reform* scenario on employment, output and real wages remain very limited. However, they mask large disparities across a small set of sectors that are heavily affected, either positively or negatively, by the policy package. Overall, employment gradually shifts from material intensive sectors (e.g. primary metals, construction & non-metallic minerals) towards less-material intensive sectors (e.g. secondary based metals and recycling) throughout both OECD and non-OECD countries (Figure 5). Moreover, this dynamic effect is amplified over time reflecting the gradual implementation of the reform over the period 2018-2040.

The changes in sectoral employment, output and wages relative to the baseline, that follow the implementation of the *material fiscal reform* scenario at the end of the implementation period in 2040, are presented in Figure 6. The recycling sector that receives purchase subsidies, and secondary-based metals that receive production subsidies, are stimulated as both directly benefit from the subsidies package. The simulations suggests that employment in secondary based materials and recycling will gradually increase by 27% and 48%[15] compared to baseline corresponding to 284,000 and 68,000 additional jobs in OECD countries, and by 26% and 42% amounting to 3,760,000 and 487,000 additional jobs in non-OECD economies in 2040. The rising demand of secondary materials and recycling combined with the reduction of their costs, boost output in these sectors.

In addition, employment and output could also been stimulated in other sectors, that produce substitutes for primary material based products. For example, the chemicals sector that produces plastics and other substitutes for raw material,[16] is projected to create over 13,000 jobs by 2040 compared to baseline within OECD economies on average.

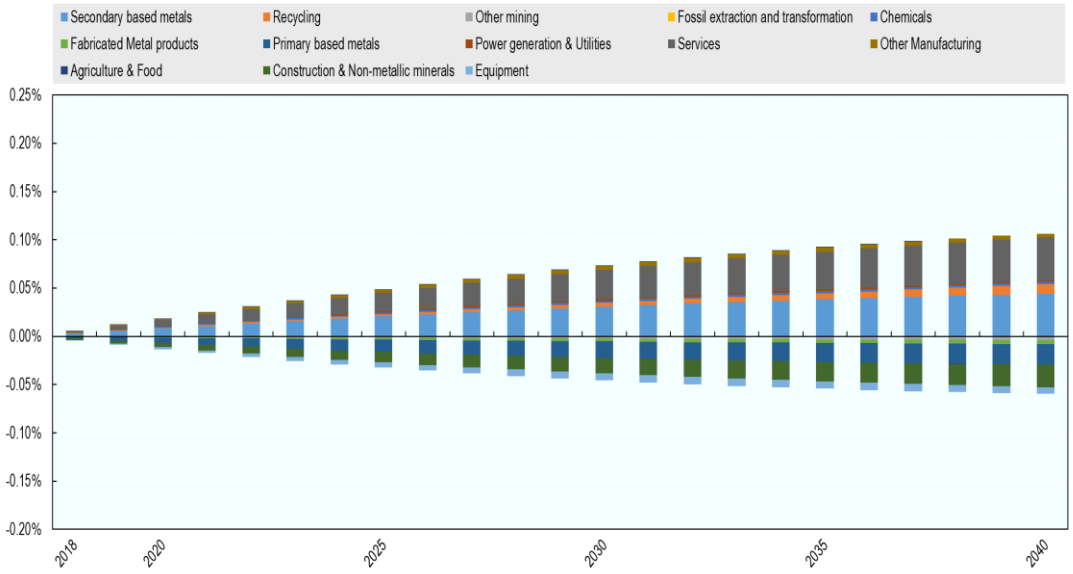
[15] See Figure C.7 for detailed results.

[16] Further studies on the substitutability of raw metals by chemical products and in particular on the share of plastics are necessary. The potential shift from raw materials to plastics could raise concerns about the relative environmental harm of plastics production and use, compared to metals.

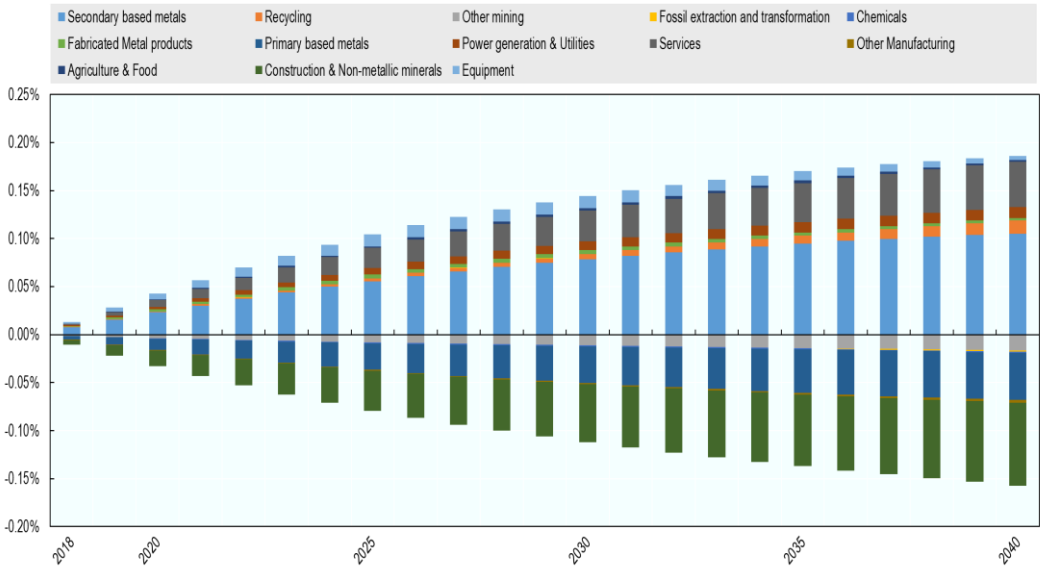
Figure 5. Dynamic of the sectoral composition of employment, *material fiscal reform* scenario

Changes w.r.t baseline as a percentage of total baseline employment, 2018-2040.

Panel A. OECD



Panel B. Non-OECD

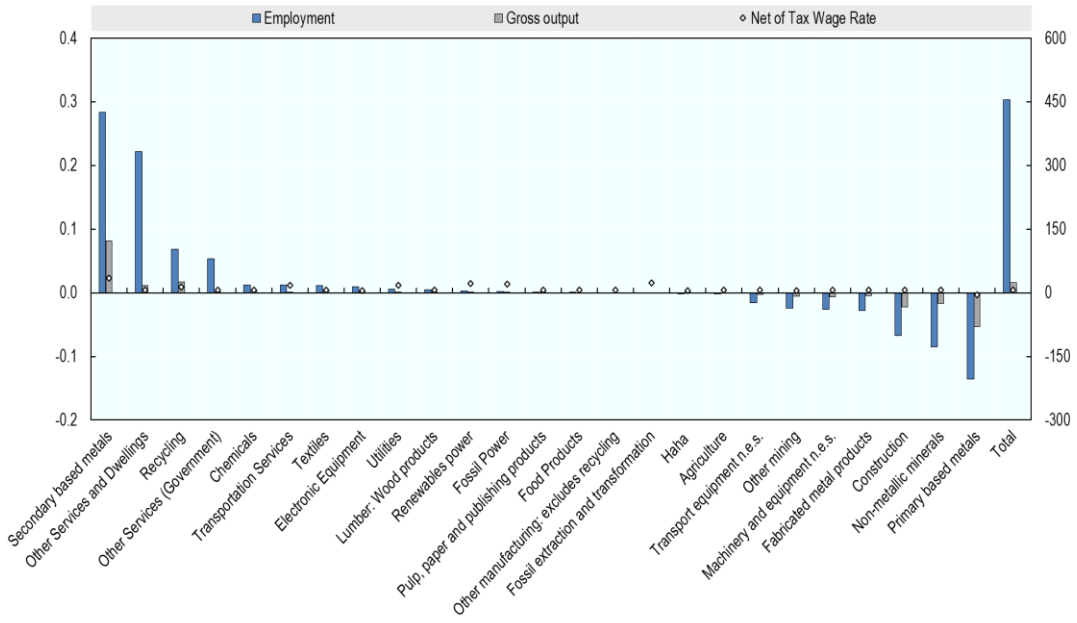


Note: In this figure, for simplicity sectors have been aggregated to 13 sectors (instead of 25 sectors presented in the rest of the graphs). The new aggregates include: Power generation & Utilities = Fossil Power + Renewable power + Utilities; Services = Transportation services, Other Services (Government), Other Services and Dwellings; Other Manufacturing = Electronic Equipment + Textiles + Lumber: Wood products + Other manufacturing: excludes recycling + Pulp, paper and publishing products; Equipment = Motor vehicles + Transport equipment n.e.s. + Machinery and equipment n.e.s; Agriculture & Food = Agriculture + Food products; Construction & Non-metallic minerals = Construction + Non-metallic minerals. The complete list of sectors in the model is reported in Table A.1 in Annex A.
Source: OECD ENV-Linkages model.

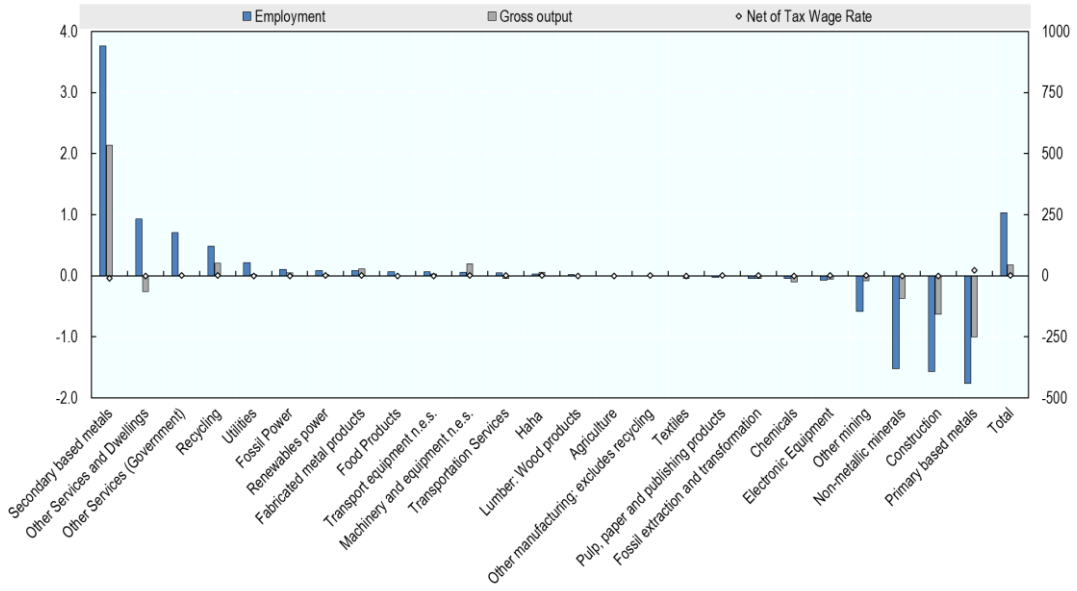
Figure 6. Sectoral employment and output levels, *material fiscal reform* scenario

Difference w.r.t. baseline, 2040 – Employment in Million jobs and Net of tax wage rate in USD (left axis), Gross output in Million USD (right axis)

Panel A. OECD



Panel B. Non-OECD



Source: OECD ENV-Linkages model.

By contrast, material intensive sectors experience reductions in output and employment compared to baseline. Across OECD countries, primary based metals, non-metallic minerals and other mining sectors would experience job destructions of approximately 135,000, 85,000 and 24,000 jobs respectively compared to baseline (corresponding to a

2.9%, 1.6% and 0.9% reduction compared to baseline) in 2040. The employment declines in these sectors are more pronounced in non-OECD economies where employment will be 5.5%, 4.1%, and 1.9 % lower compared to the baseline, amounting to 1,760,000, 1,521,000 and 585,000 job losses respectively in 2040. Primary based metals and non-metallic minerals are sectors directly impacted through the reduced sales (demand for primary metals) that follow the implementation of the materials tax.

Indirectly, sectors heavily dependent on primary materials that cannot yet be fully substitutable by secondary, recyclable or other materials, such as construction (heavily dependent on non-metallic minerals), and certain manufacturing sectors including machinery and equipment and electronic equipment (primary metals), are affected through the increased input prices for primary based products (non-metallic minerals, metal product, mining goods). Within OECD 93,000 jobs are projected to be lost in construction, and machinery and equipment combined in 2040, while in non-OECD economies, the contraction of the construction and electronics sectors would lead to a loss of 1,645,000 jobs in 2040.

The negative impact on material intensive industries is stronger in non-OECD economies, since these sectors represent a larger share of the economy and are more labour-intensive within non-OECD than OECD countries. Moreover, while large employment gains occur in the secondary material sector corresponding to approximately 8.7 million jobs, the policy package is only marginally beneficial for recycling and manufacturing sectors.

The impact of reform varies across sectors depending on their material-intensity. In fact, the increase in marginal costs of production following the taxes on primary materials, results in small GDP losses, which puts a downward pressure on labour demand and subsequently on wages. Wages follow output growth and adjust based on the productivity differentials across sectors, such as labour productive sector experience higher wage rises. In more detail, the more material-intensive a sector is, the more its aggregate production cost will increase. Since material costs cannot be outweighed by reduction in labour costs (wages), or be substituted with secondary materials, the higher the impact on output and consequently employment would be.

There are two main explanations for the overall magnitude of job reallocations. Firstly, RE-CE policies do not fundamentally reshape labour markets. Indeed, the heavily impacted sectors (material intensive sectors and sectors heavily dependent on primary material inputs) represent only a small share of total employment. Secondly, the responsiveness of labour supply is weakly affected by policies because the reform is budget neutral. A robustness analysis suggests that the level of material tax and the way extra revenues are recycled affect the reaction of employment to the material tax increases (see 0).

It is worth highlighting that the results hide job substitutions that take place where a shift in economic activity occurs across sectors from resource-intensive activities to more circular activities and whereby one activity replaces the other (e.g. from waste management to recycling, or from raw-material based to secondary-material based metal production) (UNEP et al., 2008[25]). This mechanism is not accounted explicitly within the CGE framework, rather the reported job creations and losses implicitly account for job substitutions. Laubinger, Lanzi and Chateau (2020[11]) discuss this mechanism in more detail.

4.3. Geographic dimension of employment effects of the *material fiscal reform* scenario

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 OECD found differences in labour market implications of climate and energy policies depending on regional characteristics (Chateau, Bibas and Lanzi, 2018[20]). More recently, (Dellink, 2020[30]) explored the consequences of RE-CE policies on international trade and current accounts considering different geographical coverages of a similar *material fiscal reform*.

Although the implementation of the *material fiscal reform* scenario has very limited impacts on job reallocations at the global level, it exhibits large variations across economies. In more detail, the sum of job destructions and job creations relative to baseline is lower than 0.5% of total global employment (Figure 7, Panel A), corresponding to a rotation of 18 million jobs globally compared to baseline in 2040 (Figure 7, Panel B). At the country level, job destructions and creations vary from 0.5% and 0.4% of total employment in Indonesia to 0.1% in most importers of primary metals such as the USA, corresponding to approximately 1.5 million and 343,000 jobs reallocations in Indonesia and the USA respectively in 2040.

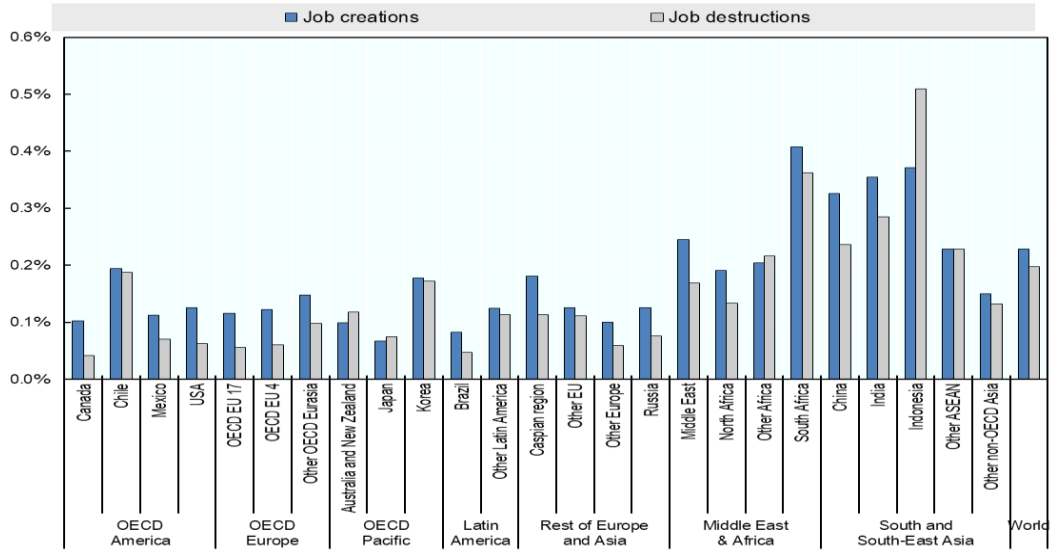
The effect across countries varies with their underlying economic structure – differences in material and labour intensities or differences in the importance of extracting sectors - and according to whether they are net exporters or importers of some of the taxed materials. The economic structure of countries differs because countries are at different stages of development and have different production specialisation and sectoral composition, due to local specificities, such as the non-uniform allocation of natural resources, and their underlying comparative advantages. Consequently, countries or regions where the domestic production is dominated by material-intensive sectors may experience larger effects (e.g. demand changes and necessary shifts in production modes) than those that have a less material-intensive economic structure.

In particular, the results suggest that countries with large extraction sectors (Indonesia, Australia and New Zealand) face a larger number of job destructions compared to job creations (Figure 7). Following the implementation of the *material fiscal reform*, material intensity drops sharply in these economies reflecting their high dependence on primary material sectors (Figure 8). The decrease in world demand for primary materials following the *material fiscal reform*, leads to a decrease in output, and depending on the capacity of the economies to diversify production towards other sectors, employment follows the same trend declining marginally by 0.1% in Indonesia and 0.02% in Australia and New Zealand (Figure 8). As in the long-run labour demand is exogenously determined, wages adjust to equilibrate labour demand and supply. Consequently, household income falls driven by a fall in labour income.[17]

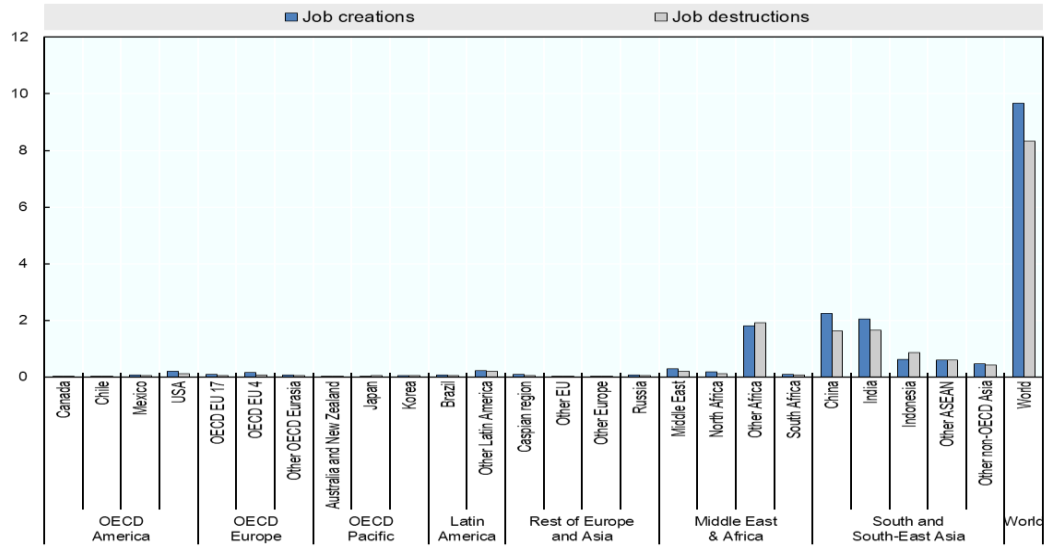
[17] Figure C.9 provides details on the changes of net of tax wages, as well as capital to labour share across countries and regions.

Figure 7. Total job destructions and job creations by region, *material fiscal reform* scenario

Panel A. Deviation from Baseline, % of total baseline employment



Panel B. Difference to baseline, 2040 (millions jobs)



Source: OECD ENV-Linkages model.

On the other hand, economies with manufacturing sectors that are also net importers of primary materials (Korea, Japan, China, USA, OECD EU 4), exhibit net employment gains of magnitude 0.1% compared to baseline in 2040 (Figure 8). In response to the output falls driven by material cost increases, production shifts towards less material intensive sectors. In more detail, the fiscal intervention results in a shift of capital from material and capital intensive sectors that tend to be more productive (manufacturing) towards less capital intense but less productive sectors and more labour intensive (services). Since services employ a high share of workers, the average impact on wages is positive. At the same time,

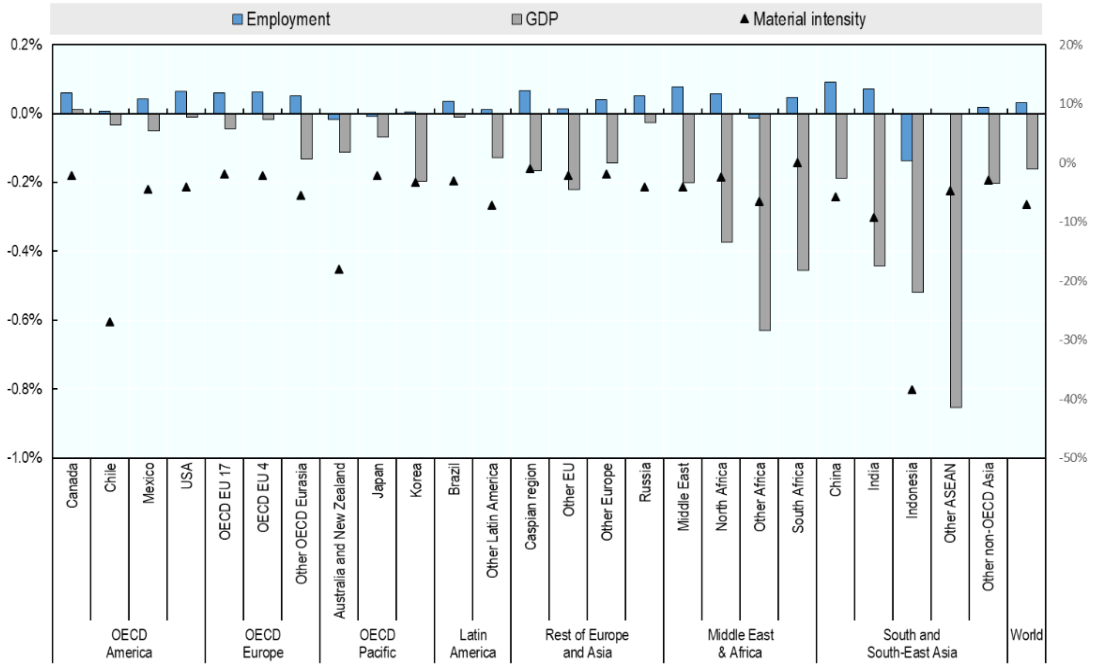
workers face a decrease in their capital income, which they compensate for by increasing working hours.

In interpreting the results, it is worth highlighting that in addition to difference in economic structures, the impacts vary across countries also due to differences in the tax level within their policy packages – by design the tax levels differ across countries to account for existing royalties and taxes (OECD, 2020, forthcoming[22]). Overall, the GDP and employment impacts of the *material fiscal reform* scenario are proportionally linked to the size of the average material tax rate. Thus, countries imposing lower tax levels may experience lower employment losses compared to a scenario where material tax would be uniform across countries (such scenario is discussed in (OECD, 2020, forthcoming[22]).

The progressive phasing out of primary materials will present particular challenges for countries heavily dependent on primary material extractions as they are generally characterised by weak economic diversification and extraction sectors often count for a large share of employment. This holds not only at country level but also within countries, at local or regional level, since mineral resources and thus mining and other primary activities (and the corresponding jobs) are concentrated in a few areas. In this situation, ensuring a just transition requires reducing primary material use while minimizing the impact on local economies and workers. For example, investments in green technologies and green business opportunities, could improve the competitiveness of existing firms, while, at the same time, by promoting new technologies and business models, they could help upgrade and diversify local economies and thus create new opportunities for workers (OECD, 2019[31]).

Figure 8. Changes in employment, GDP and material intensity by region: *material fiscal reform* scenario

Percentage changes w.r.t baseline in 2040.



Source: OECD ENV-Linkages model.

4.4. Partial geographical coverage of the *material fiscal reform*

Although the implementation of the policy at the global level would bear the highest environmental benefits, not all countries have an incentive to implement the *material fiscal reform*. In particular, net exporters of raw materials might be better off not introducing any material taxes, to gain competiveness and thus market share (against domestic producers), through the relative reduction in their production cost against competitors implementing the policy. Moreover, the small projected gains in employment make it challenging to raise RE-CE policies at the top of the political agenda. Policy makers might be concerned to lose political support if not all countries adopt the reform, in which case material use might increase in non-acting countries that benefit from a relative reduction in material prices. To address this issue, this section explores an illustrative scenario where only OECD countries implement the fiscal reform: the *OECD-only material reform* scenario, and discusses the aggregate and sectoral employment effects across both acting (OECD) and non-acting economies.

The partial implementation of the *material fiscal reform* will have limited macroeconomic impacts while curbing primary material uses substantially less than in the global scenario. At the global level, when only OECD economies implement the reform material use drops by only 1.1% with respect to the baseline, compared to a 7.2% fall in the global scenario (Table 7). The underlying reason is that material use increases in regions that are not implementing the policies and in particular, the largest increase of materials use in the baseline will occur in BRIICS countries.

Moreover, a so-called "rebound-effect" could be observed: non-acting countries increase their demand for primary materials (relative to baseline levels) when some acting countries implement policies, since the former benefit of lower international prices for these materials. Interestingly, across regions the partial scenario yields smaller employment gains in non-acting regions compared to the global scenario.

Table 7. Impact of the geographical coverage of policies on materials use, GDP and employment

Percent change in 2040 w.r.t. central baseline scenario.

	Scenario	Material use	GDP	Employment
OECD	OECD-only Material fiscal reform	-5.3%	0.0%	0.05%
	Global Material fiscal reform	-5.0%	0.0%	0.05%
BRIICS	OECD-only Material fiscal reform	0.2%	0.0%	0.00%
	Global Material fiscal reform	-9.5%	-0.3%	0.05%
Rest of the world	OECD-only Material fiscal reform	0.3%	0.0%	0.00%
	Global Material fiscal reform	-4.8%	-0.4%	0.01%
WORLD	OECD-only Material fiscal reform	-1.1%	0.0%	0.01%
	Global Material fiscal reform	-7.2%	-0.2%	0.03%

Source: OECD ENV-Linkages model.

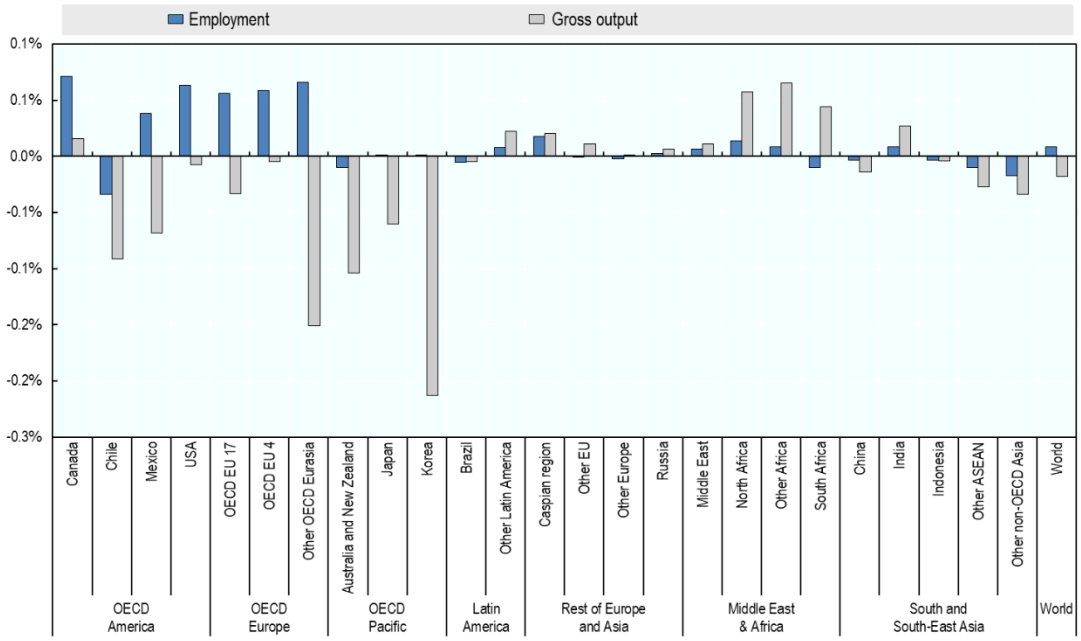
When only OECD countries adopt the *material fiscal reform*, employment rises in OECD with respect to baseline and more so than in the global scenario except for net exporters of primary materials (Figure 9). In particular, Chile, Australia and New Zealand lose competitiveness due to higher domestic primary metals prices, and as a result, output and marginal employment will be 0.03% and 0.01% lower compared to baseline respectively in 2040. On the other hand, OECD net importers of primary materials benefit from lower input costs (both secondary materials and recyclables, as well as imported primary

materials prices drop), and consequently output falls less while employment rises more than in the global scenario.

The employment impact varies across non-acting economies. Most non-OECD economies and in particular importers of primary materials, such as India and other Latin America, benefit from lower prices, boosting production and in turn employment beyond the baseline level. Others such as Other ASEAN, Other non-OECD Asia and South Africa, however, experience employment losses. This result is primarily driven by the reduced demand for primary materials from OECD economies, which shift towards secondary materials and recyclables.[18]

Figure 9. Changes in employment and output, by region: *OECD-only material fiscal reform*

Percentage changes w.r.t baseline, employment and gross output (left axis); gross wage (right axis), 2040



Source: OECD ENV-Linkages model.

At the sectoral level, the employment profile within OECD economies remains similar to the one under the global scenario with secondary materials and recycling sectors rising and primary materials falling. At the same time, the relative decline in primary metal prices in non-acting economies, boosts primary metal production in these regions (BRIICS and the Rest of the World) putting further downward pressures on the international prices of primary materials. As a result, since OECD countries are large importers of primary

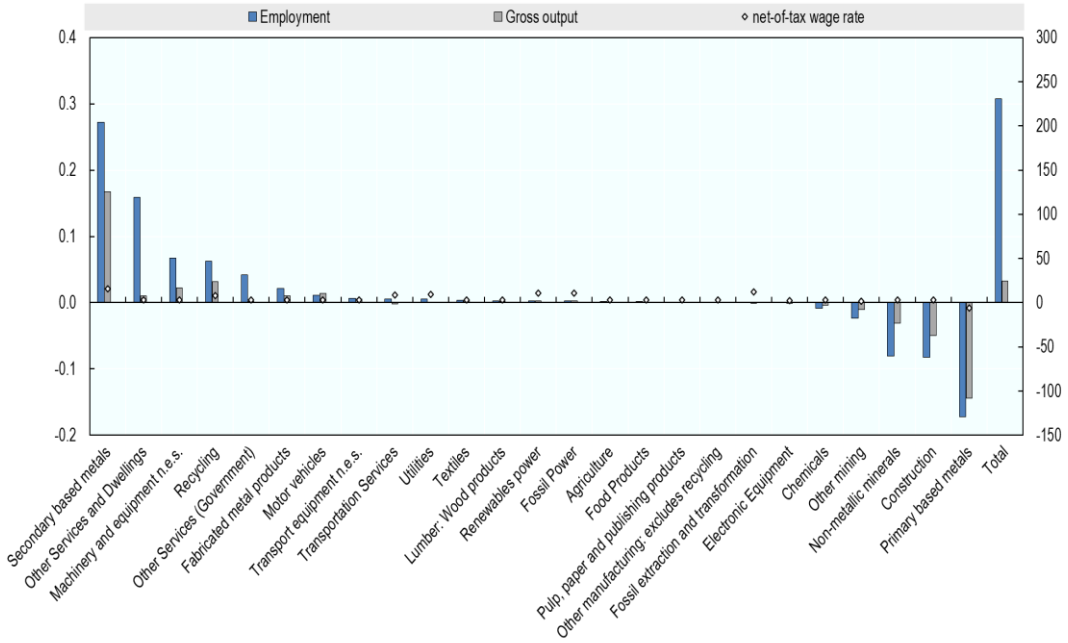
[18] When the material fiscal reform is only implemented in OECD countries, OECD economies shift demand from primary to secondary materials, while increasing demand for primary materials produced in non-OECD economies. The overall impact on OECD's primary metals demand depends on the relative prices between secondary materials within OECD economies and primary materials in non-OECD countries, and the substitutability of primary by secondary materials. Given the magnitude of subsidies and the economic structure of OECD economies, demand declines overall.

materials produced by their trade partners, they benefit from the fall in prices and supply increase, which in turn could stimulate OECD's production in certain manufacturing sectors in which they hold a comparative advantage (e.g. motor vehicles and transport equipment). For non-OECD economies, in addition to large employment boosts in material sectors (primary and secondary metals, recyclables and chemicals), output and employment in construction and services rise due to increased domestic demand (Figure 10).[19]

Figure 10. Change in sectoral composition of employment and output, *OECD-only material fiscal reform*

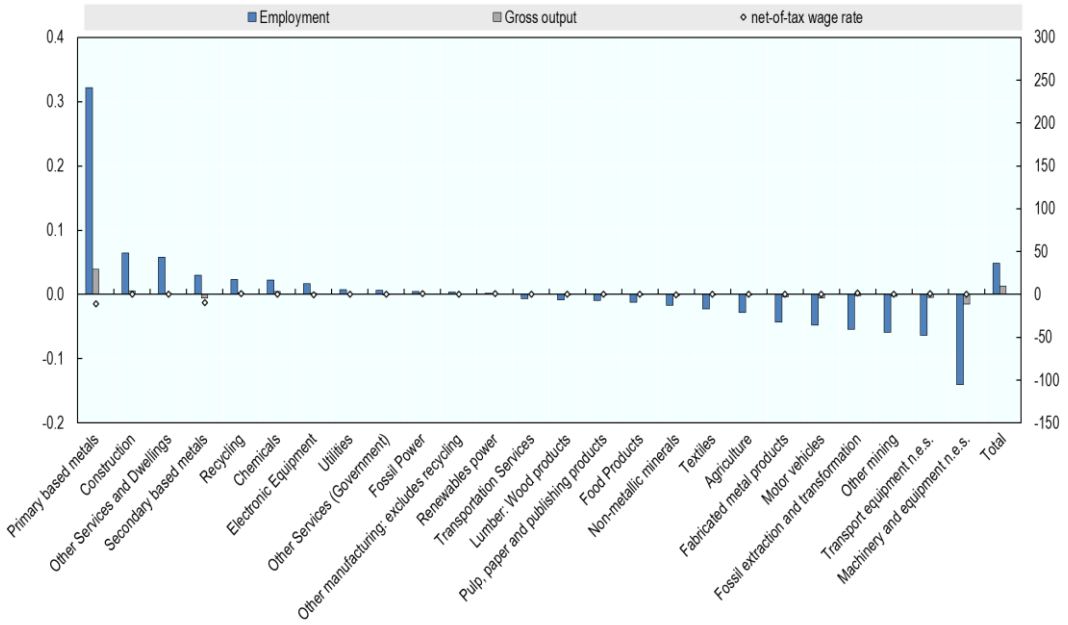
Difference to Baseline, 2040 - Million jobs (left axis), Million USD (right axis)

Panel A. OECD



[19] For detailed results including a distinction between Non-OECD exporters and importers of primary metals, see Figure C.11-Figure C.9 in Annex C.

Panel B. Non-OECD



Source: OECD ENV-Linkages model.

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

Structural changes of a 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.

Research on skill shifts and demands due to a transition to RE-CE economy is scarce and involves large uncertainties. In particular, quantitative (modelling) insights are still lacking (Laubinger, Lanzi and Chateau, 2020[11]). 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 and a comparison of skill composition of declining and emerging sectors in a circular economy.

Overall, the literature suggests that a transition towards RE-CE would most likely require to top-up skills instead of acquiring new skills. Previous work on green policies (Chateau, Bibas and Lanzi, 2018[20]) find that while the occupations in the different sectors vary widely, the broad level of skills required for the different jobs types tend to be more homogeneous. In the case of RE-CE policies, the European Commission (2018[16]) 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 RE-CE transition and vice versa. Moreover, the report highlights the importance of transversal skills as jobs will be evolving and workers will need to be adopting. In addition to ICT and transversal skills, the projected increase in service sectors could lead to an increase in highly skilled jobs (International Labour Organisation, 2018[17]). Finally, some of the studies attempt to define "green skills" demanded by circular economy job categories, such as recycling and waste (Cedefop, 2018[23]; Cedefop, 2012[32]). Such 'green skills' can be defined as "the knowledge, abilities, values and attitudes needed to live in, develop and support a sustainable and resource-efficient society" (Cedefop, 2010[33]) and include specific skills to modify products, services or operations due to RE-CE adjustments, requirements or regulations.

The current modelling analysis assumes a frictionless reallocation of labour across sectors and abstracts from additional employment frictions that could impose higher costs on the economy. Previous work on green policies (Chateau, Bibas and Lanzi, 2018[20]) used a static version of the ENV-Linkages model to investigate long-term labour market effects and how the distribution of workers across different job categories responds to the structural changes induced by decarbonisation policies. However, this approach is not possible under the dynamic version of the model, which in addition to long-term effects simulates the short and medium-term dynamics associated with RE-CE policies. The main reason is a practical one; to study the dynamics of the transition to resource efficient and circular economy, it is necessary to rely on projections of labour supply by job category. But not such projections exist at the global level or the sectoral level adopted in ENV-Linkages, and is beyond the scope of this paper to project these trends.

Instead of a CGE approach, an empirical approach is applied to obtain qualitative results. In particular, skills projections by (Cedefop, 2018[23]) at the European level are used, to draw a connection between the sectors affected by the *material fiscal reform* policy, and their corresponding occupational and skills shifts (see Annex E for more details). The available projections cover all OECD EU countries up to 2030.

The results suggest that following the implementation of the *material fiscal reform* within OECD economies at the sectoral level, there could be some skills reallocation across sectors (e.g. shifts of low skill workers from metal production to chemicals), but overall there will be an increase in demand for medium and high skills. In particular, at the sectoral level the top five "winners" and top five "losers" in terms of percentage employment changes as a result of *material fiscal reform* intervention, based on the projections by (Cedefop, 2018[23]), will demand medium and high skill workers by 2030, while demand for low skills is projected to decline. Thus, policies to support the acquisition of new skills for low skills workers might be helpful to ensure a just transition.

6. Discussion

This paper discusses the employment consequences of a stylised resource efficiency and circular economy policy package based on fiscal instruments, at the aggregate, sectoral and country levels. Overall, the net employment impacts are small but hide large disparities across countries and sectors. Such disparities depend heavily on material and labour intensity of individual sectors and the economic structure of the different economies. Primary material extraction sectors and material intensive sectors experience employment losses while secondary materials and recycling are the main beneficiaries of RE-CE policies.

There are certain limitations to the current analysis and thus the results should be interpreted with care. One important caveat is the lack of distinction between different skill sets. The effect on employment could vary with the type of jobs within a sector. For instance, workers might not be interchangeable because they are trained for different jobs. To reinforce the scope of this analysis, future work could focus on differentiating across different types of jobs.

The RE-CE policy package considered in this analysis is based on a material tax reform that aim at shifting consumption away from material primary use towards secondary materials and recyclables. Therefore, it does not take into consideration a wider set of policies and societal changes that can contribute to the RE-CE transition. For instance, 'softer' policies such as information campaigns, eco-design, labelling, and stimulating the sharing economy are not included in the analysis. Such policies can significantly alter consumption modes. Moreover, the scenario abstracts from the additional changes on production modes due to policies such as extended producer responsibility and green public procurement, as well as the effect of increased digitalisation and R&D investments in resource efficiency.

Moreover, the analysis does not account for changes in sectoral composition of production as a result of climate change within (rural versus urban areas) or across countries. Indeed, climate change related risks such as increased risks of natural disasters and increase in temperatures etc., could force the move of production across regions within/or across countries. Enhancing the analysis with country-sectoral risks assessment could provide a fuller picture. To our knowledge, no such database is available for the country coverage of this analysis.

Finally, reallocations across sectors would have distributional consequences. In the current analysis, distributional impacts are mostly focused on the wage income distribution and abstract from other sources of non-wage income and capital. Moreover, consumption and saving patterns are identical across workers. Including heterogeneity in the income sources and consumption and saving patterns could enhance the study of distributional impacts and help to assess how distributional changes can in turn affect the efficiency of resource efficiency and circular economy policies.

References

Aguiar, A., B. Narayanan and R. McDougall (2016), "An Overview of the GTAP 9 Data Base", *Journal of Global Economic Analysis*, Vol. 1/1, pp. 181-208, http://dx.doi.org/doi:dx.doi.org/10.21642/JGEA.010103AF. [36]

Bosello, F. et al. (2016), *Report on Economic Quantitative Ex-Ante Assessment of DYNAMIX Policy Mixes*, DYNAMIX European Commission. [14]

Cedefop (2018), *Cedefop Skills Forecast*, European Centre for the Development of Vocational Training, Thessaloniki, Greece, https://www.cedefop.europa.eu/en/events-and-projects/projects/skills-forecast. [23]

Cedefop (2012), *Green skills and environmental awareness in vocational education and training*, European Centre for the Development of Vocational Training, European Commission, Luxembourg. [32]

Cedefop (2010), *Skills for green jobs*, Thessaloniki, Greece, https://op.europa.eu/en/publication-detail/-/publication/6b5a1d04-1db7-4ee3-95b6-dc3d798fd2b7/language-en. [33]

Chateau, J., R. Bibas and E. Lanzi (2018), "Impacts of Green Growth Policies on Labour Markets and Wage Income Distribution: A General Equilibrium Application to Climate and Energy Policies", *OECD Environment Working Papers*, No. 137, OECD Publishing, Paris, https://dx.doi.org/10.1787/ea3696f4-en. [20]

Chateau, J., R. Dellink and E. Lanzi (2014), "An Overview of the OECD ENV-Linkages Model: Version 3", *OECD Environment Working Papers*, No. 65, OECD Publishing, Paris, https://dx.doi.org/10.1787/5jz2qck2b2vd-en. [19]

Chateau, J., A. Saint-Martin and T. Manfredi (2011), "Employment Impacts of Climate Change Mitigation Policies in OECD: A General-Equilibrium Perspective", *OECD Environment Working Papers*, No. 32, OECD Publishing, Paris, https://dx.doi.org/10.1787/5kg0ps847h8q-en. [21]

Davis, S. and J. Haltiwanger (1999), *Chapter 41 Gross job flows*, http://dx.doi.org/10.1016/S1573-4463(99)30027-4. [24]

Dellink, R. (2020), "The Consequences of a more resource efficient and circular economy for international trade patterns: A modelling assessment", *OECD Environment Working Papers*, No. 165, OECD Publishing, Paris, https://doi.org/10.1787/fa01b672-en. [30]

Dutch Ministry of Infrastructure and the Environment & Ministry of Economic Affairs (2016), *A circular economy in the Netherlands by 2050*, Dutch Ministry of Infrastructure and the Environment & Ministry of Economic Affairs, https://www.government.nl/documents/leaflets/2016/09/22/a-circular-economy-in-the-netherlands-by-2050. [7]

Ekins, P. et al. (2012), "Increasing carbon and material productivity through environmental tax reform", *Energy Policy*, Vol. 42, pp. 365-376, http://dx.doi.org/10.1016/j.enpol.2011.11.094. [12]

European Comission (2018), *Commission and its priorities - Towards a circular economy*, https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/towards-circular-economy_en (accessed on 9 July 2018). [4]

European Commission (2018), *Impacts of circular economy policies on the labour market*, https://publications.europa.eu/en/publication-detail/-/publication/fc373862-704d-11e8-9483-01aa75ed71a1/language-en/format-PDF/source-72385040. [16]

European Commission (2016), *Circular economy package Four legislative proposals on waste*, http://www.europarl.europa.eu/EPRS/EPRS-Briefing-573936-Circular-economy-package-FINAL.pdf (accessed on 9 July 2018). [8]

Eurostat (2018), "Population projections", *Eurostat (online data code: tps00002)*, http://ec.europa.eu/eurostat/web/products-datasets/-/tps00002 (accessed on July 2018). [35]

G20 (2017), *G20 Resource Efficiency Dialogue*, http://www.g20.utoronto.ca/2017/2017-g20-resource-efficiency-dialogue-en.pdf (accessed on 9 July 2018). [3]

G7 (2015), *Leaders` Declaration G7 Summit, 7-8 June 2015*, https://www.g7germany.de/Content/EN/_Anlagen/G7/2015-06-08-g7-abschluss-eng_en.pdf?__blob=publicationFile&v=3 (accessed on 9 July 2018). [2]

Groothuis, F. et al. (2016), *New Era. New Plan. Europe: A fiscal strategy for an inclusive, circular economy*, The Ex'tax Project Foundation, http://www.neweranewplan.com/wp-content/uploads/2016/12/New-Era-New-Plan-Europe-Extax-Report-DEF.compressed.pdf. [15]

Guillemette, Y. and D. Turner (2018), "The Long View: Scenarios for the World Economy to 2060", *OECD Economic Policy Papers*, No. 22, OECD Publishing, Paris, https://dx.doi.org/10.1787/b4f4e03e-en. [26]

Hatfield-Dodds, S. et al. (2017), "Assessing global resource use and greenhouse emissions to 2050, with ambitious resource efficiency and climate mitigation policies", *Journal of Cleaner Production*, Vol. 144, pp. 403-414, http://dx.doi.org/10.1016/j.jclepro.2016.12.170. [37]

International Labour Organisation (2018), *World Employment and Social Outlook 2018 – Greening with jobs*, http://www.ilo.org/publns. (accessed on 16 August 2018). [17]

Laubinger, F., E. Lanzi and J. Chateau (2020), "Labour market consequences of a transition to a circular economy: A review paper", *OECD Environment Working Papers*, No. 162, OECD Publishing, Paris, https://dx.doi.org/10.1787/e57a300a-en. [11]

McCarthy, A., R. (2018), "The macroeconomics of the circular economy transition: A Critical Review of Modelling Approaches", *OECD Environment Working Paper No. 130*, OECD Publishing, Paris, http://dx.doi.org/10.1787/af983f9a-en. [29]

Ministry of the Environment Finland (2017), *Action Plan for a Circular Economy*, https://www.ym.fi/en-US/The_environment/Circular_economy (accessed on 9 July 2018). [6]

Morgan, J. and P. Mitchell (2015), *Opportunities to tackle Britain's labour market challenges through growth in the circular economy*, Green Alliance, http://www.wrap.org.uk (accessed on 15 October 2019). [13]

Ngai, L. and C. Pissarides (2007), "Structural change in a multisector model of growth", *American Economic Review*, Vol. 97/1, pp. 429-443, http://dx.doi.org/10.1257/aer.97.1.429. [28]

OECD (2019), *Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264307452-en. [1]

OECD (2019), *Regions in Industrial Transition: Policies for People and Places*, OECD Publishing, Paris, https://dx.doi.org/10.1787/c76ec2a1-en. [31]

OECD (2018), *Job Creation and Local Economic Development 2018: Preparing for the Future of Work*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264305342-en. [27]

OECD (2012), *The jobs potential of a shift towards a low-carbon economy*, OECD Publishing, Paris, https://www.oecd.org/els/emp/50503551.pdf. [18]

OECD (2020, forthcoming), *Policy scenarios for a transition to more resource efficient and circular economy*, ENV/EPOC/WPIEEP(2019)11, OECD Publishing, Paris. [22]

Plan Climat (2017), *50 mesures pour une économie 100% circulaire 50*, https://www.ecologique-solidaire.gouv.fr/sites/default/files/Feuille-de-route-Economie-circulaire-50-mesures-pour-economie-100-circulaire.pdf (accessed on 9 July 2018). [9]

Thieriot, H. (2015), *China's Economy: Linear to Circular*, http://www.chinawaterrisk.org/resources/analysis-reviews/chinas-economy-linear-to-circular/ (accessed on 9 July 2018). [5]

UN (2017), "World Population Prospects: key findings and advance tables", https://esa.un.org/unpd/wpp/publications/Files/WPP2017_KeyFindings.pdf (accessed on 18 May 2018). [34]

UNEP et al. (2008), *Green Jobs: Towards decent work in a sustainable, low-carbon world*, http://adapt.it/adapt-indice-a-z/wp-content/uploads/2013/08/unep_2008.pdf (accessed on 8 January 2018). [25]

Wijkman, A. and K. Skånberg (2015), *The Circular Economy and Benefits for Society*, Winthertur, The Club of Rome, http://wijkman.se/wp-content/uploads/2015/10/The-Circular-Economy-and-Benefits-for-Society.pdf (accessed on 18 January 2018). [10]

Annex A. A brief overview of the modelling methodology

Multi-sectoral Computable General Equilibrium (CGE) models are the appropriate tool for quantifying the macroeconomic consequences of the transformation of the economy needed to improve resource efficiency and transition to a circular economy. CGE models can take into consideration both direct and indirect effects of the policies (e.g. through changes in trade and production structure), and thus quantify the overall economy-wide consequences of the policies.

The OECD's in-house CGE model, ENV-Linkages has been used extensively in the past to assess the consequences of environmental policies. One of the key advantages of the ENV-Linkages model is that it encompasses major economies in the world, as well as several regional groups that allows for a global analysis (see details on table A.1). This ensures that all quantitative analyses will be directly relevant for both OECD countries and key emerging economies, including China, India, Indonesia, South Africa and Brazil. The multi-sectoral nature of the model also allows for detailed insights into the consequences of policy reform on the mining and industrial activities, and thus provides key indicators of the consequences for main policy objectives such as material intensity and sectoral performance. In this report, 60 materials linked to 55 sectors and 43 commodities are considered (see details on Table A.1).

In order to provide in-depth analysis of the macroeconomic consequences of circular economy enabling policies, these modelling tools have been enhanced by linking physical material flows to specific economic activities and integrating essential elements of a circular economy, not least an explicit representation of the use of secondary inputs as substitutes for primary resource use (OECD, 2019[1]). This provides internally consistent and globally connected policy scenarios for primary and secondary materials use and their economic drivers as they evolve over time, and the main sectors and materials where resource efficiency and circularity policies have an impact.

Material flows are linked to the economic flows at the detailed sectoral level. The dataset on physical material flows from the International Resource Panel (UNEP, 2018) is used as the basis for the projection of primary material extraction. The basic principle for linking is that physical flows (materials use in tonnes) for each of the 60 materials is attached to the corresponding economic flow (materials demand in USD). A coefficient of physical use per USD of demand is calculated and used to project materials use to 2060. For a detailed discussion on the modelling and splitting of the underlying GTAP database to include primary metals, secondary metals and recyclables, please refer to Chapter 2 in OECD (2019[1]).

Labour market functioning in ENV-Linkages: assumption of fully flexible labour markets

The modelling framework assumes perfect mobility of workers across sectors. Implicitly, all workers are uniform, in terms of inherent skills, and all job categories across production sectors are interchangeable. Consequently, at equilibrium, if sectoral productivity and production process across sectors were identical the wage rates would have been identical across job categories, and equal to average wage rate. In this framework, difference in production structure and labour productivity imply that sectoral wage rates are different and are more or less reactive to a policy shock.

This fully flexible labour market assumption implies that following the implementation of a policy, the labour market clears such that aggregate (and sectoral) wage adjusts to balance total labour supply by households and total labour demand by firms. In addition, the model assumes that households adjust their labour supply with the level of the net-of tax-wage income. This underlying assumption is relatively conservative and supposes that total employment increase by 0.15% when net-wage income increases by 1% relative to the baseline trajectory.

Following the implementation of a policy such as RE-CE policies, the assumption of a fully flexible labour market implies that job reallocations across economic sectors are "costless" and take place instantaneously in response to any change of relative wages across sectors until the relative wages are once again equal to their relative marginal labour productivity, under the new economic conditions. However, since labour productivity is different across sectors the change in labour demand across two sectors following a policy implementation, is not strictly proportional to output changes across these two sectors.

Table A.1. Sectoral aggregation of ENV-Linkages

Agriculture, Fisheries and Forestry	Manufacturing
Paddy Rice	Food Products
Wheat and Meslin	Textiles
Other Grains	Wood products
Vegetables and Fruits	Chemicals
Oil Seeds	Pulp, Paper and Publishing products
Sugar Cane and Sugar Beet	Non-metallic Minerals
Fibres Plant	Fabricated Metal products
Other Crops	Electronics
Cattle and Raw Milk	Motor Vehicles
Other Animal products	Other Transport Equipment
Fisheries	Other Machinery and Equipment
Forestry	Recycling
Non-manufacturing Industries	Iron and Steel - Primary
Coal extraction	Iron and Steel – Secondary
Crude Oil extraction	Aluminium – Primary
Natural Gas extraction	Aluminium – Secondary
Other Mining	Copper – Primary
Petroleum and Coal products	Copper – Secondary
Gas distribution	Other Non-ferrous Metals – Primary
Water Collection and Distribution	Other Non-Ferrous metals – Secondary
Construction	Other Manufacturing
Electricity Transmission and Distribution	**Services**
Electricity Generation (8 technologies)	Land Transport
Electricity generation: Nuclear Electricity; Hydro (and Geothermal); Solar; Wind; Coal-powered electricity; Gas-powered electricity; Oil-powered electricity; Other (combustible renewable, waste, etc.).	Air Transport
	Water Transport
	Business Services
	Other Services (incl. Government)

Table A.2. ENV-Linkages model regions

Macro regions		ENV-Linkages countries and regions	Most important comprising countries and territories
OECD	OECD America	Canada	Canada
		Chile	Chile
		Mexico	Mexico
		USA	United States of America
	OECD Europe	OECD EU 17	Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Ireland, Luxembourg, Netherlands, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden
		OECD EU 4	France, Germany, Italy, United Kingdom
		Other OECD Eurasia	Iceland, Israel[1], Norway, Switzerland, Turkey
	OECD Pacific	Australia and New-Zealand	Australia, New-Zealand
		Japan	Japan
		Korea	Korea
Non OECD	Other America	Brazil	Brazil
		Other Latin America	Other non-OECD Latin American and Caribbean countries
	Eurasia	Caspian region	Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
		Other EU	Bulgaria, Croatia, Cyprus[2], Latvia, Lithuania[3], Malta, Romania
		Other Europe	Albania, Andorra, Belarus, Bosnia and Herzegovina, Gibraltar, Former Yugoslav Rep. of Macedonia, Rep. of Moldova, Montenegro, San Marino, Serbia, Ukraine
		Russia	Russian Federation
	Middle East and Africa	Middle East	Bahrain, Iraq, Islamic Rep. of Iran, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, United Arab Emirates, Syrian Arab Rep., Yemen
		North Africa	Algeria, Egypt, Libya, Morocco, Tunisia, Western Sahara
		Other Africa	Sub-Saharan Africa excl. South Africa
		South Africa	South Africa
	Other Asia	China	People's Rep. of China, Hong Kong (China)
		India	India
		Indonesia	Indonesia
		Other ASEAN	Brunei Darussalam, Cambodia, Lao People's Dem. Rep., Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste, Viet Nam
		Other non-OECD Asia	Other non-OECD Asian and Pacific countries

Notes:

1. The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

2. Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

3. Lithuania has become member of the OECD in July 2018. The regional aggregation of the model could not be revised to reflect this.

Table A.3. Average material taxes by region in 2040, Policy scenarios

		Mining Taxes in 2017 [a]	Average additional tax rates in 2040 (2017 USD/tonnes)		Average subsidy rates in 2040 [b]
			Non-metallic minerals	primary Metals	Secondary metal productions
OECD America	Canada	0.7%	2.8	9.7	13.4%
	Chile	3.7%	1.1	4.2	9.7%
	Mexico	0.9%	2.5	8.0	22.6%
	USA	0.2%	5.3	17.4	21.5%
OECD Europe	OECD EU 17	0.3%	3.6	10.6	14.3%
	OECD EU 4	0.1%	5.3	15.1	5.1%
	Other OECD Eurasia	0.2%	3.9	10.3	16.3%
OECD Pacific	Australia & New Zealand	3.5%	3.2	10.0	25.3%
	Japan	0.1%	5.0	15.4	1.6%
	Korea	0.1%	7.1	19.8	7.6%
Other America	Brazil	1.2%	3.2	7.7	13.7%
	Other Latin America	0.7%	2.8	9.6	36.2%
Eurasia	Caspian region	1.2%	0.7	2.4	30.5%
	Other EU	0.2%	5.3	20.5	21.2%
	Other Europe	0.8%	2.8	7.0	11.4%
	Russia	0.1%	6.0	18.2	6.7%
Middle East & Africa	Middle East	0.5%	4.3	13.6	26.6%
	North Africa	1.2%	2.8	7.7	50.3%
	Other Africa	1.4%	3.6	13.9	30.6%
	South Africa	1.0%	0.7	2.2	38.6%
Other Asia	China	1.2%	4.3	11.1	19.2%
	India	0.0%	7.1	15.7	23.3%
	Indonesia	1.2%	2.5	8.4	34.4%
	Other ASEAN	0.3%	3.0	17.7	49.4%
	Other non-OECD Asia	0.6%	4.3	12.6	18.3%

Note:
[a] Mining taxes comprise specific mining tax ("royalty") on mineral exploitation (excluding fossil fuels) and if relevant specific mining production taxes. The general income tax and production tax that applies to all firms in all sectors are excluded from this calculation. Mining tax revenues are very fluctuating and highly depend of international prices of natural resources.
[b] The average subsidy to secondary metal productions are endogenously calculated in the "material tax reform" scenario to balance government budget, in a neutral way.
Source: Authors' calculations based on the GTAP database (version 9), the OECD's "Environmentally related tax revenue" database and the OECD ENV-Linkages model.

Annex B. Detailed baseline projections results

This Annex includes the results underlying the projections of population and GDP based on the analysis presented in (OECD, 2019[1]).

Detailed population projections and the ageing process

Global population growth is projected to slow down. This global trend results from a decrease in population growth in all regions, including both OECD and non-OECD countries (see Table B.1).

Table B.1. Population by region, historical and projected trends, Baseline scenario

	Average annual growth		Percentage of world total	
	1980-2020	2020-2060	2000	2060
World	*1.4%*	*0.7%*	*100%*	*100%*
Japan	0.2%	-0.5%	2.1%	1.0%
Korea	0.8%	-0.2%	0.8%	0.5%
OECD Oceania countries	1.3%	0.8%	0.4%	0.4%
Canada	1.1%	0.5%	0.5%	0.4%
Chile	1.3%	0.3%	0.2%	0.2%
Mexico	1.7%	0.5%	1.7%	1.6%
United States of America	0.9%	0.5%	4.6%	4.0%
European Union OECD 17 Smaller countries	0.3%	-0.2%	3.1%	1.8%
European Union OECD 4 Larger countries	0.3%	0.0%	4.3%	2.7%
European Union Non OECD countries	-0.4%	-0.7%	0.7%	0.3%
Other OECD Eurasian countries	1.5%	0.5%	1.3%	1.3%
Non-EU Eastern Europe countries	-0.2%	-0.7%	1.3%	0.6%
Russia	0.1%	-0.3%	2.4%	1.2%
Caspian countries	1.2%	0.5%	1.2%	1.1%
Middle East countries	2.6%	1.1%	2.7%	3.8%
North African countries	1.9%	1.0%	2.4%	2.9%
Other African countries	2.8%	2.2%	10.2%	25.0%
South Africa	1.7%	0.4%	0.7%	0.7%
Other ASEAN countries	1.6%	0.5%	5.2%	4.7%
China	0.9%	-0.2%	20.9%	12.6%
Indonesia	1.5%	0.5%	3.5%	3.2%
India	1.7%	0.6%	17.3%	17.2%
Other Developing Asia countries	2.0%	0.8%	6.0%	6.9%
Brazil	1.4%	0.2%	2.9%	2.3%
Other Latin America countries	1.5%	0.5%	3.8%	3.6%

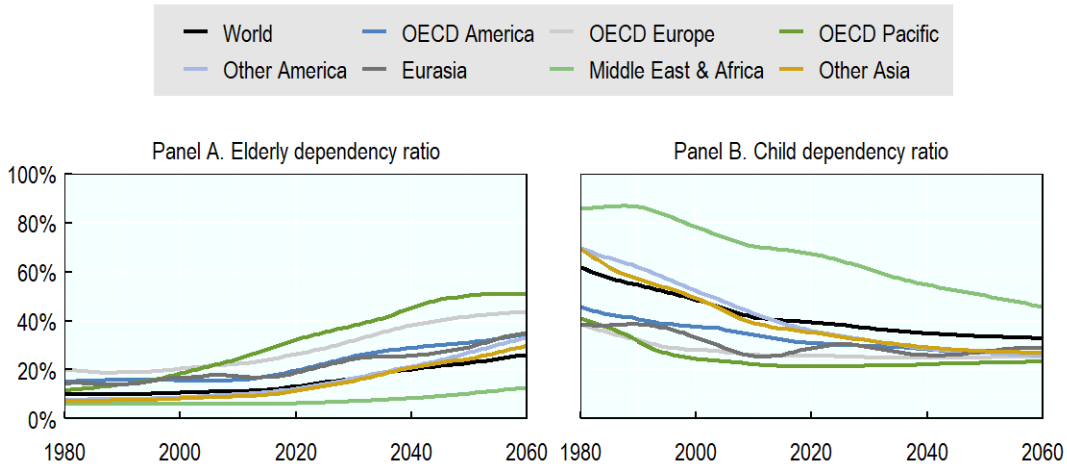
Source: Own calculation from The World Population Prospects: 2017 Revision (UN, 2017[34]) and Eurostat (Eurostat, 2018[35]).

The slowdown in population growth is mostly due to ageing. The ageing process is ongoing at both extremities of the age pyramid (i.e. children and seniors). Indeed Panel A, Figure B.1 shows that the senior population is projected to increase faster in the 2020-2030 period than in the past, due to the ageing of the numerous baby-boomer cohorts. After 2030, the increase is still substantial but at a slower pace.

The share of children in total population is projected to decrease everywhere (Panel B, Figure B.1). As a result, there will be fewer and fewer new entrants to the active population in the next decades. A more detailed analysis shows that the total number of children is

going to decrease in 2060 relative to the actual level in most countries. Only Middle East & Africa, North America and Oceania project an increase of this population over the next four decades.

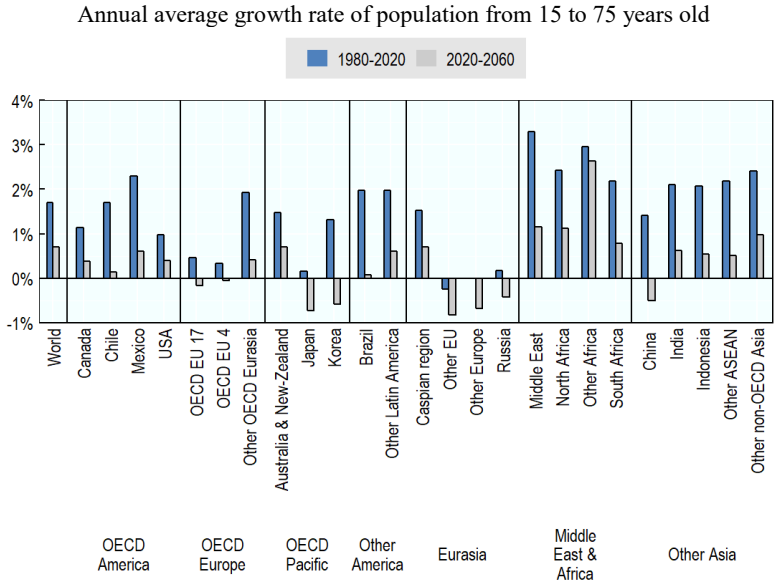
Figure B.1. Shares of children and elderly in total population, Baseline scenario



Note: *Elderly dependency ratio* is population over 65 years old to population between 15 and 65 years old; *Child dependency ratio* is population younger than 15 years old to population between 15 and 65 years old.
Source: Own calculations from The World Population Prospects: 2017 Revision (UN, 2017[34]).

The increasing share of elderly people and the decline in the number of children lead to the projected decrease (Figure B.2) in growth rate of the working-age population for the period 2020-2040 (relative to the period 1980-2020.

Figure B.2. Growth of the working age population, Baseline scenario



Source: Own calculation from The World Population Prospects: 2017 Revision (UN, 2017[34]).

In the last 40 years globally, the working age population accounted for almost 1.7% increase per year; in the next four decades, the same indicator is projected to fall to a modest 0.7%/year, this slow down for working age population is therefore more pronounced than that of the total population. Most European countries, Japan and Korea, currently observe a decline in their working age population, and this decline is projected to accelerate in the coming years, and then stabilize around 2040 at about -0.25% per year. Projections for China and Russia exhibit a similar profile, while for OECD America and Oceania, the growth is 0.4% per year. In contrast, many African countries observe a 2% growth per year in active population. Projected profiles for other countries are close to the world average.

Detailed GDP growth and assumptions about drivers of GDP per capita

GDP growth is projected to stabilise at global level (see Table B.2). However, this is the result of uneven changes in GDP growth in different regions. In most OECD countries GDP growth will remain stable or decline in the long-term. In emerging economies growth will be high in the short-term and then decrease in the longer term. In many developing countries instead GDP growth will increase in the longer run.

For making long-term projections, GDP per capita growth is a common reference indicator to study economic trends. However, it does not explain the sources and the drivers of economic growth. It is therefore worthwhile to isolate the underlying drivers of GDP per capita. A first step to explain GDP per capita consists in comparing projected trends in employment rates (measured as the share of employment in total population) and in labour productivity (measured as GDP per person employed). A second step consists in isolating the internal drivers of changes in employment rates and then the drivers of changes in GDP per worker (which includes the effects of other drivers of growth, such as capital deepening).

Table B.2. Real GDP by region, historical and projected trends, Baseline scenario

	Average annual growth		Percentage of world total	
	1990-2020	2020-2060	2000	2060
World	3.5%	2.8%	100%	100%
Japan	1.0%	1.2%	6.7%	2.1%
Korea	4.9%	1.7%	1.6%	1.1%
OECD Oceania countries	3.1%	2.7%	1.2%	1.0%
Canada	2.5%	1.9%	1.9%	1.0%
Chile	4.6%	2.0%	0.4%	0.3%
Mexico	2.3%	2.5%	2.6%	1.7%
United States of America	2.5%	1.9%	21.2%	10.6%
EU - OECD 17 Smaller countries	2.3%	1.7%	8.1%	3.9%
EU - OECD 4 Larger countries	1.5%	1.7%	14.4%	5.8%
EU - Non OECD countries	2.9%	2.1%	0.8%	0.6%
Other OECD Eurasian countries	3.9%	2.9%	2.6%	2.8%
Non-EU Eastern European countries	0.8%	3.1%	0.8%	0.7%
Russia	-0.4%	0.8%	3.1%	1.3%
Caspian countries	3.0%	3.7%	0.5%	1.3%
Middle East countries	4.0%	2.9%	4.1%	5.0%
North African countries	3.3%	4.2%	1.9%	3.1%
Other African countries	4.4%	5.3%	1.7%	6.5%
South Africa	2.7%	2.7%	0.7%	0.6%
Other ASEAN countries	5.2%	3.6%	2.9%	5.2%
China	8.9%	2.3%	7.8%	16.7%
Indonesia	5.1%	3.6%	1.9%	3.5%
India	7.0%	4.4%	4.4%	16.4%
Other Developing Asian countries	4.8%	4.0%	2.3%	4.4%
Brazil	5.6%	1.8%	3.1%	1.7%
Other Latin America countries	3.6%	2.8%	3.5%	3.0%

Source: ENV-Growth model (OECD Environment Directorate) and OECD Economics Department (Guillemette and Turner, 2018[26]).

Projections of employment rates

Employment rates are projected to change in the future according to three main components: (i) the structure of the population (defined as the share of working age population in total population), (ii) the labour participation rate (defined as the share of active population to working age population) and (iii) the unemployment rate (the share of unemployed to active population).

Figure B.3 indicates a negative contribution of employment rates to GDP per capita (diamond mark in the figure) at world level (last column), over the projection period (2015-2030). Looking more deeply at the results shows that the unemployment rates are projected to decline or remain constant in almost all regions but Africa, Middle East and in some part of Asia and Latin America.

The bars in Figure B.3 show the contributions of the three components to employment rate. For ageing countries like OECD countries and Russia, the decline in employment rates is largely but not entirely attributable to the changes in population structure (e.g. the reduction of the size of working age population to total population). For these same countries, the participation rates are increasing (mostly women joining the workforce), and therefore partly offset the effect of ageing.

In emerging and developing economies characterized by a dynamic growth of both population and income (like many African economies), both changes in population structures and employment contribute positively to the increase in employment rates. For

Asian countries, no common pattern could be highlighted. China, for example, is characterized by decrease in both the contributions of the population structure and the participation rates. Indonesia is projected to face exactly the opposite situation of both components growing, while for India the decline in the participation rate component overcomes the positive impact of the population structure component.

Figure B.3. Changes in the drivers of employment rates, Baseline scenario

Annual average growth rate of employment to total population, 2015-2060

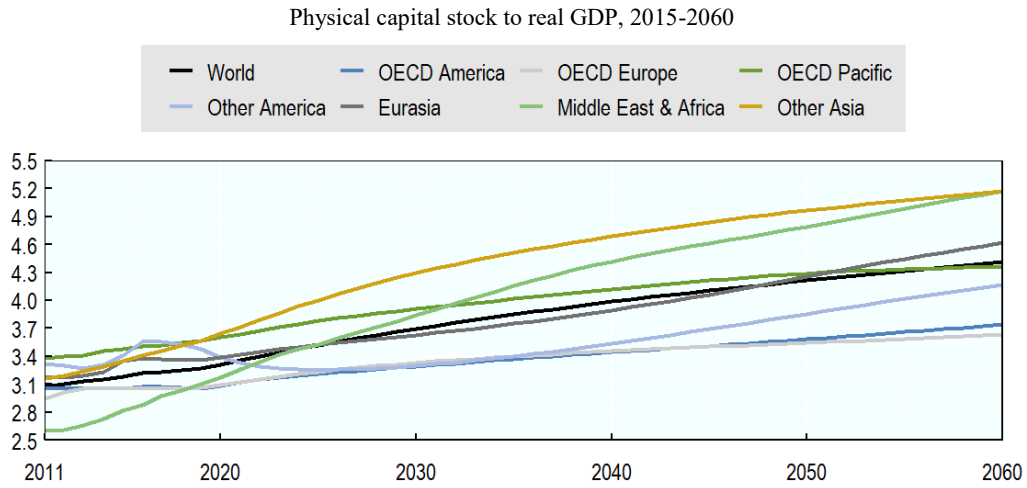
Note: The changes in the employment rate (ER) is mechanically decomposed in the sum of three components: (i) changes in the population structure, defined as the share in working-age population in total population (WR); (ii) changes in labour participation rate (PR); (iii) changes in unemployment rate (UR). Hence, Δ (ER) / ER = Δ (PR) / PR + Δ (WR) / WR – [UR/(1-UR)]. Δ (UR) / UR.
Source: ENV-Growth model (OECD Environment Directorate) and OECD Economics Department (Guillemette and Turner, 2018[26]).

Projections of Labour productivity

In the long run, labour productivity, i.e. GDP per worker, accrues from labour efficiency improvements, as well as *capital deepening*, including land and other natural resources use. Over the projection period, the productive capital stock follows projected investment in physical capital (such as building, machines and equipment). The latter is mostly driven by savings (where demographic changes play a central role), but not only, since the assumptions about current account imbalances include partly dissociating investment from national savings (see details in Figure 3.A.5 of the "Global Material Resources Outlook to 2060" (OECD, 2019[1])).

As shown in Figure B.4 the projection framework assumes that in the long run the physical capital stock and the GDP will increase at the same pace. In the medium run capital generally increases faster than GDP. This is either because it is necessary to invest in new capital to match the growth in labour input (in regions where employment is growing fast) or to adjust to the gains of technical progress (e.g. robotization, AI, etc.).

Figure B.4. Evolution of capital to GDP ratios, Baseline scenario



Source: ENV-Growth model (OECD Environment Directorate).

Annex C. Detailed modelling results on the baseline and policy simulations

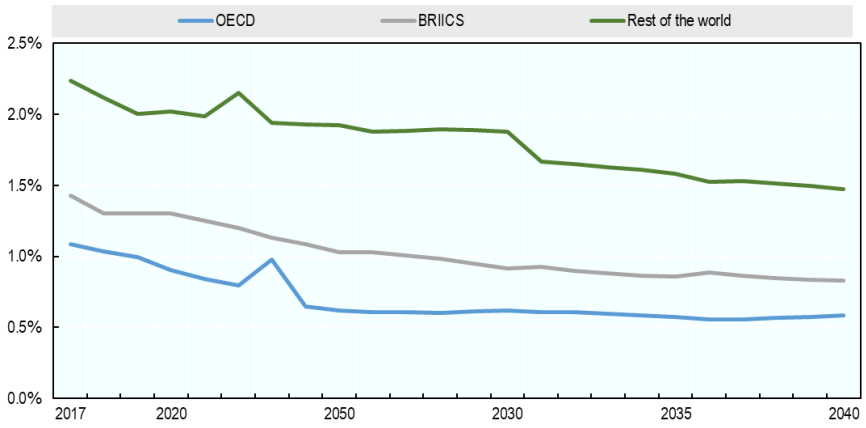
This Annex includes further detailed results underlying the baseline, *material tax only*, *material fiscal reform* and *OECD-only material fiscal reform* simulations. Baseline Projections.

Projections of job reallocations by large region

Job reallocations across regions are expected to decline over time as economies increasingly transition to a service-based economy with less structural change involved. Figure C.1 shows the total job reallocations as a percentage of total employment across aggregate regions for the period 2017-2040. In the long run, in ageing economies (OECD and BRIICS) job destructions as percentage of total employment are progressively less offset by job creations.

Figure C.1. Total job reallocations across regions in baseline scenario

Percentage of total employment.



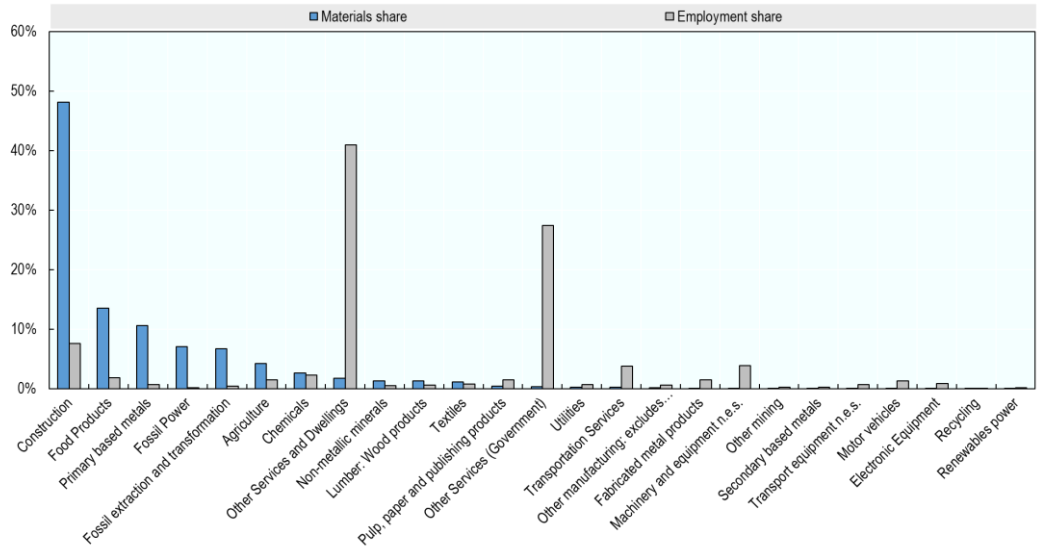
Source: OECD ENV-Linkages model.

Material use and employment by aggregate sector in 2017

Based on 2017 data (the last year before the implementation of the policy reforms), sectors that are heavily dependent on materials such as renewable power, fossil extraction and transformation, and construction, employ a small share of labour.

Figure C.2. Material use and employment shares in 2017

Employment and material use shares to total global employment and material use respectively



Source: Author calculation, based on GTAP database (2016[36]) and UNEP-IRP global material flows database

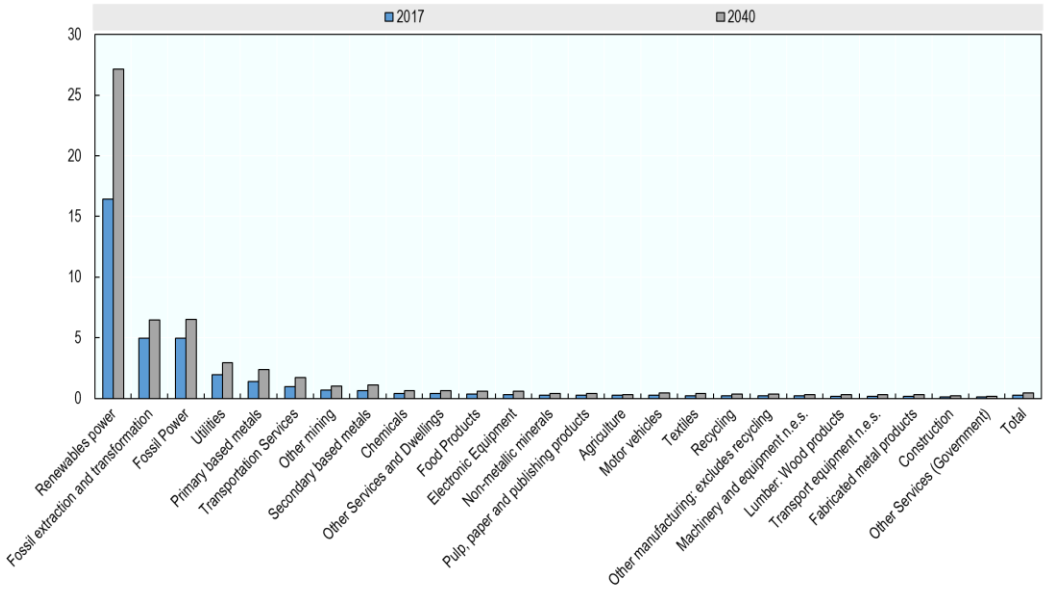
Projected Capital and Labour intensity by aggregate sector

Figure C.3 depicts the capital to labour ratio, which are highest in renewable energies, fossil and primary metals across both OECD and non-OECD economies. The extent to which sectors rely on labour force determines which sectors are most sensitive to changes in labour market conditions. Thus, the impacts of RE-CE policies, which will be stronger on primary materials (capital-intensive sectors), would imply only a moderate effect on overall labour market. These same policies are also likely to induce a shift of labour from material intensive sectors towards less material intensive and more-labour-intensive sectors. This holds particularly for non-OECD countries that, as indicated by the 'Total' column, have a higher capital-to-labour ratio than OECD countries.

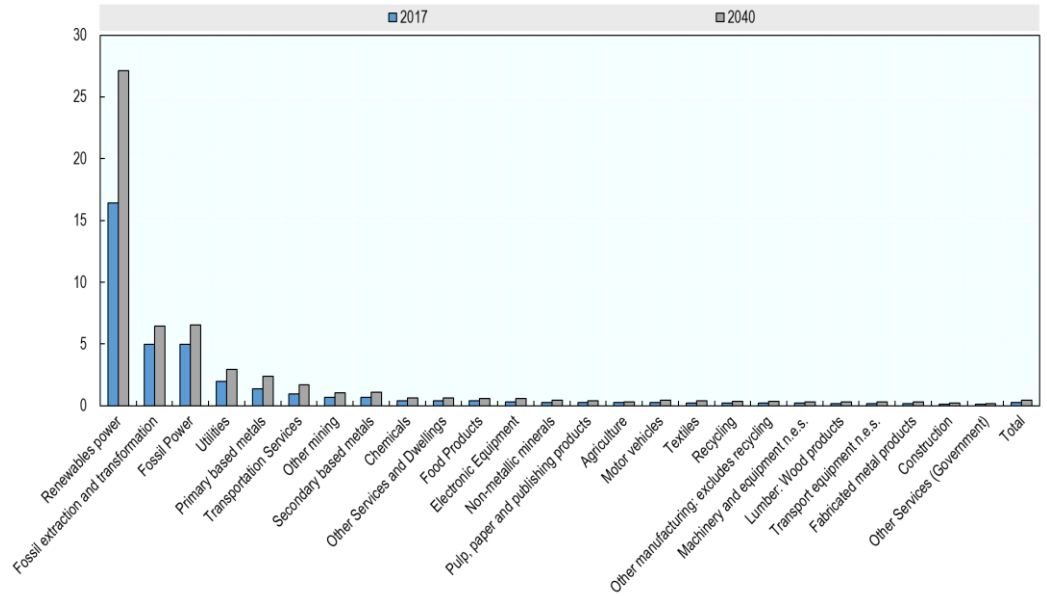
Figure C.3. Capital to Labour intensity per sector, OECD

Capital stock per worker, 2017 and 2040.

Panel A. OECD countries



Panel B. Non-OECD countries



Note: The capital to labour ratio is measured as the total installed capital stock (in thousands of 2011 USD) divided by total employment (millions of persons).
Source: OECD ENV-Linkages model.

Projected labour productivity by aggregate sectors

Labour productivity is projected to rise across sectors except for Fossil extraction and transformation. The increase in labour productivity varies across sectors depending on their projected technological changes.

Table C.1. Labour productivity in 2017 and 2040, Baseline scenario

Value Added at market prices per person employed

Panel A. OECD

	2017	2040	Change in Labour productivity 2017-2040
Renewables power	2011691	3124667	55%
Fossil extraction and transformation	1152781	960393	-17%
Fossil Power	712265	942122	32%
Utilities	329863	458709	39%
Primary based metals	313706	578348	84%
Transportation Services	283773	574897	103%
Secondary based metals	216071	344916	60%
Other mining	138827	188536	36%
Chemicals	94278	153923	63%
Other Services and Dwellings	90012	127998	42%
Food Products	89594	127363	42%
Electronic Equipment	85273	146117	71%
Agriculture	82791	105521	27%
Non-metallic minerals	80250	138123	72%
Total	77918	111171	43%
Motor vehicles	76807	132283	72%
Pulp, paper and publishing products	72906	110428	51%
Textiles	72791	110221	51%
Machinery and equipment n.e.s.	69298	104809	51%
Fabricated metal products	66214	103857	57%
Transport equipment n.e.s.	64775	99329	53%
Lumber: Wood products	64019	98805	54%
Recycling	62401	102470	64%
Other manufacturing: excludes recycling	61813	99848	62%
Construction	61643	78809	28%
Other Services (Government)	57074	75706	33%

Panel B. Non-OECD

	2017	2040	Change in Labour productivity 2017-2040
Fossil extraction and transformation	116432	95349	-18%
Renewables power	90605	130030	44%
Primary based metals	55499	144922	161%
Transportation Services	34778	93745	170%
Secondary based metals	33716	85570	154%
Fossil Power	33661	45344	35%
Utilities	28620	52332	83%
Other Services and Dwellings	11805	24861	111%
Other mining	11763	19222	63%
Chemicals	11759	29162	148%
Recycling	11687	26316	125%
Other manufacturing: excludes recycling	10742	24453	128%
Food Products	10044	20246	102%
Non-metallic minerals	9827	21197	116%
Total	9328	17494	88%
Electronic Equipment	9197	24614	168%
Motor vehicles	9156	23564	157%
Machinery and equipment n.e.s.	8494	22048	160%
Fabricated metal products	8320	20422	145%
Transport equipment n.e.s.	7947	20000	152%
Lumber: Wood products	7891	15356	95%
Textiles	7582	17093	125%
Pulp, paper and publishing products	7542	14175	88%
Construction	7490	16497	120%
Agriculture	7464	8132	9%
Other Services (Government)	5050	7886	56%

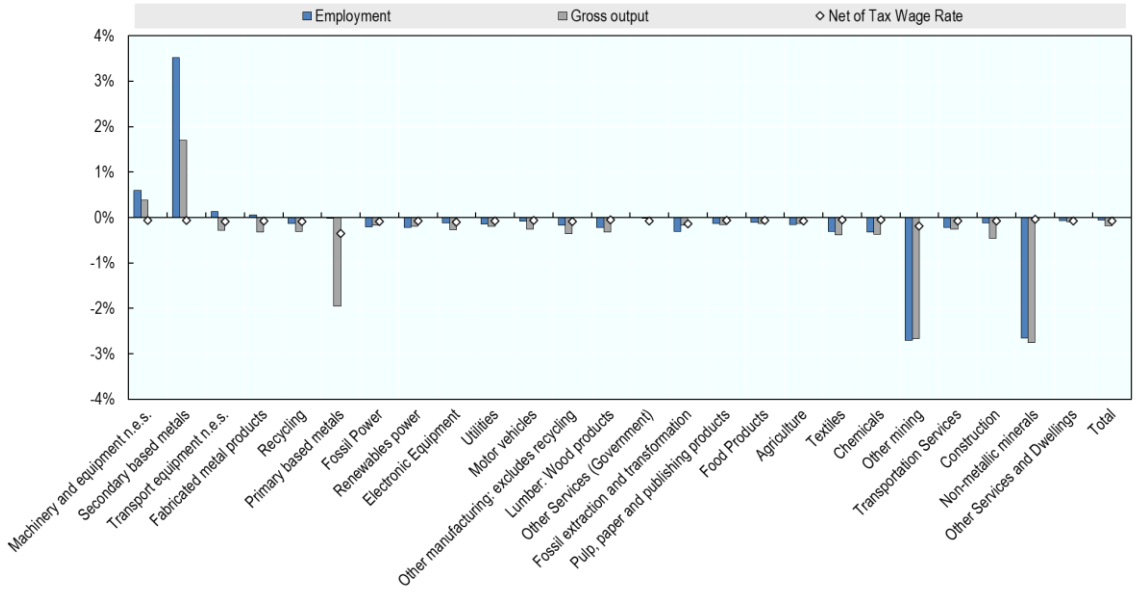
Source: OECD ENV-Linkages model.

Detailed results for the *material taxes only* scenario

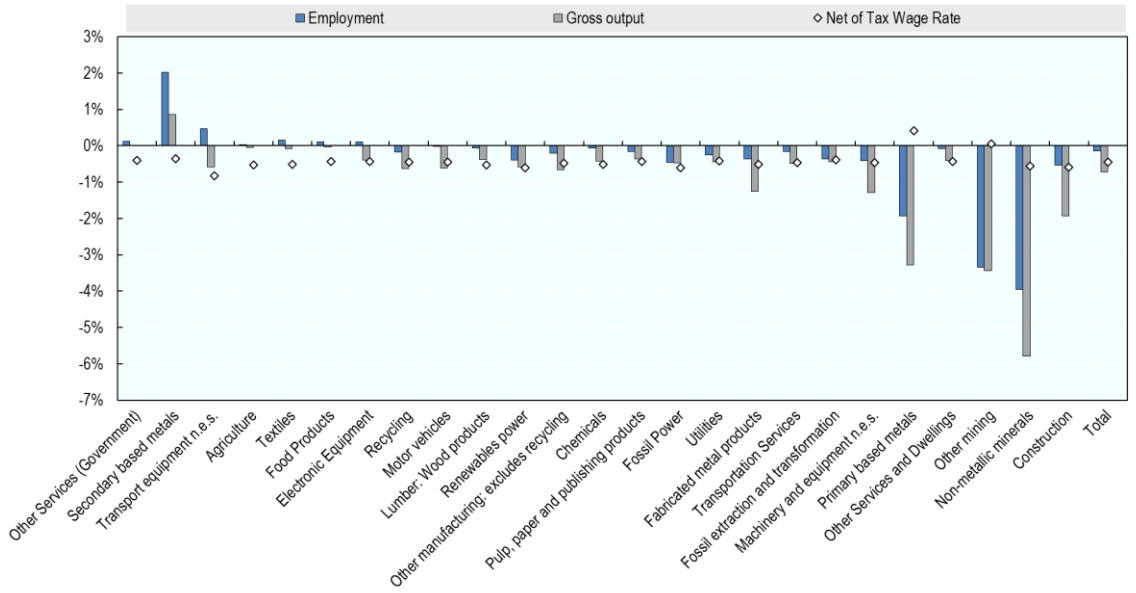
Figure C.4. Changes in sectoral composition of employment and output, *Material tax only* scenario

Percentage changes w.r.t. baseline, 2040

Panel A. OECD countries



Panel B. Non-OECD countries

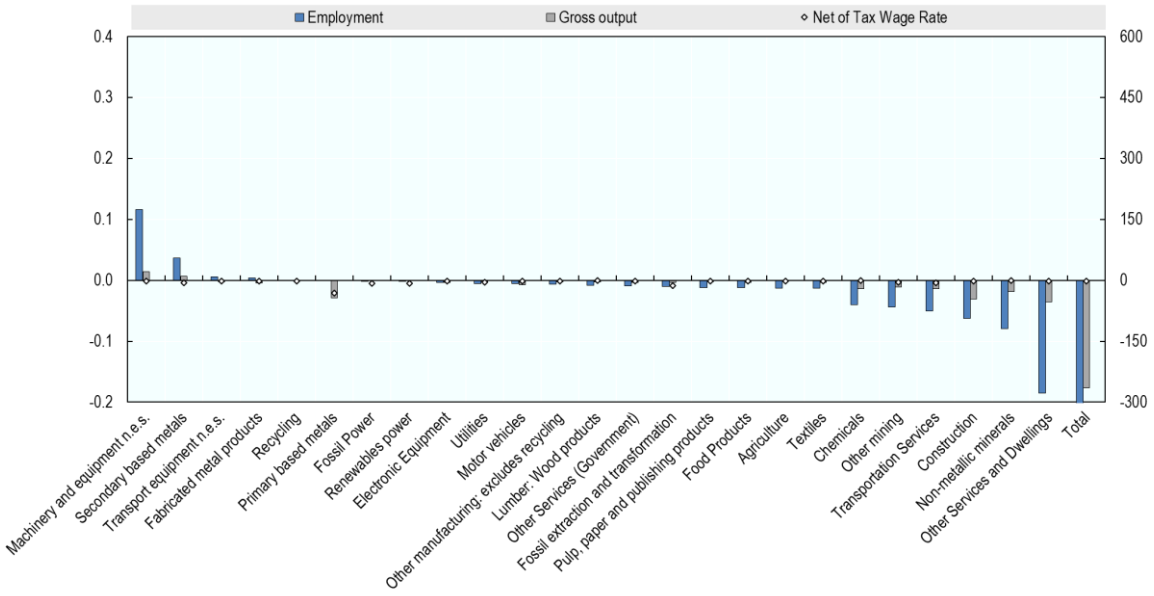


Source: OECD ENV-Linkages model.

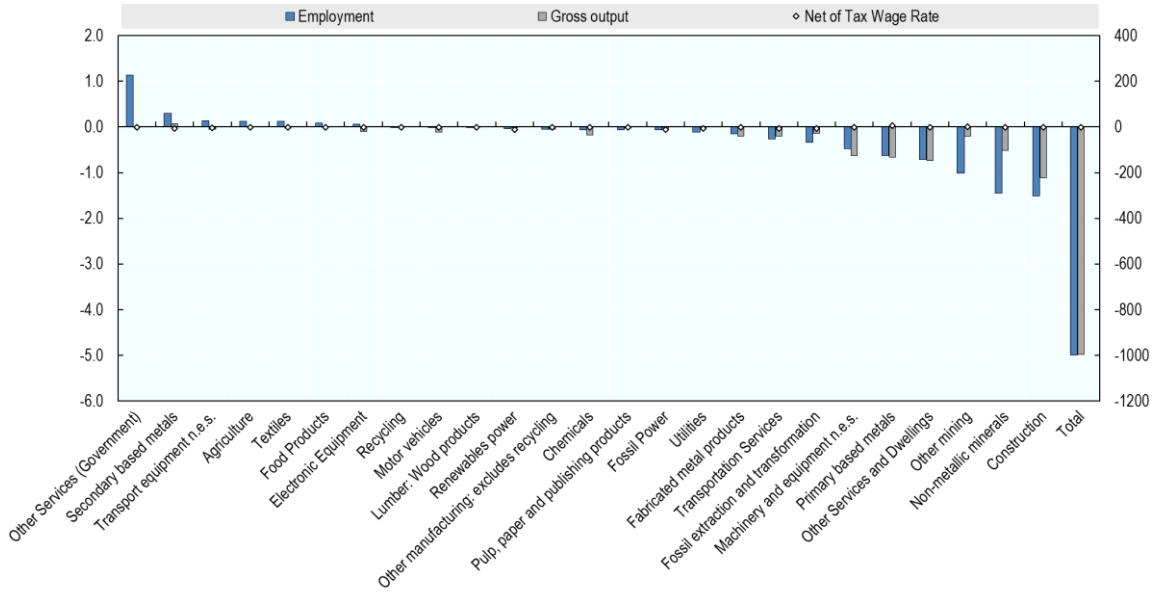
Figure C.5. Sectoral employment and output levels, *Material tax only* scenario

Difference w.r.t. baseline, 2040 - Million jobs and USD (left axis), Million USD (right axis)

Panel A. OECD countries



Panel B. Non-OECD countries

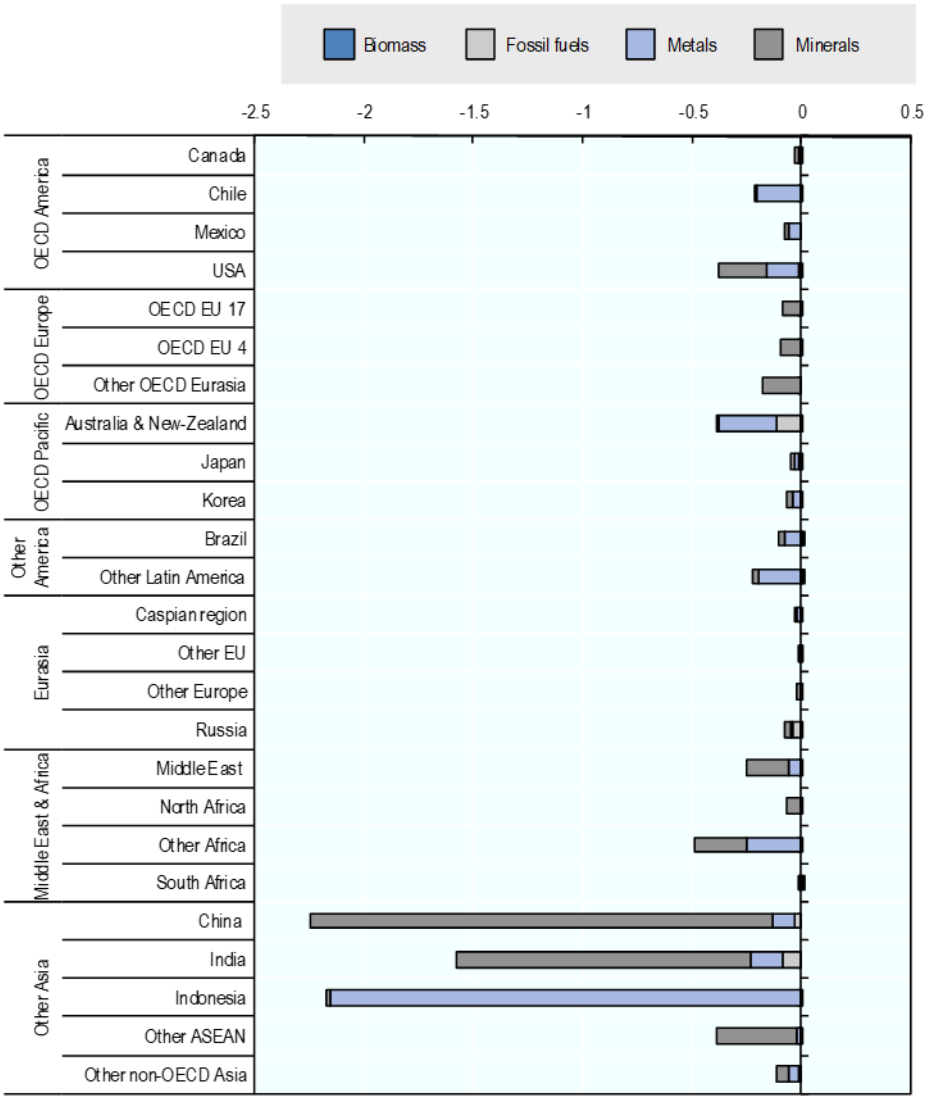


Source: OECD ENV-Linkages model.

Detailed results for the *material fiscal reform* scenario

Figure C.6. Material use changes, *material fiscal reform* scenario

Material use in Gt relative to baseline in 2040

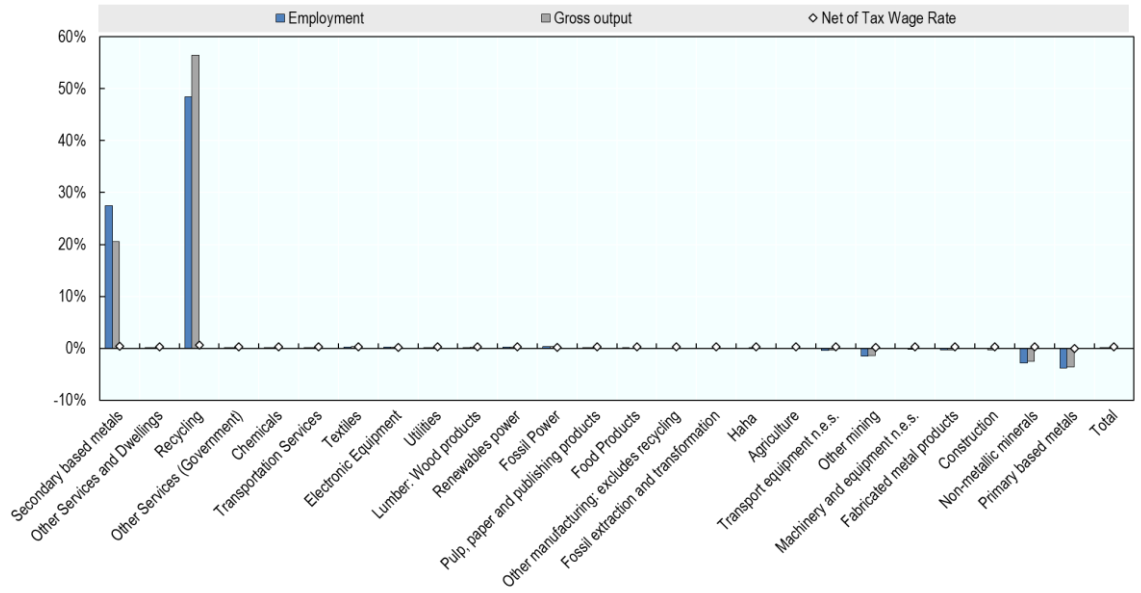


Source: OECD ENV-Linkages model.

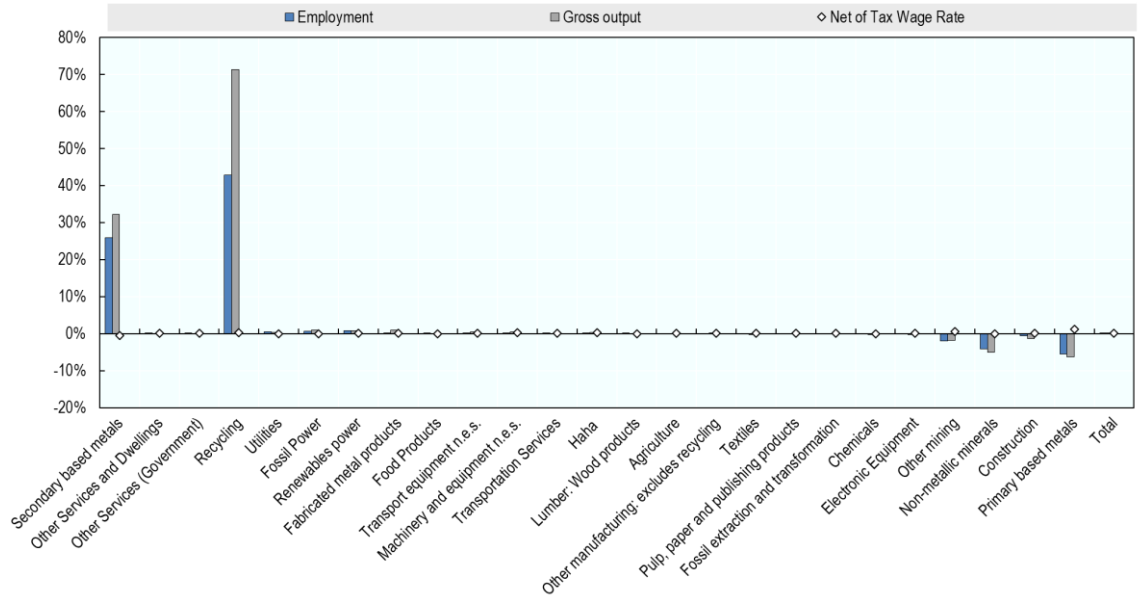
Figure C.7. Sectoral employment and output, *material fiscal reform* scenario

Percentage changes w.r.t baseline, 2040.

Panel A. OECD countries



Panel B. Non-OECD countries

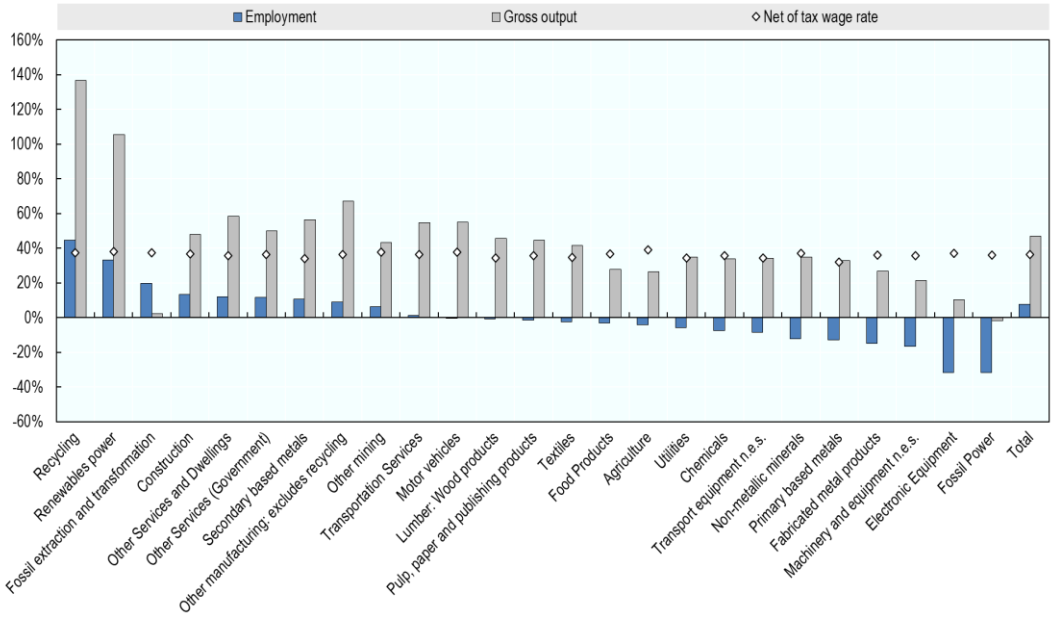


Source: OECD ENV-Linkages model.

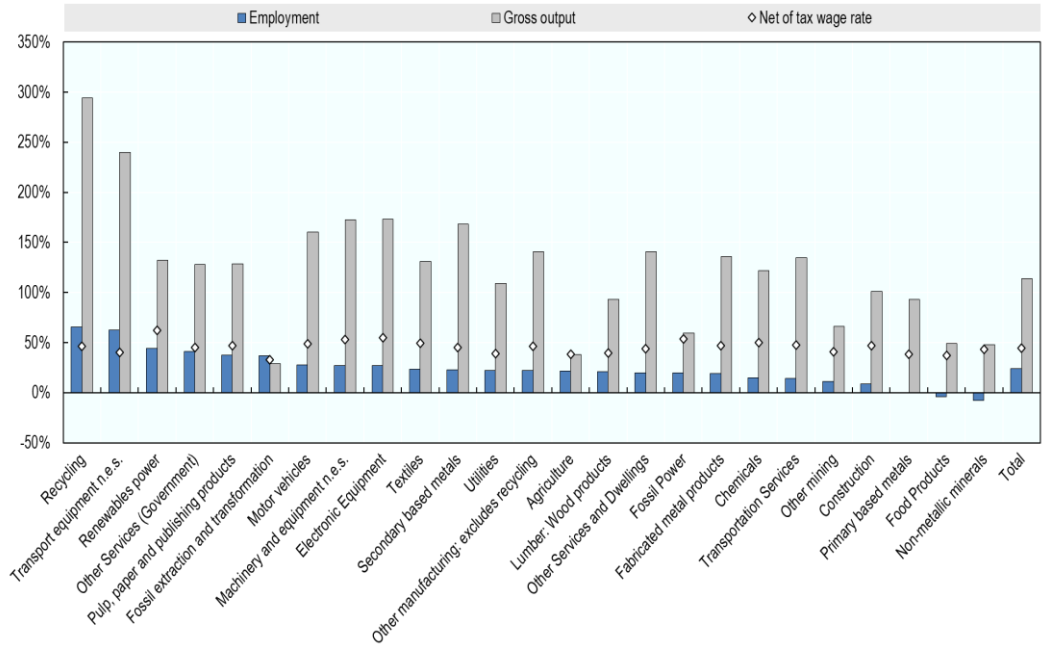
Figure C.8. Changes in sectoral composition of employment and output, *Material fiscal reform* scenario

Percentage changes in 2040 projection relative to 2017 values.

Panel A. OECD countries



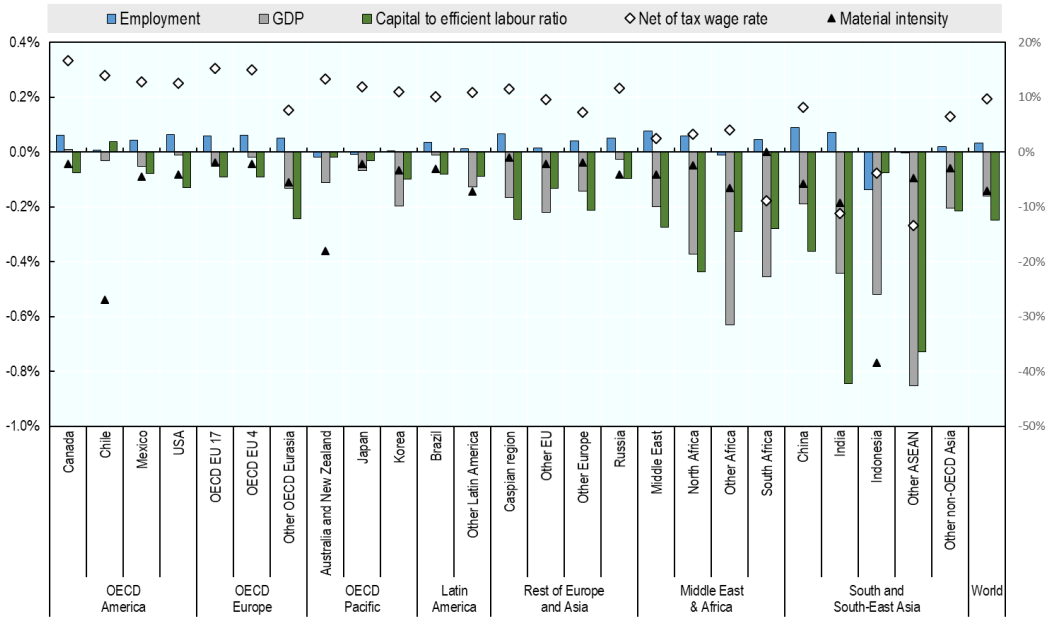
Panel B. Non-OECD countries



Source: OECD ENV-Linkages model.

Figure C.9. Changes in employment, GDP, capital to labour and wage rate by region: *material fiscal reform* scenario

Percentage changes w.r.t baseline in 2040.



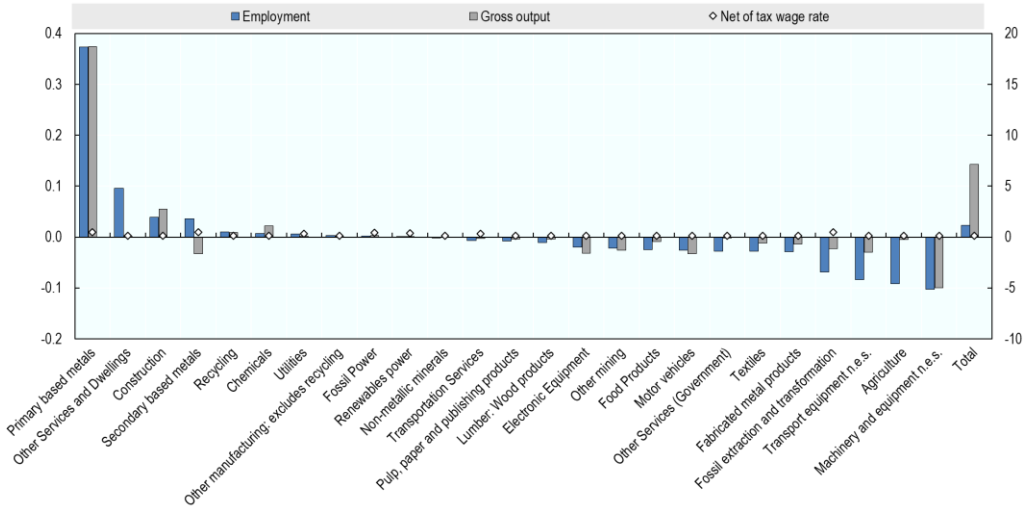
Source: OECD ENV-Linkages model.

Detailed results for the *OECD-only material fiscal reform* scenario

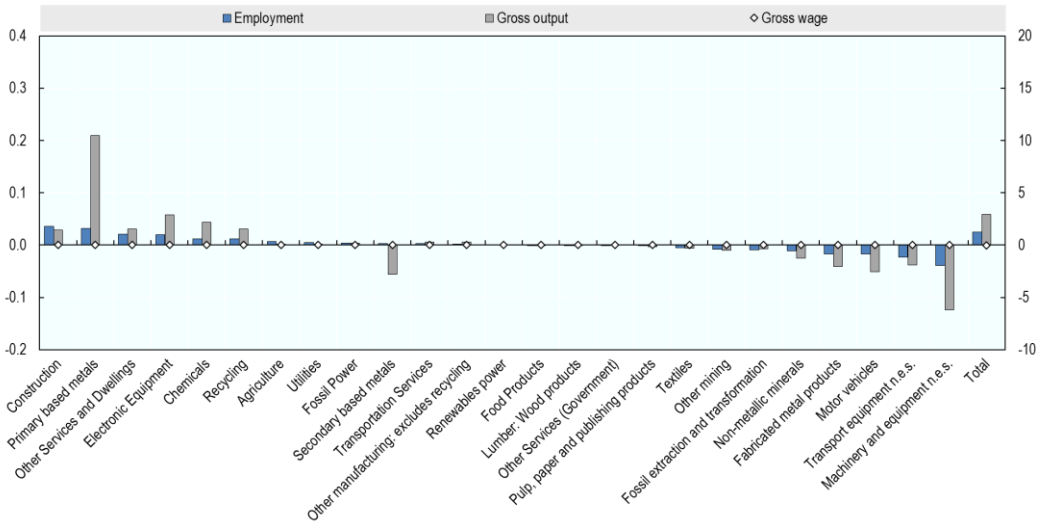
Figure C.10. Change in sectoral composition of employment and output, *OECD-only material fiscal reform* scenario, by Non-OECD groups

Difference to Baseline, 2040 – Million jobs (left axis), Million USD (right axis)

Panel A. Non-OECD Exporters of Primary Materials



Panel B. Non-OECD Importers of Primary Materials

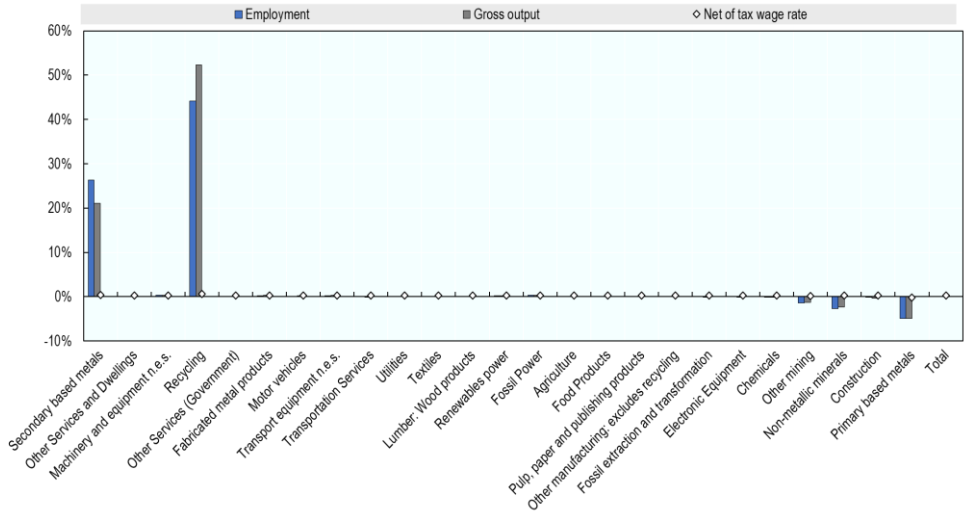


Note: Non-OECD net exporters of primary materials: Middle East, Indonesia, Brazil, Russia, South Africa, Other ASEAN, Other Latin America, Caspian Region, Other Africa, North Africa, Other non-OECD Asia; Non-OECD net importers of primary materials: China, India, Other EU, Other Europe; Classification based on (Hatfield-Dodds et al., 2017[37]).
Source: OECD ENV-Linkages model.

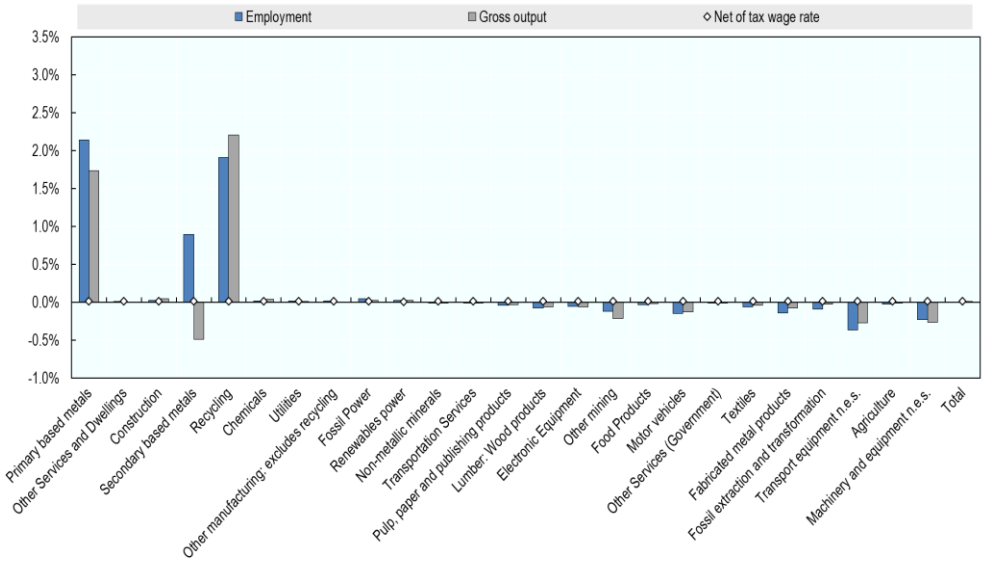
Figure C.11. Sectoral employment and output, OECD-only material fiscal reform scenario

Percentage changes w.r.t baseline, 2040.

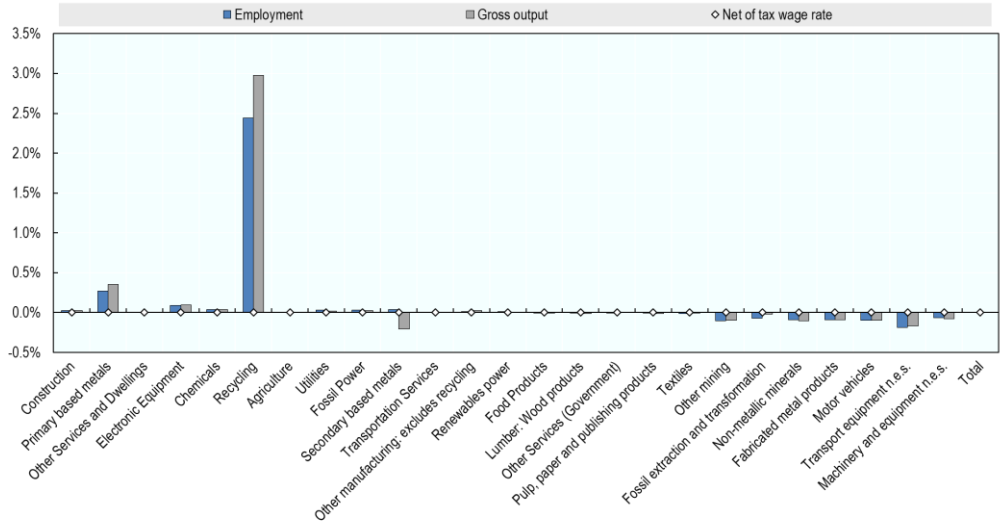
Panel A. OECD countries



Panel B. Non-OECD Exporters of Primary Materials



Panel C. Non-OECD Importers of Primary Materials

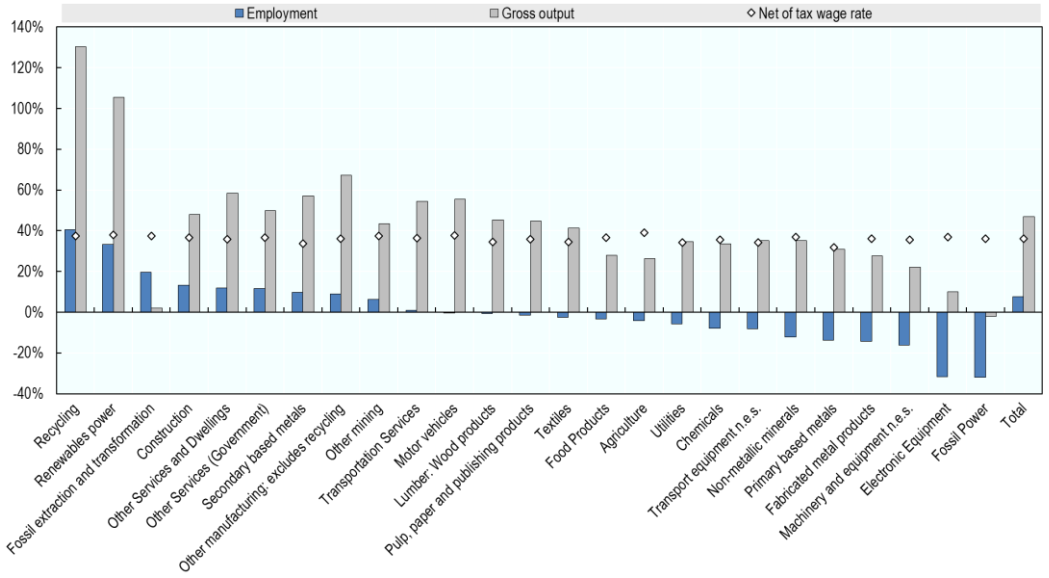


Note: Non-OECD net exporters of primary materials: Middle East, Indonesia, Brazil, Russia, South Africa, Other ASEAN; Non-OECD net importers of primary materials: China, India, Other EU; Classification based on (Hatfield-Dodds et al., 2017[37]).
Source: OECD ENV-Linkages model.

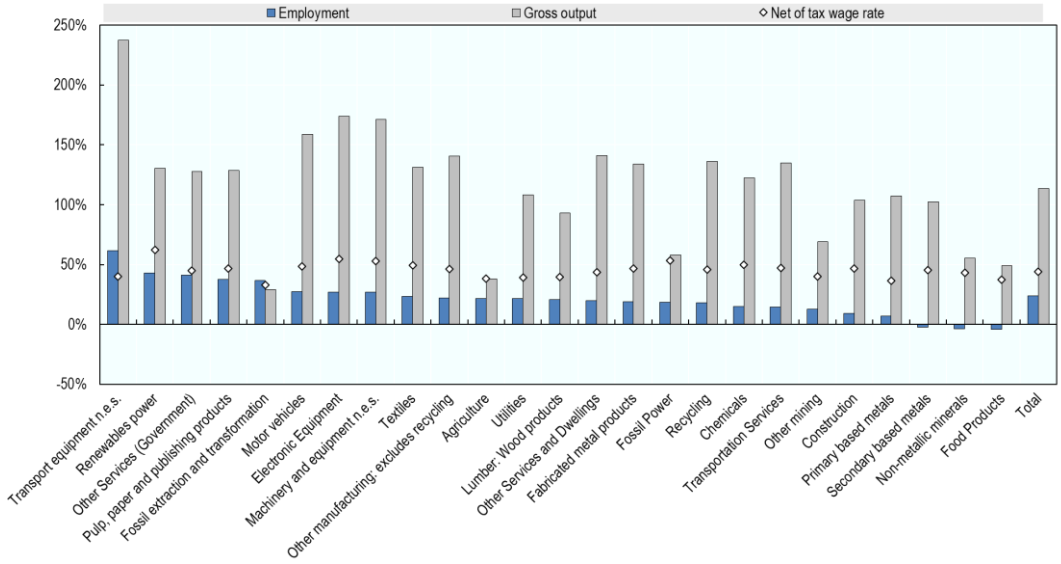
Figure C.12. Changes in sectoral employment and output, *OECD-only material fiscal reform* scenario

Percentage changes in 2040 projection relative to 2017 values.

Panel A. OECD countries



Panel B. Non-OECD countries



Source: OECD ENV-Linkages model.

Annex D. Sensitivity analysis to modelling choices

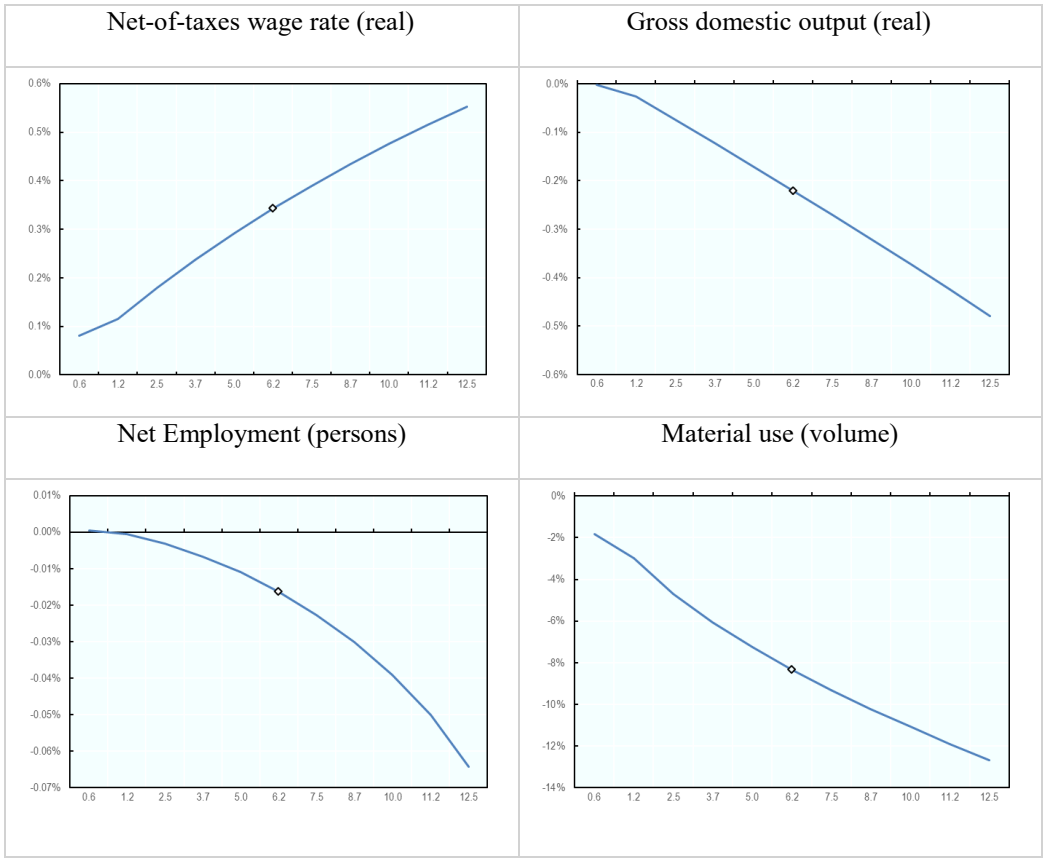
This Annex explores robustness of the results to three modelling assumptions: (i) the level of material taxes, and (ii) the scheme used to recycle the revenues from the material taxes, and (iii) the degree of responsiveness of labour supply to net-of-taxes wage rates (elasticity of labour supply). For sake of simplicity the policy considered here is the *material tax only* scenario with an additional assumption that material taxes are uniform across countries, therefore results discussed here are not directly comparable to those presented in in Table 6.

The impact of varying material tax levels

This exercise explores how the level of material taxes impacts key macroeconomic variables under the assumption that the tax revenues from the material tax are used to decrease labour taxation (Figure D.1).

Figure D.1. Changes in macroeconomic variables for various levels of material taxes: *material tax only* scenario[#], with recycling to lower labour tax

Percentage change w.r.t baseline, 2040 (y-axis), average global material tax level in USD/tonne (x-axis)



Note: Diamonds indicate the central simulation where average tax level is 6.2 USD/tonne.
[#] The scenario considered here assumed uniform material taxes across countries.

Source: OECD ENV-Linkages model.

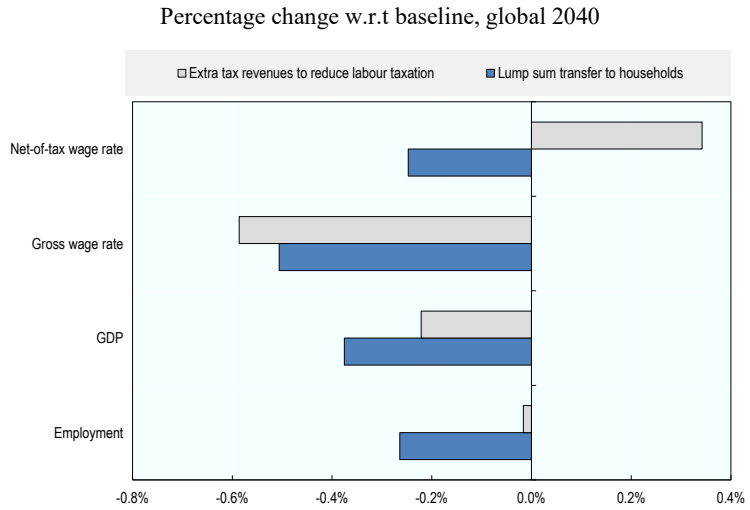
As material taxes increase, material use drops almost linearly, net wages rise (the more tax revenues rise due to material taxes increases, the more labour taxes decrease), gross output decreases marginally (due to rising production costs), while employment follows a similar decreasing pattern. The positive effect on net wages is outweighed by the negative effect on total output, and employment decreases below the baseline levels, and more so as material tax levels increase.

The impact of tax revenue recycling scheme

Implementing new taxes would generally imply additional fiscal revenues to be spend, here the government can choose either to transfer them back to household via lump-sum payments or to reduce labour taxation. The reduction of labour income tax rate will increase substantially the net-of-tax real wage rate received by households, contrary to the case where extra revenues were redistributed as a lump sum. In turn, this will stimulate household labour supply in such a way that total employment impact is now slightly positive at world level, despite the fact that some regions still record employment losses. The resulting increase in employment levels, relative to the case with lump sum transfers, will in turn limit the GDP losses.

Recycling through labour taxation is the most efficient option within the present framework compared to lump-sum recycling. In particular, GDP and employment both drop significantly less in the case of labour tax decreases, as the reduction in labour tax decreases the labour cost and mitigates partially the increased cost in production inputs (Figure D.2).

Figure D.2. Lump-sum transfers versus labour tax reductions, *material tax only* scenario[#]



Note: [#] The scenario considered here assumed uniform material taxes across countries.
Source: OECD ENV-Linkages model.

The dynamic of "double dividend"

In the first years of the policy implementation impacts on global employment are positive (Figure D.3, Panel A) and the policy shows a so-called "double dividend" effect associated to the reduction of labour income tax rates. After few year the negative impact of the policy overtake the positive impact of reduced labour tax. This happens, first because material tax

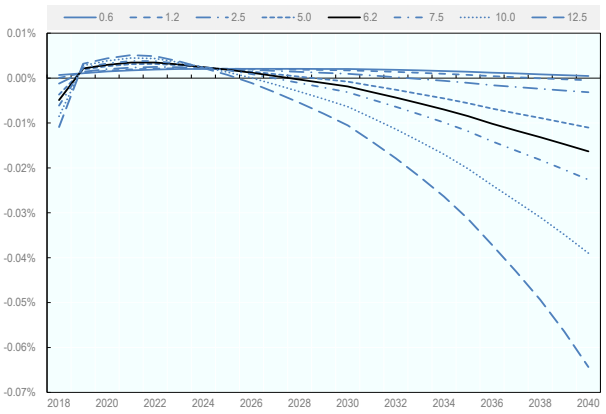
rate, and therefore the cost of the policy, is gradually increased from 2017 to 2040, while the positive impact on labour supply has attained some limit. Second, in the long run the policy cost gradually falls on capital stock (which was slightly rigid in short run), reducing the total potential output.

Panel B of Figure D.3, shows that the larger the responsiveness of labour to change in net-of-taxes is, the larger double dividend is in the short run, but the greater long run negative impact is.

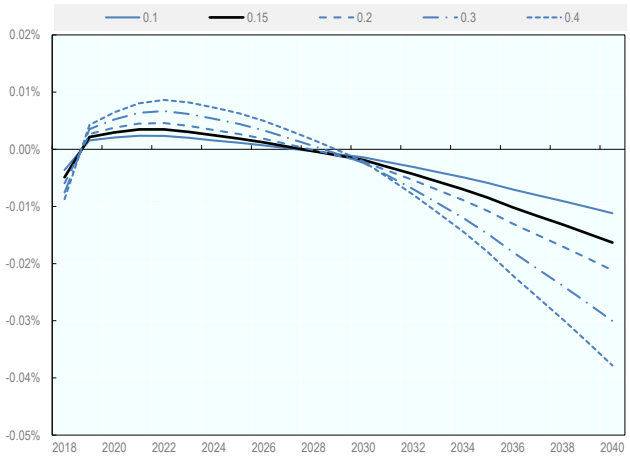
Figure D.3. Employment effect for various levels of material taxes and elasticity of labour supply, *material tax only* scenario

Percentage change w.r.t baseline (y-axis), global, 2017-2040

Panel A. Sensitivity to the stringency of the material tax



Panel B. Sensitivity Labour supply elasticity



Note: Panel A. the lines give employment for different levels of the average material tax in USD/tonne, 6.2 USD/tonne is the level of the tax in 2040 in the central case.
Panel B. the lines give employment for different levels of the elasticity of substitution, 0.15 is the central case.
Source: OECD ENV-Linkages model.

Annex E. Skills protection

This section presents an attempt to link sectors with occupation and skills projections based on (Cedefop, 2018[23]). To ensure comparability, sectors in ENV-Linkages that follow the GTAP classification, were re-grouped to the underlying NACE-4 classification used in (Cedefop, 2018[23]) projections. The later provides projections for occupations and skills across sectors up to 2030 for the OECD EU economies.

Table E.1 shows the top and bottom 5 occupations in terms of employment shares per sector for 2018 (the first year of the MFR simulations) and 2030 (the last available year of skills projections). Only the main five sectors that gain and lose employment for OECD are considered. The results suggest that within OECD at the sectoral level, the top five winners and top five losers in terms of percentage employment changes, will mostly demand medium and high skill workers by 2030, while demand for low skills is projected to decline. Overall, there is some shift of skills across sectors (e.g. low skills demanded in Chemicals), but the results do not suggest an overall reallocation.

Table E.1. OECD main sectors affected by MFR and projected occupations and skills

Top and bottom 5 sectors affected by MFR within OECD, Top and bottom 5 occupations and corresponding skills per sector within OECD EU

Sectors	Occupations increased	Skills	Occupations reduced	Skills
Secondary based metals	Legal, social, cultural and related associate professionals	High, Middle & Low	Labourers in mining, construction, manufacturing and transport	Low
	Building and related trades workers, excluding electricians	High	Numerical and material recording clerks	Low
	Drivers and mobile plant operators	High	Electrical and electronic trades workers	Low
	Protective services workers	High	Chief executives, senior officials and legislators	Low
	Labourers in mining, construction, manufacturing and transport	High	Other clerical support workers	Low
Other Services and Dwellings	Assemblers	High	General and keyboard clerks	Low
	Market-oriented skilled forestry, fishery and hunting workers	High	Other clerical support workers	Medium
	Protective services workers	High	Numerical and material recording clerks	Low
	Labourers in mining, construction, manufacturing and transport	High	Armed forces	Low
	Drivers and mobile plant operators	High	Other clerical support workers	Low
Recycling	Handicraft and printing workers	High	Market-oriented skilled forestry, fishery and hunting workers	Medium
	Health associate professionals	Low	Other clerical support workers	Medium
	Market-oriented skilled agricultural workers	High	Protective services workers	Low
	Legal, social, cultural and related associate professionals	Medium	Metal, machinery and related trades workers	Medium
	Market-oriented skilled agricultural workers	Low	Other clerical support workers	Low

Chemicals	Street and related sales and service workers	Medium	Labourers in mining, construction, manufacturing and transport	Low
	Legal, social, cultural and related associate professionals	High	Information and communications technicians	Low
	Building and related trades workers, excluding electricians	High	Other clerical support workers	Medium
	Market-oriented skilled agricultural workers	High	Health professionals	Low
	Drivers and mobile plant operators	High	Armed forces	Medium
Transportation Services	Subsistence farmers, fishers, hunters and gatherers	Medium	Drivers and mobile plant operators	Low
	Food preparation assistants	High	Customer services clerks	Low
	Armed forces	Medium	Building and related trades workers, excluding electricians	Low
	Legal, social, cultural and related associate professionals	High	Electrical and electronic trades workers	Low
	Refuse workers and other elementary workers	High	Other clerical support workers	Low
Non-metallic minerals	Legal, social, cultural and related associate professionals	High	Business and administration associate professionals	Low
	Street and related sales and service workers	Medium	Health professionals	Medium
	Building and related trades workers, excluding electricians	High	Hospitality, retail and other services managers	Low
	Agricultural, forestry and fishery labourers	Medium	Teaching professionals	Low
	Labourers in mining, construction, manufacturing and transport	High	Market-oriented skilled forestry, fishery and hunting workers	High
Fabricated metal products	Legal, social, cultural and related associate professionals	High	Labourers in mining, construction, manufacturing and transport	Low
	Street and related sales and service workers	Medium	Numerical and material recording clerks	Low
	Building and related trades workers, excluding electricians	High	Business and administration associate professionals	Low
	Agricultural, forestry and fishery labourers	Medium	Chief executives, senior officials and legislators	Low
	Labourers in mining, construction, manufacturing and transport	High	Other clerical support workers	Low
Construction	Handicraft and printing workers	High	General and keyboard clerks	Low
	Street and related sales and service workers	Medium	Building and related trades workers, excluding electricians	Low
	Food preparation assistants	Medium	Numerical and material recording clerks	Low
	Labourers in mining, construction, manufacturing and transport	High	Chief executives, senior officials and legislators	Low
	Food preparation assistants	High	Other clerical support workers	Low
Primary based metals	Legal, social, cultural and related associate professionals	High, Medium & Low	Labourers in mining, construction, manufacturing and transport	Low
	Building and related trades workers, excluding electricians	High	Numerical and material recording clerks	Low
	Drivers and mobile plant operators	High	Electrical and electronic trades workers	Low
	Protective services workers	High	Chief executives, senior officials and legislators	Low

	Labourers in mining, construction, manufacturing and transport	High	Other clerical support workers	Low
Machinery and equipment n.e.s.	Subsistence farmers, fishers, hunters and gatherers	Medium	General and keyboard clerks	Low
	Legal, social, cultural and related associate professionals	High, Medium & Low	Food processing, wood working, garment and other craft and related trades	Low
	Building and related trades workers, excluding electricians	High	Numerical and material recording clerks	Low
	Teaching professionals	Low	Other clerical support workers	Low
	Cleaners and helpers	High	Assemblers	Low

Source: Sectors: OECD ENV-Linkages model; Occupations and Skills: (Cedefop, 2018[23]).