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THE CONSEQUENCES OF A MORE RESOURCE EFFICIENT AND CIRCULAR ECONOMY FOR INTERNATIONAL TRADE PATTERNS:

A MODELLING ASSESSMENT – ENVIRONMENT WORKING PAPER N°165

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Abstract

This report investigates the effects of a resource efficiency and circular economy (RE-CE) transition on international trade flows, using the OECD's ENV-Linkages model. A global RE-CE policy package will cause secondary materials to become cheaper, while primary materials become more expensive to produce. By 2040, primary non-ferrous metals are projected to decline by 35-50%, primary iron & steel by 15% and primary non-metallic minerals by around 10%. Regional shifts in production and trade-related effects (shifts in the regional sourcing of the primary materials by the materials processing sectors) account for roughly one-third of the total reduction in materials use. The other two thirds of materials use reduction come from scale effects (reduced economic activity) and efficiency effects (reduced materials use per unit of output of the processed commodities).

Countries are generally better off when they are not the only regions implementing the policy package. Indeed, by 2040, when other regions also implement the policy package, the regional GDP is projected to increase up to 0.4% above baseline levels. As imports by the home country become cheaper, domestic demand is stimulated. However, this trade effect is dominated by the domestic implementation of the policy package, which reduces domestic economic activity levels. Overall, the impact of the policy package varies between -0.1% and -0.9% from baseline levels across countries by 2040.

Some countries, not least those with a high Revealed Comparative Advantage (RCA) in materials-related commodities, have economic incentives not to implement the policy package. However, if opting out of the policy package can prevent losses in the materials exporting sectors, it also significantly lowers the global effectiveness of the policy package. Indeed, while the global GDP loss is halved, materials use reductions are cut more than tenfold for metals and threefold for non-metallic minerals.

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

JEL codes: C68 ; F18 ; O13 ; O44 ; Q53.

Résumé

Ce rapport examine les effets d'une transition vers une économie efficace en ressources et circulaire (RE-CE) sur les échanges commerciaux internationaux, sur la base de simulations du modèle ENV-Linkages de l'OCDE. La mise en place, au niveau mondial, d'un groupe de politiques RE-CE entraînerait une réduction du prix des matières secondaires, tandis que la production de matières primaires deviendrait plus coûteuse. À l'horizon 2040, la production de métaux non ferreux primaires devrait diminuer de 35 à 50%, celle de fer et d'acier primaire de 15% et celle des minéraux non métalliques primaires d'environ 10%. Le changement dans la répartition des productions mondiales et les effets liés au commerce (changements géographiques de l'approvisionnement en matières premières par les secteurs de la transformation des matériaux) représentent environ un tiers de la réduction totale de l'utilisation des matières. Les deux autres tiers de la réduction de l'utilisation des matières proviennent des effets d'échelle (activité économique réduite) et des effets d'efficacité (utilisation réduite des matières par unité de production des produits transformés).

Dans chaque pays, la mise en œuvre de ces mesures de politiques dans autres pays entraine généralement une hausse des niveaux d'activité économique. En effet, d'ici 2040, lorsque d'autres régions mettent en œuvre les mesures, le PIB régional augmente jusqu'à 0,4% au-dessus des niveaux de référence. Les importations deviennent moins chères, ce qui favorise les acheteurs domestiques. Cependant, cet effet sur le commerce est dominé par la mise en œuvre des mesures au niveau nationale, qui réduit les niveaux d'activité économique. Globalement, d'ici 2040, l'impact des mesures dans les différentes régions varie entre -0,1% et -0,9% du PIB nationale par rapport aux niveaux de référence.

Certains pays, notamment ceux qui ont un avantage comparatif révélé élevé pour les produits de base liés aux matériaux, ne sont a priori pas inciter à mettre en œuvre ces mesures de RE-CE. Mais si l'absence de politiques sur l'efficacité de ressources peut empêcher des pertes dans les secteurs exportateurs de matériaux, il réduit également de manière significative l'efficacité globale des mesures. Par conséquent, alors que la perte du PIB mondial est divisée par deux lorsque l'ensemble des pays agissent ensemble, les réductions d'utilisation des matériaux sont plus que décuplées pour les métaux et triplées pour les minéraux non métalliques.

Mots clés: Économie circulaire; efficacité des ressources; commerce internationale et environnement; model d'équilibre générale.

Classification JEL: C68; F18; O13; O44; Q53.

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Executive Summary

A transition to a more resource efficient, circular economy – hereafter RE-CE – will have significant effects on international trade patterns. Global use of primary materials may decline, while secondary materials and sectors that do not rely on primary materials may see an increase, especially if overall economic activity is boosted by the transition. Furthermore, regional competitiveness to produce materials-intensive commodities will shift. All this affects sectoral trade patterns.

This paper aims to contribute to the understanding of the linkages between international trade and the RE-CE transition. Specifically, this paper presents a quantitative analysis of the effects of a RE-CE transition on international trade patterns. The analysis is based on the OECD's ENV-Linkages model. Baseline trends to 2060 are contrasted with trade patterns arising from a hypothetical illustrative RE-CE policy package that consists of a primary materials tax, a subsidy on secondary materials and recycling, and a labour tax reduction. The focus of this paper is on the way that the policy package shifts sectoral and regional competitive positions and the resulting changes in trade flows and on a quantification of the extent to which the macroeconomic results are driven by trade effects.

At the global level, the baseline projections suggest that exports and imports grow slightly more slowly than GDP. The share of the OECD in global exports is projected to diminish from 60% to 44% by 2060. Trade in services gradually becomes a larger part of total exports. Currently, metals reflect almost 6% of total global exports, minerals a little less than 3%. Iron and steel is the largest group of metals in terms of exports, followed by mining products, but these are projected to grow less rapidly than non-ferrous metals and recycling products.

The consequences of a RE-CE policy package will be wide-ranging. Given the differences among countries in endowments, specialisation patterns, and income levels, a global policy will cause some products to become cheaper, while others become more expensive to produce. As these changes in costs and the resulting changes in demand patterns differ across regions, the competitive position of countries on the global market shifts, and export and import flows adjust. The stylised policy package abstracts from a number of important regional differences, not least in the environmental consequences of the extraction and production of materials-related commodities, and – to some extent – in the specification of production methods. Thus, the results should be interpreted with care.

In most regions, metals use is reduce more than the use of non-metallic minerals: by 2040, non-ferrous metals are projected to decline by 35-50%, iron & steel by 15% and non-metallic minerals by around 10%. This reflects higher tax rates as well as the availability of secondary materials. In general, the materials tax rates will disproportionately affect materials processing sectors in regions where materials input costs reflect a large share of total production costs. As a consequence, production will shift towards more materials-efficient producers. Regional shifts in production and trade-related effects (shifts in the regional sourcing of the primary materials by the materials processing sectors) account for roughly one-third of the total reduction in materials use. The size of this effect is smaller for iron and steel (less than one-tenth), and larger for non-ferrous metals (more than two-thirds). The other two thirds of materials use reduction come from scale effects (reduced economic activity) and efficiency effects (reduced materials use per unit of output of the processed commodities) in roughly equal shares, albeit with big variations between

materials as efficiency improvements induced by the policy package are substantially lower for iron and steel and non-metallic minerals.

Several regions can increase exports and imports of materials-related commodities – including OECD America and OECD Europe for aluminium, OECD Europe for copper, all regions for iron and steel, and OECD Europe and South and South-East Asia for other non-ferrous metals. In these regions, the policy package boosts their economies, with increased competitiveness on the international market and demand growth on the domestic market. Then there are several regions with reductions in exports and increases in imports of materials-related commodities. These regions are projected to have domestic materials-related production sectors that lose competitive position on both domestic and international markets. Thirdly, a few countries have a contraction of the economy, with lower production and lower export and import levels of materials-related commodities. Finally, there are regions where domestic producers gain competitive position on both domestic and international markets for materials-related commodities, without significantly boosting overall demand levels. There are very few regions in this situation, as the boost to the domestic economy from improved competitiveness tends to increase overall demand, which in turn boosts the level of imports. In all regions, the policy package induces a very significant increase in trade in recycling products (around 50% above baseline level in 2040).

The domestic implementation of the policy package tends to lead to reduced domestic economic activity levels; with a negative impact up to -0.9% across countries by 2040. The size of the effect depends on the characteristics of the regional economy (not least the size of the materials-related sectors): these determine the relative importance of the materials taxes versus the labour cost reductions for the macro economy. The macroeconomic slowdown is partially offset by the effect of other countries implementing the policy package, which tends to be positive for GDP: foreign production costs decrease in most sectors as a result of the reduced taxes on labour. This implies imports by the home country become cheaper, which is good for domestic demand. Furthermore, exporters of materials-related commodities in the home country can benefit from the production cost increases in the other countries and thus reap a larger share of the global market. The foreign policy implementation has positive consequences for total domestic demand, and the lack of a domestic policy package does not steer demand away from the materials-related commodities, thereby leading to import levels of materials-related commodities that can – in some regions – outstrip the baseline projection.

Some countries, such as those with a high Revealed Comparative Advantage (RCA) in materials-related commodities, have economic incentives not to implement the policy package. The same mechanism extends to the scenario where all net exporters of materials opt out of implementation of the policy package and the scenario where countries exclude those taxes from the policy package that aim at exported materials acts. But while opting out of the policy package can prevent losses in the materials exporting sectors, it reduces the tax revenues available for reforming labour taxes, which hurts the other economic sectors. It also significantly lowers the global effectiveness of the policy package to decouple economic activity from materials use.

There are several trade effects of a circular economy transition that cannot be addressed in this paper. First, the breadth of the policy package is limited, and excludes e.g. stimulus of resource efficiency, which could potentially boost GDP while reducing materials use. A broad policy package could also encompass measures that are directly aimed at trade flows. Second, the granularity of the analysis is limited, and bilateral trade flows of specific

materials in physical terms could not be assessed. Third, changes in trade policies and trade agreements to facilitate the transition are not considered.

While the current analysis does not predict future trade flows in a circular economy, it highlights how economic mechanisms will likely influence future trade patterns when countries implement policies to improve resource efficiency and shift away from primary materials use.

1. Introduction

A transition to a more resource efficient, circular economy – hereafter the RE-CE transition – will have significant effects on international trade patterns. Global use of primary materials may decline, while other sectors may see an increase, especially if overall economic activity is boosted by the transition. This in turn affects the sectoral trade patterns.

For countries that are net importers of materials, improved resource efficiency and a more circular economy entails a substitution of imported commodities by domestic economic activity. This may boost domestic economic growth, generate jobs and improve environmental quality (McCarthy, Dellink and Bibas, 2018[1]). For materials-exporting countries, the situation is more nuanced, but the increased demand for sustainably produced goods and services provides new export opportunities that may replace more traditional export patterns (for instance, the Netherlands have developed a vision on circular agriculture (Ministry of Agriculture, 2018[2]) building on this case).

There are strong links between the RE-CE transition and international trade. Yamaguchi (2018[3]) highlights the potential impacts of the transition on a number of trade flows, including primary materials, services, second-hand goods, goods for refurbishment and remanufacturing, waste and scrap for recovery and secondary materials. It also discusses the need to align RE-CE policies and trade policies, and the potential opportunities for trade to facilitate the RE-CE transition.

A second stream of existing work uses modelling tools to explore the evolution of materials use and the associated economic activities in the coming decades. The *Global Material Resources Outlook to 2060* (OECD, 2019[4]) presents the economic drivers and environmental consequences of materials use until 2060 at the regional and sectoral level. It highlights how materials use is projected to increase between 2017 and 2060 as a result of economic growth and income convergence (with growth rates in emerging and developing countries being higher than in the OECD, on average). But a relative decoupling of materials use from Gross Domestic Product (GDP) is possible due to the combined effect of structural change (a shift towards less materials-intensive sectors, especially services) and technological changes (i.e. reduction of materials intensity of production at the sectoral level). The report also stresses the significant worsening of environmental pressures from expanded extraction, processing and use of materials. The *Outlook* also highlights that – at least at global level – secondary materials are associated with substantially smaller environmental impacts than primary materials.

This paper aims to contribute to the understanding of the quantitative linkages between international trade and the RE-CE transition. It does so by exploiting the modelling framework presented in OECD (2019[4]) and applying it to a more detailed analysis of shifting trade patterns over time.[1] Thus, the focus of this paper is on the *indirect* consequences of the RE-CE policy package on international trade patterns – i.e. the way that the policy package shifts sectoral and regional competitive positions and the resulting changes in trade flows.

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[1] This reflects just one possible projection, and not a prediction of the future. Although these projections are very carefully constructed, using the best available information, numerical results should always be interpreted with care.

CGE models such as the ENV-Linkages model used in OECD (2019[4]) – and summarised in Annex A – are traditionally well-suited to the type of analysis in this report, as they focus on linkages between economic sectors in various regions, based on national accounts and international trade flows at sectoral level. In the model, prices adjust endogenously to clear markets. When a tax is introduced, this drives a wedge between the price paid by the buyer and the price received by the seller. The market-clearing price will then adjust, taking into account the possibilities of firms and households to accommodate the tax by changing their consumption and production patterns, and a new equilibrium price emerges where part of the price shock is propagated down the chain.

A central assumption on the representation of international trade in the model is the so-called Armington assumption: domestic and foreign goods and services are considered to be imperfect substitutes. This approach, which is common in CGE models, can mimic plausible levels of bilateral trade by differentiating the price of each good across countries. The model abstracts from an explicit representation of international capital markets, and instead assumes specific pathways for regional trade balances. This latter assumption implies that regional trade balances follow an exogenous path and real exchange rates will adjust in each period to reproduce these balances, and thus maintain model closure.[2]

The analysis focuses on metals and non-metallic minerals, rather than biotic resources, fossil fuels, plastics or textiles. The main rationale for this is twofold. First, these minerals are inherently recyclable, whereas biomass and fossil fuels are usually expended in consumption. Second, materials such as plastics and textiles are not raw materials but processed commodities, which would require a different modelling set-up. Table 1 presents the materials that are included in the policy analysis. For each primary material, the physical flows (calibrated to the latest material flow dataset of the International Resource Panel; UNEP, 2018) are linked to the corresponding economic flow. For secondary metals, sector-specific reprocessing industries are modelled (see also Box 2 below). As discussed in OECD (2019[4]), decoupling of materials flows from economic activity is assumed to be reflected in the corresponding economic flow: improved resource efficiency occurs when less input of materials is needed in production.

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[2] It is a common assumption in CGE models to decouple international capital markets from international goods markets. In this context trade balances are exogenously given and there are no financial variables in the model. The baseline real exchanges rates of emerging and developing economies progressively increase relative to those of OECD, reflecting a Balassa-Samuelson effect: high productivity growth in sectors that produce tradable goods drive wage increases in the slower growing non-tradable sectors. Hence, domestic price levels increase, as well as relative prices vis-a-vis other countries, i.e. the real exchange rate.

Table 1. Overview of materials included in the analysis

Category	Materials	Corresponding economic flow
Non-metallic minerals	Gypsum, Limestone, Sand gravel and crushed rock, Structural clays	Non-metallic minerals used in construction*
	Ornamental or building stone	Mining inputs used in construction
	Chemical minerals n.e.c., Fertiliser minerals n.e.c., Salt	Mining inputs used in chemicals, rubber, plastics production
	Chalk, Dolomite, Industrial minerals n.e.c., Industrial sand and gravel, Other non-metallic minerals n.e.c., Specialty clays	Mining inputs used in non-metallic minerals production
Primary metals	Iron ores	Mining inputs used in iron and steel production
	Bauxite and other aluminium ores	Mining inputs used in aluminium production
	Copper ores	Mining inputs used in copper production
	Chromium ores, Gold ores, Lead ores, Manganese ores, Nickel ores, Other metal ores, Platinum group metal ores, Silver ores, Tin ores, Titanium ores, Zinc ores	Mining inputs used in other non-ferrous metals production
Secondary metals	Recycling products (scrap)	Recycling input in reprocessing sectors for iron and steel, aluminium, copper, and other non-ferrous metals production (4 sectors)

Note: * The non-metallic minerals sector is not an extraction sector, but the assumption is made here that construction materials that need to be processed (e.g., cement) follow the economic flow of the non-metallic minerals processing sector into construction rather than the mining sector into non-metallic minerals.
Source: OECD (2019[4]).

To investigate the effects of a RE-CE transition, baseline trends are contrasted with trade patterns arising from a hypothetical stylised policy package. Box 1 summarises the main assumptions in this policy package. The policy package only deals with market instruments to improve resource efficiency and facilitate the transition to a circular economy. It does not encompass specific policy instruments to deal with other major environmental objectives such as climate change mitigation. There are significant interaction effects between materials use and climate change, not least in the materials requirements for renewable energy, and between the associated policy instruments, which should be explored with a broader policy package.

The policy instruments are chosen because they are cost-effective. Among trade experts, it remains debated whether international tax regimes allow for differentiating taxes on the basis of the production process for "like products". Imposing a tax on imported primary production while subsidising domestic secondary production could be seen as discriminatory and be open to a dispute at the WTO. Such legalistic issues are beyond the scope of the current paper, which adopts a global collaborative approach. Nonetheless, the potential discriminatory effects on trade and competition should be carefully reviewed when countries are designing their resource efficiency and circular economy policies.

One major limitation of the analysis in this report is that the data on physical material flows do not allow investigation of trade flows of primary materials in physical units. Therefore, the analysis in this paper is limited to economic values, i.e. trade flows of the commodities that comprise the material categories – for example, trade in non-metallic minerals in dollars rather than trade in gypsum or limestone in kilotonnes. This also implies that while production volumes are measured for primary and secondary processing sectors separately,

the associated trade flows are lumped together under assumption that both production methods produce identical commodities.

This paper also abstracts from an analysis of changes in trade policies. In principle, revising existing trade policies or adding new ones could improve economic outcomes by re-aligning environmental and trade policies under revised circumstances. One potential issue to be explored in this area would be the revision of import and export restrictions on materials and waste, building on (OECD, forthcoming[5]). Such analysis is left for future research.

This paper is set up as follows. Section 2 describes trends in international trade until 2060 according to a business-as-usual baseline projection, in line with OECD (2019[4]). Section 3 then investigates how the stylised RE-CE policy package affects these trade projections. Section 4 explores scenarios where exporters of materials-related commodities opt out of implementing the policy package. Section 5 concludes. The Annexes provide background information on the modelling framework and relevant results for the baseline projection and the stylised RE-CE policy package.

Box 1. The stylised RE-CE policy package

OECD (2020, forthcoming[6]) investigates the macroeconomic consequences of a broad RE-CE policy package. It also describes the policy package in detail and explains the rationale for the policy instruments that are included in the analysis.

As a hypothetical, stylised policy package for analytical purposes, the policy package is limited to a materials tax reform, and only includes a tax reform that aims at shifting consumption away from primary materials use. These instruments have been chosen primarily on the basis of the insights from OECD (2019[4]), which highlights the stronger environmental implications of primary materials extraction and processing over secondary forms of production. The specific elements of the stylised policy package as specified in OECD (2020, forthcoming[6]) are:

- A tax on primary materials use for all metals and minerals, with tax rates varying between 5 and 50 USD/tonne; the specific tax rates are calibrated such that at the margin the cost-benefit ratio is the same, where the benefits are calculated as the reduction in global environmental damage as calculated in OECD (2019[4]);

- A 75% subsidy on (the output of) recycling;

- A 25% subsidy on (the output of) the reprocessing of recycled metals;

- A reduction in labour taxes for all sectors that ensures the full package is revenue-neutral.

These policies are assumed to be implemented gradually between 2020 and 2040. The focus of the policy analysis is 2040, so no assumptions are made on the policy package for the 2040-2060 period and results are only presented until 2040.

While different taxes are implemented simultaneously in the policy package, double taxation of the same externality is avoided as each material is only taxed at one point in the value chain: the inputs from the extractive sector in the processing sector are taxed in proportion to the physical material flow associated with that transaction. The tax is applied on both imported and domestically extracted materials, in line with the global nature of the policy package.

If regionally specific environmental consequences of extraction and production were available, it would make sense to apply regional differentiation of the tax rates; unfortunately, the currently available data (OECD, 2019[4]) prevents such a refinement in the current report.

Future revisions of OECD (2020, forthcoming[6]) may investigate a broader policy package that is more aligned with the wider objectives of the RE-CE transition (see the brief discussion in Section 5 below). Such a broader analysis will provide essential context against which to interpret the results of the stylised narrower policy package investigated here. Nonetheless, the generic taxes included in the stylised policy package serve as an adequate reference point for analysis, as they allow a cost-effective solution in the model, which is helpful in studying the sectoral, regional and international mechanisms that are triggered by the policy shock.

2. Baseline trends in international trade

2.1. Macroeconomic trends in exports and imports

The OECD has a long history of projecting trends in international trade. One major example is Chateau et al. (2015[7]), who projected that the trend of economic integration and intensified global trade will continue in the future, albeit at a slower pace than in the last decades. The analysis in Chateau et al. (2015[7]) builds on the seminal work of Feenstra (1998[8]), who posits that in the long run, global trade and its relative size to global income are driven by (i) transportation and communications costs (including "transaction costs"), (ii) income growth and changes in preferences, (iii) sectoral comparative advantage in production of goods and services, and (iv) trade policies and trade agreements. Changes in each country's specialisation depend ultimately on differences in these drivers amongst countries. The products in which countries specialise are determined by the availability of inputs used in the manufacture of different products and by access to different technologies. As such, specialisation is strongly driven by unevenly distributed natural resources across the globe. For the analysis in this report, the focus is on the second and third driver: transportation and communication costs are assumed to follow an exogenous trend, and changes in trade policies are excluded from the analysis.

Chateau et al. (2015[7]) are relatively optimistic about long-term trends in trade liberalisation, and have global exports growing more rapidly than global GDP. Recently, export growth has decelerated (OECD, 2018[9]). In the most recent long-term projections, the assumptions on trade liberalisation are also more cautious, and growth in trade is no longer projected to outpace growth in global GDP.

The baseline economic trends underlying the projections in the *Global Material Resources Outlook to 2060* (OECD, 2019[4]) also encompass projections for international trade.[3] Some key results from that analysis, with a focus on the economic trends, are copied in Annex B. This section teases out the main developments in international trade patterns in this baseline projection. It serves as a reference point for investigating the consequences of the RE-CE policy package in the next section.

The projected growth in regional total imports, total exports and GDP are presented in Figure 1. At the global level, the projections suggest that exports and imports grow slightly more slowly than GDP. This reflects an extrapolation of recent trends, as well as a detailed analysis of changes in the major driving forces of economic activity; see (OECD, 2019[4]) for more details.

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[3] As explained in (OECD, 2019[4]), these are not predictions of what will happen, but scenario-based projections of what may happen, given a detailed analysis of the sectoral and regional drivers of economic activity and demographic trends for the coming decades.

Figure 1. Regional growth in trade volumes
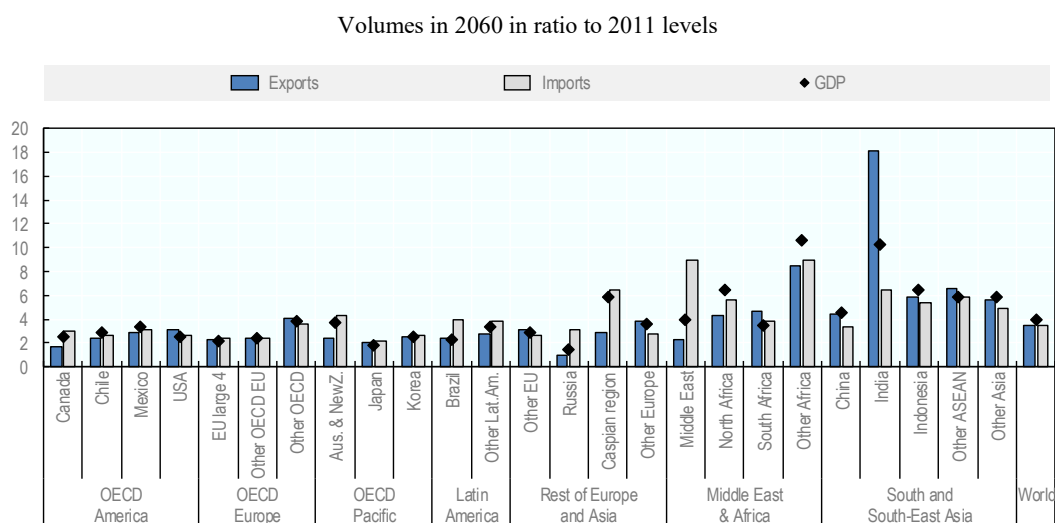
Volumes in 2060 in ratio to 2011 levels

Note: Exports and imports reflect all goods and services, not only materials.
Source: OECD ENV-Linkages model.

In most OECD countries, which generally have mature, diversified economies, international trade largely follows GDP (e.g. the OECD EU countries). For the USA, export growth is projected to outpace GDP growth somewhat, reflecting *inter* alia the dominance of the USA in the digitalisation of the economy, which brings strong growth in trade in services.[4] In contrast, in Canada and Australia & New Zealand, export growth falls behind GDP growth, while imports grow faster; resulting in a deterioration of their trade balance. In both cases, exports of services represents a fraction of total exports that is below the OECD average. Given the fast increase in services demand, and hence services trade, the relatively low revealed comparative advantage (RCA) of Canada and Australia & New Zealand in services hampers their export growth potential.[5]

For the emerging and developing economies, increased infrastructure development and rising domestic demand are the prime drivers of GDP growth, rather than international trade. A major exception to this is India, where the projections suggest that high GDP growth is coupled with even stronger growth of exports; the large export of services by India plays a significant role in this. At the other extreme are Russia and the Middle East, where the baseline projections suggest that imports rise more rapidly than GDP and exports. In Russia, the low productivity growth of the domestic production sectors influences this result, while in the Middle East it reflects – among others – that consumption patterns diversify more rapidly than production patterns. Both regions also suffer from lower fuel revenues as the global energy market further diversifies. In most other regions, exports and imports follow GDP or grow slightly more slowly.

Figure 2 confirms that trade – or more specifically trade liberalisation – is no longer a leading driver of growth for the coming decades. This does not imply that trade

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[4] Telecommunications, computers and information services are a major and increasingly important category, as are financial services.

[5] Other modelling projections tend to be more bullish on the export potential of Australia and New Zealand, citing their strong trade links with the rapidly emerging economies in Asia.

liberalisation has become ineffective. Rather, the modelling scenario assumes that there is no major trend towards further liberalisation. Consequently, trade patterns are projected to roughly align with domestic production and consumption patterns. Thus, there is a weak correlation between trade openness and the growth of trade between 2011 and 2060. In the fastest growing regions, trade openness – measured as the average of exports and imports divided by GDP – tends to increase, but the effect is not universal and not very strong.

Figure 2. Trade openness and growth of exports

Trade openness as share of GDP (left axis); growth of exports as ratio to 2011 levels (right axis)
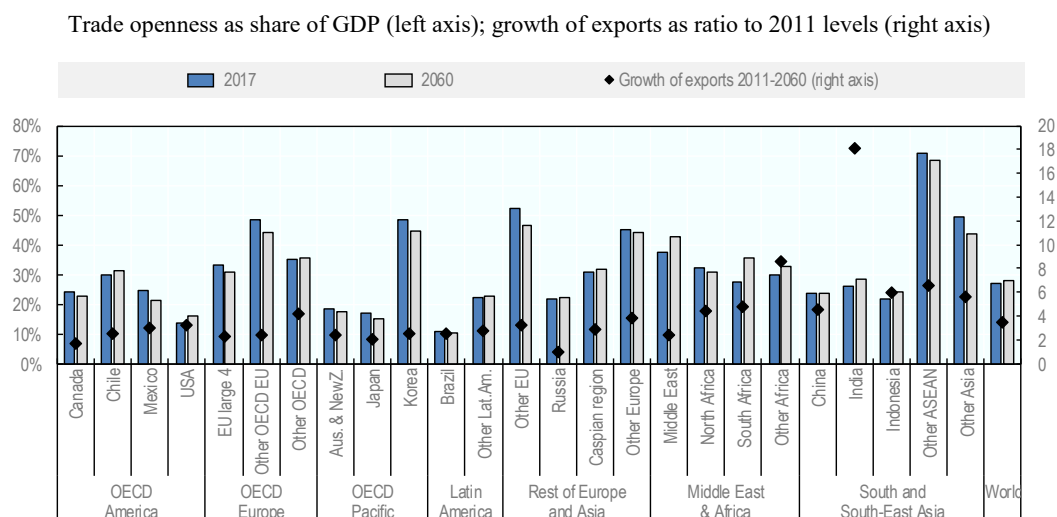
Note: Trade openness is calculated as the average of exports and imports, divided by GDP.
Source: OECD ENV-Linkages model.

The shift in geographical composition of the world economy implies that the share of the OECD in global exports is projected to diminish from 60% to 44%; simultaneously, the share of OECD in global imports declines from 64% to 48% (Figure 3). Nonetheless, OECD to OECD exports remain the largest single category. The biggest growth is projected for exports from the emerging economies to the developing countries (almost 9-fold increase) and between developing countries (almost 7-fold increase).

Figure 3. Regional composition of global trade

Shares in global exports
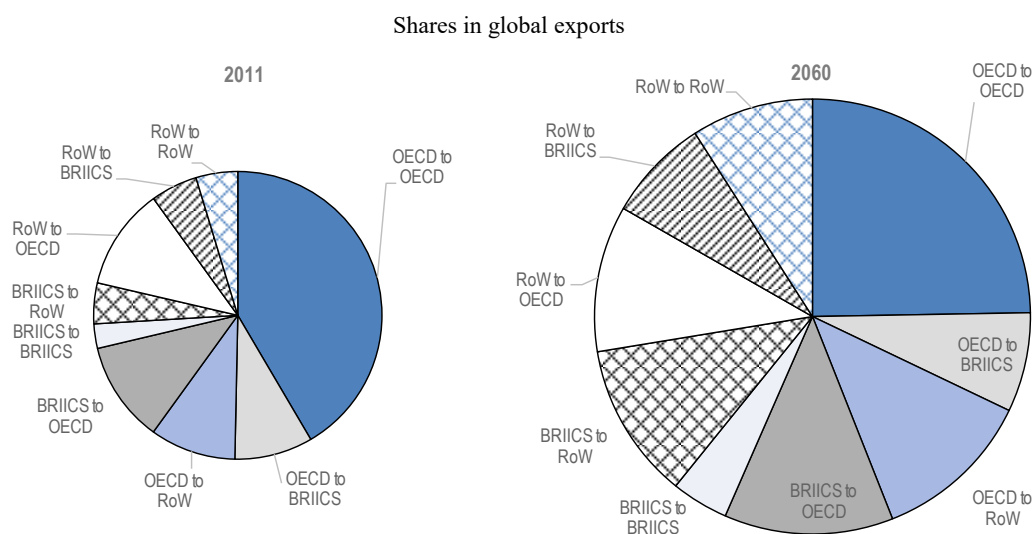
Note: Trade flows are measured at the 25 region level, and abstract from trade flows within each region. This implies that trade shares for large aggregation regions are especially underestimated. The size of the charts have been sized according to global export volume (a 3.5-fold increase between 2011 and 2060).
Source: OECD ENV-Linkages model.

For a long time, trade imbalances were deemed untenable in the long run, and historically, most projections assumed that trade imbalances would gradually disappear. Following more recent insights, the baseline projection presented here is less conservative, and does not impose trade imbalances in absolute terms to fade over time. Rather, as shown in Figure 4, the assumption is made that in the long run these imbalances very gradually become smaller when expressed as share of GDP. In the short and medium run (until 2035), however, the growth boom in non-OECD Asian economies (Other Asia), is accompanied with increasing trade surpluses.

Figure 4. Evolution of regional trade balances

Trade balance as percentage of regional GDP
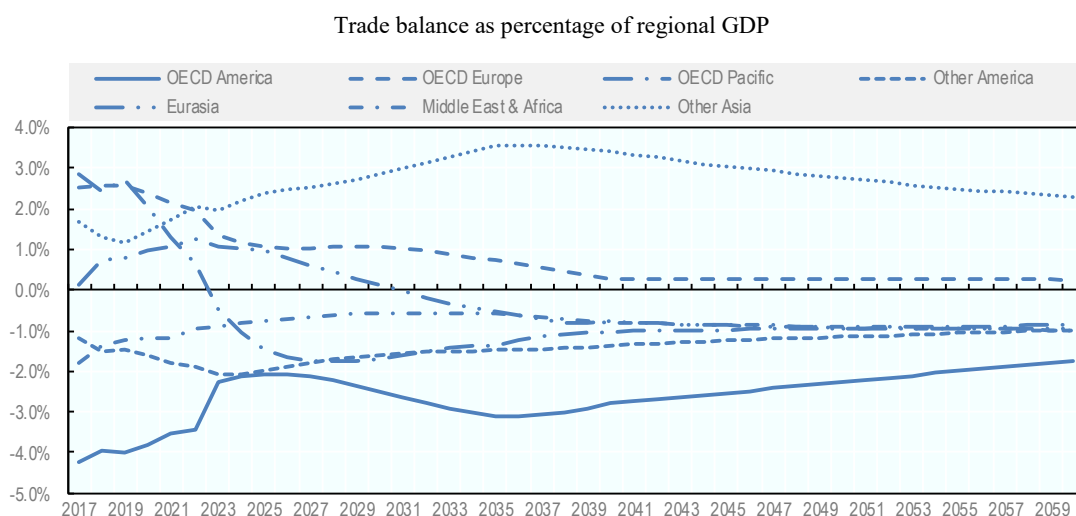
Source: OECD ENV-Linkages model.

The profile of trade imbalances in the OECD Pacific region, comprising of Japan, Korea, Australia and New Zealand, is dominated by demographic and macroeconomic trends in Japan. Specifically, the ageing population in Japan correlates with declining savings rates.[6] As investments decline less, this is facilitated by a decline in the trade balance. Korea is projected to undergo a similar process, but more gradually, and with a less pronounced impact on the aggregate region.

Figure 5 shows the sectoral composition of global exports. As consumption patterns of all regions become more oriented towards services, and e.g. industrial production requires more services as inputs, it is not surprising that trade in services gradually becomes a larger part of total exports. This comes largely at the expense of non-manufacturing industrial exports, mostly related to the low growth of trade in energy. Global exports of crude oil and petroleum products is projected to increase by 70% between 2011 and 2060, substantially slower than total exports; this trend is aligned with the projections of the IEA (2017[10]).

Figure 5. Projected composition of global exports

Shares in total exports
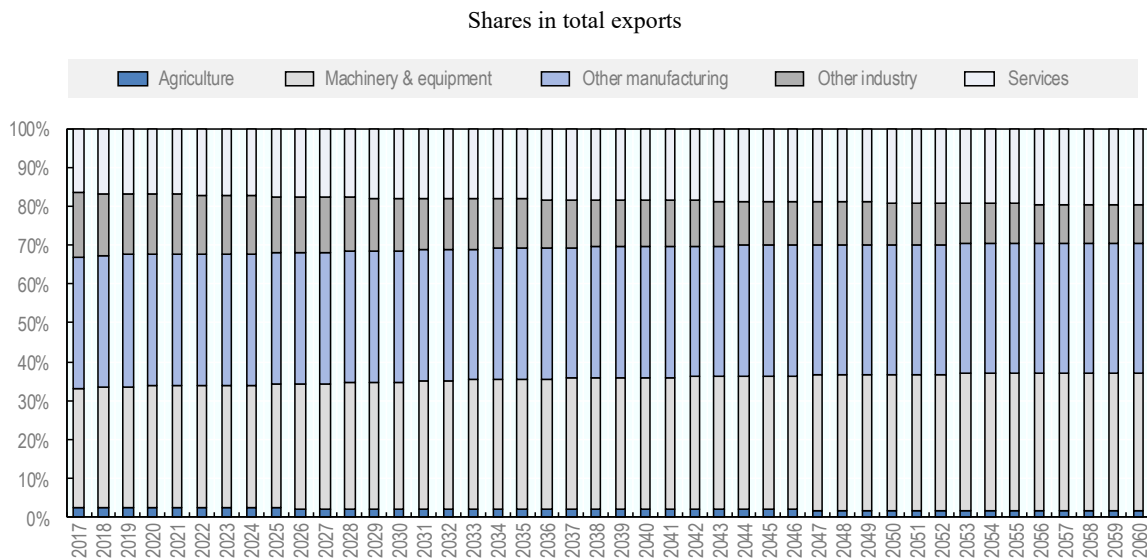
Source: OECD ENV-Linkages model.

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[6] These macroeconomic trends in the baseline projection are all aligned with the long-term OECD economic outlook (OECD, 2018[9]).

2.2. Trends in exports and imports of materials and recycling

Metals, non-metallic minerals and recycling products are the core commodities in the transition to a more resource-efficient and circular economy. Box 2 explains the main concepts in the modelling framework.

Box 2. Materials-related activities and commodities in the modelling framework

The modelling framework distinguishes between activities (production sectors) and commodities (goods and services). Production is measured at the activity level (see Table A.1 in Annex A for the full list of production sectors), separating e.g. processing of primary raw materials (input from the mining sector) and the reprocessing of secondary scrap materials (input from the recycling sector). Consumption and trade flows are measured at the commodity level. Primary material processing and secondary material reprocessing activities both produce the same commodity: the processed material.

The mining sector encompasses the extraction of materials (excluding fossil fuels extraction), including e.g. bauxite, copper ores, sand, gravel.

The metal sectors reflect the processing of these materials; for instance, the copper sector processes the copper ores it obtains from the mining sector to make copper products. Each metal sector is split into a subsector that processes primary materials and a subsector that processes secondary materials (see Annex B for information on the relative sizes of these subsectors).

The non-metallic minerals sector reflect the processing of non-metallic minerals (analogous to the metals processing sectors). In line with OECD (2019[4]), no split is made between primary and secondary subsectors.

The recycling sector generates "recycling products" including scrap, which can be used as secondary material into a reprocessing sector (see OECD (2019[4]) for details on the modelling of recycling for metals in ENV-Linkages). The modelling framework does not specify a separate waste sector, and therefore does not distinguish waste as a commodity. This implies that a full life-cycle analysis of materials flows is not possible within the modelling framework.

OECD (2019[4]) provides more details on the specification of the modelling framework and the rationale for the sectoral and commodity disaggregation.

Currently, metals reflect almost 6% of total global exports, minerals a little less than 3% (Figure 6). Iron and steel is the largest group of metals in terms of exports, followed by mining products (which excludes coal and other extracted fossil fuels, but includes the mining of metal ores). These two categories are, however, projected to grow less rapidly than other categories (a 2.8 and 2.2 fold increase between 2017 and 2060, respectively), and thus their share in total exports declines over time. Recycling products, which include scrap metal, reflect less than 0.1% of total exports (not least because of low prices for many recycling products and limited international trade flows), but grow more rapidly (3.2-fold increase). These trends are the result of interactions at the sectoral level, where overall

demand growth is combined with structural change (servitisation) and technological change (improved materials efficiency) to lead to an increase in materials use that is less rapid than the growth in GDP. OECD (2019[4]) describes these trends in detail, and translates them to the use of specific materials in kilotonnes.

Figure 6. Global exports of materials

Sectoral exports in bln USD (2011 PPP exchange rates)
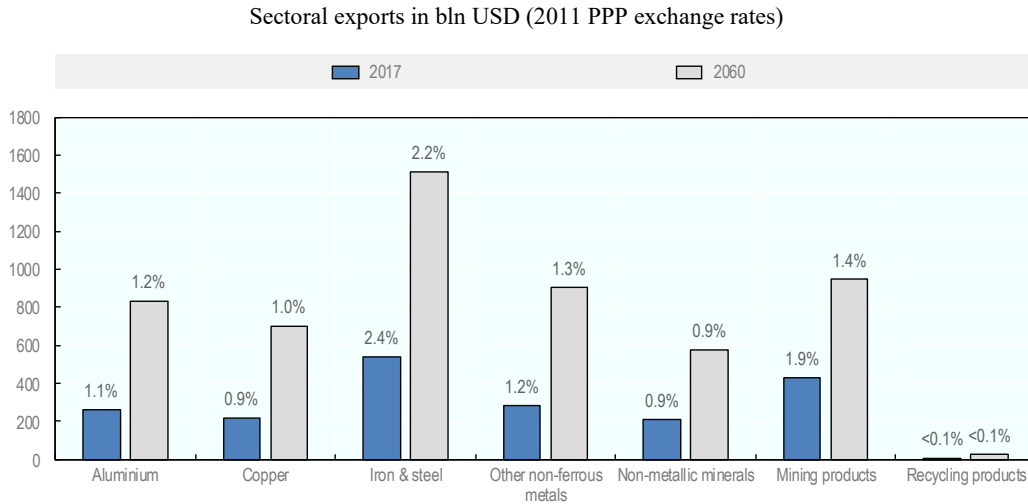
Note: The numbers above the bars reflect the share of the sector in total exports.
Source: OECD ENV-Linkages model.

Figure 7 presents the regional composition of international trade in metals and non-metallic minerals. The same general patterns as seen in Figure 3 apply: a dominance of the OECD in current trade flows, but increasing shares for emerging economies and developing countries until 2060.

Figure 7. Regional composition of trade in materials

Shares in global exports of the selected commodities

Panel A. Metals
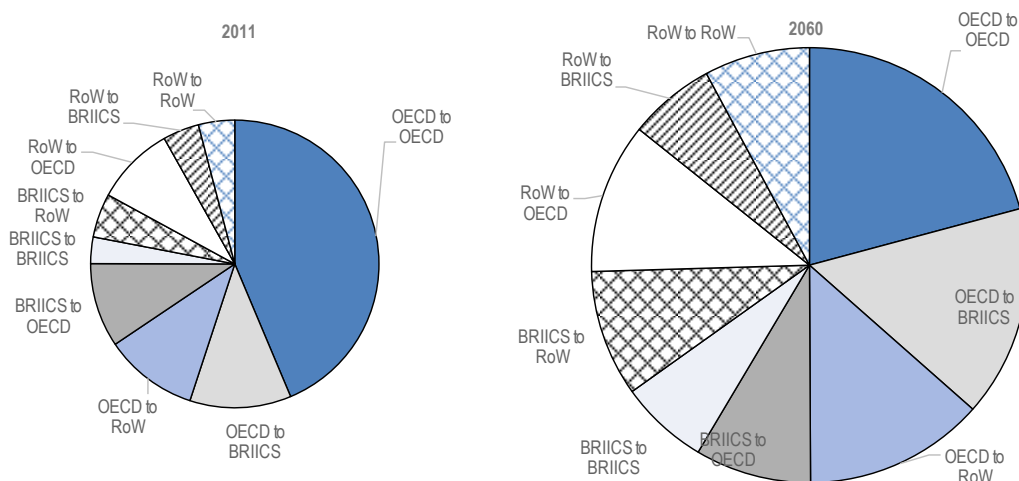
Panel B. Non-metallic minerals
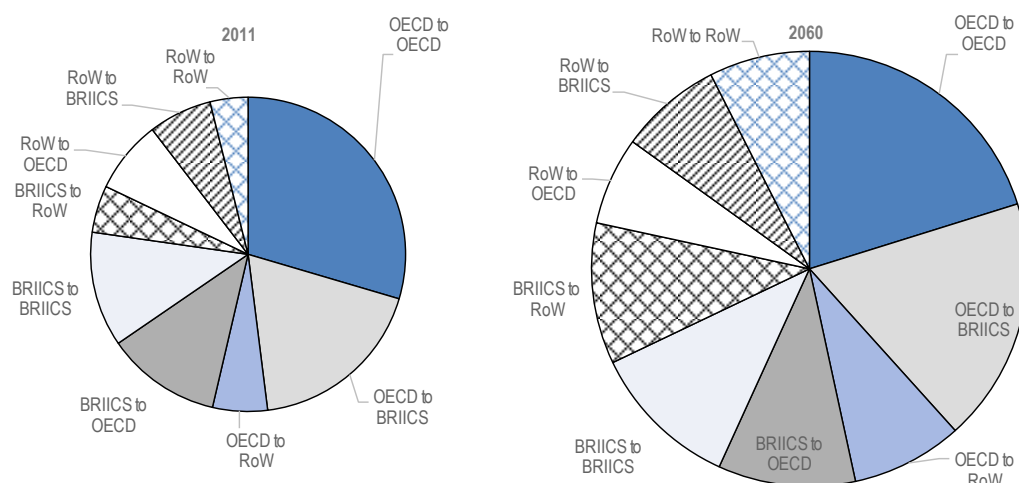
Notes:
- *Metals* includes trade in iron and steel, aluminium, copper and other non-ferrous metals; *Minerals* includes non-metallic minerals and mining products.
- Shares for recycling products are not shown due to their relatively small traded volumes. The sizes of the charts are adjusted to reflect growth between 2011 and 2060, but do not reflect the relative sizes of metals exports compared to minerals exports.

Source: OECD ENV-Linkages model.

Finally, Figure 8 presents the revealed comparative advantage (RCA; defined as the ratio of the share of a commodity in a region's exports to the share of that commodity in global exports) of the regions for the materials-related commodities.[7] Countries with large, diversified economies and large, diversified export flows, have relatively low RCA values. Countries that specialise in materials exports (or more precisely exports of materials-related commodities) are more vulnerable to changes in global demand for materials. South Africa, Chile, the non-EU OECD European countries and Russia have a high RCA in metals, while Chile, Australia and Brazil have a high RCA for non-metallic minerals (mostly mining products).[8] Trade in minerals is more specialised than trade in metals; this is not surprising as metal trade flows are twice as large as mineral trade flows (see Figure 6). Figure 8 presents values for 2060, as these are most helpful in explaining the impact of an RE-CE policy package on international trade flows.[9]

Figure 8. Regional revealed comparative advantage for metals and minerals in 2060

Ratio of the share of a commodity in a region's exports to the share of that commodity in global exports
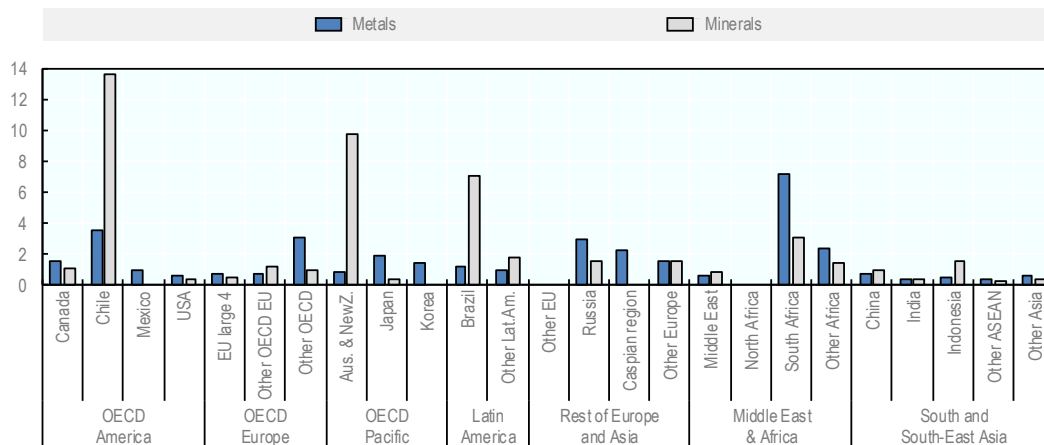
Notes:
- *Metals* includes trade in iron and steel, aluminium, copper and other non-ferrous metals; *Minerals* includes non-metallic minerals and mining products.
- RCA values for exports that reflect less than 1% of global exports of that commodity are excluded. Values above unity denote a relative specialisation of the region in that commodity. Recycling products are excluded from the table as trade volumes are too small to create meaningful indicator values.

Source: OECD ENV-Linkages model.

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[7] In principle, the analysis of revealed comparative advantage is most insightful at the individual commodity level. Detailed results are provided in Table C.1 in Annex C.

[8] Australia is also the biggest exporter of iron ore, but in terms of value that is only a minor part of the total iron and steel group of products; therefore, the Australian RCA for metals is not as high as one might have expected.

[9] While the numbers change over time, there are very few cases where the RCA in 2017 is below (above) unity, and above (below) unity in 2060.

3. Consequences of the RE-CE policy package on trade patterns to 2040

3.1. Macroeconomic and trade consequences of the policy package

The consequences of a broad RE-CE policy package will be wide-ranging. First, in a comprehensive package, some instruments may directly target material trade flows, e.g. restrictions on international trade in waste and recycling products. Secondly, domestic policies change relative prices and thus the competitive position of the various countries on both domestic and global markets. As explained in the introduction, the purpose of this section is to numerically assess the second type of consequences using a hypothetical, stylised policy package that aims at illustrating the mechanisms at work in the transition to a more resource efficient, circular economy. As the policy package is stylised, it abstracts from a number of important regional differences, not least in the environmental consequences of the extraction and production of materials-related commodities, and – to some extent – also in the specification of regional differences in production methods. Feedback effects from environmental degradation on economic activity (and thus GDP) are also not considered in these calculations. Thus, the results presented below should be interpreted with sufficient care.

The macroeconomic, sectoral and international consequences of a global implementation of the policy package are all linked: given the different endowments of countries, their different specialisation patterns, and their different income levels, a uniform policy shock on all regions will cause some products to become cheaper, while others become more expensive to produce. This causes changes in relative prices on domestic markets, leading to changes in the composition of demand. As these changes in costs, and the resulting changes in demand patterns, differ across regions, the competitive position of countries on the global market start to shift as well. Thus, export and import flows are adjusting to the new competitiveness situation.

The macroeconomic and macro trade effects can be summarised by looking at how GDP, exports and imports differ between the baseline projection and the simulation of the policy package. Figure 9 presents these deviations from baseline for the year 2040 (the assumed year of full implementation of the policy package).

Figure 9 shows that the policy package leads to small negative impacts on GDP in all regions. Indonesia, a major metals and mining products exporter, is most significantly affected with a projected loss of 0.9% of GDP in 2040. At the global level, the loss in 2040 is limited to 0.2% of GDP. The small negative effect of the preliminary policy package should be seen in the context of the narrow set of policies: the combination of taxes and subsidies distort the economy, and the underlying externalities that these instruments try to correct (such as the environmental consequences of materials extraction and use), as well as changes in material supply risks, are not included in the modelling framework. As McCarthy, Dellink and Bibas (2018[1]) show, the existing literature suggests that more positive results might be expected from a broader policy package that also includes policies to stimulate materials efficiency improvements. Thus, the results presented here are an indication of a lower bound on the macroeconomic impacts.

Figure 9. Effects of the policy package on GDP and trade volumes
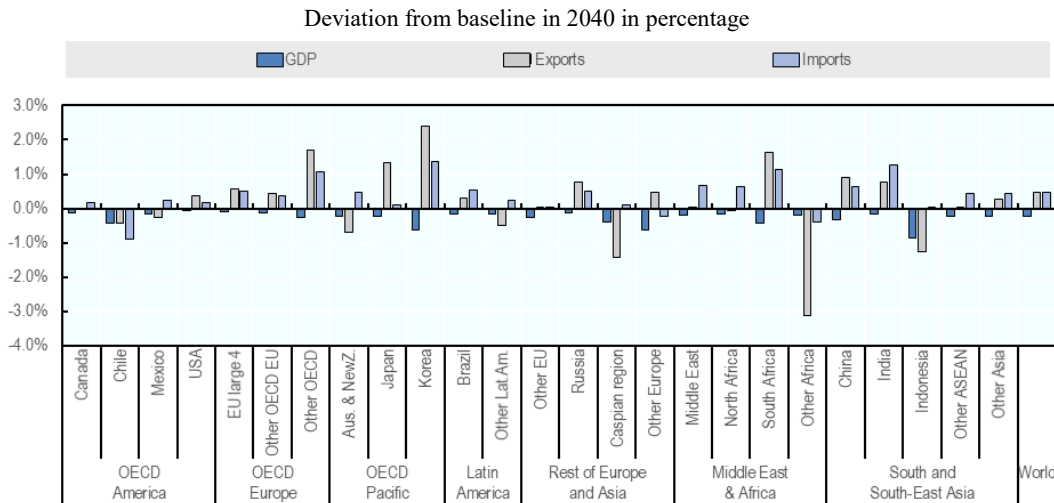
Deviation from baseline in 2040 in percentage

Note: Exports and imports reflect all goods and services, not only materials.
Source: OECD ENV-Linkages model.

At the regional level, changes in overall exports are only weakly correlated with the domestic GDP impact of the policy package. As expected, changes in domestic demand have only very little impact on production for foreign demand. Nonetheless, changes in regional exports and imports are in many cases of the same order of magnitude as changes in domestic economic activity (as exemplified by GDP). The correlation between GDP impacts and imports is the result of two opposing effects: (i) a smaller GDP loss implies a smaller loss of demand and therefore also a smaller loss of demand for imported goods; (ii) negative GDP impacts reflect increased domestic production costs, and thus a loss of competitive position vis-à-vis international competitors on both domestic and international markets.

Overall impacts on exports and on imports are more strongly correlated. This is partially driven by the model assumption of an exogenous trade balance at the regional level, which does not allow both volumes to drastically diverge.[10] Thus, as global export volumes increase, imports also increase across the board. This is more easily visible in Figure C.2 in Annex C, which plots the impacts on exports and imports as a scatterplot.

Global trade increases a little bit more than in the baseline (+0.5% by 2040 compared to baseline). Savings and investments are slightly more negatively affected than consumption. The growth in trade is stimulated by this shift as consumption is on average more trade-intense than investment. Furthermore, the global implementation of the policy package leads to a shift in comparative advantage of the directly affected production sectors (mining, materials processing and recycling), with a net effect that production becomes more geographically concentrated and trade volumes of materials-related commodities increase. Specifically, the commodities that are most heavily affected by the policy, i.e. materials processing, are the ones that show a significant reduction in production and simultaneously an increase in global trade (Figure 10). This is, however, partially biased as

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[10] As relative prices change and the sectoral composition of exports and imports differs, some divergence is however possible even under a fixed trade balance assumption.

the export flows include exports of the secondary (reprocessing) subsectors, which are projected to increase significantly.

Figure 10. Effects of the policy package on sectoral output and exports

Deviation from baseline in 2040 in percentage
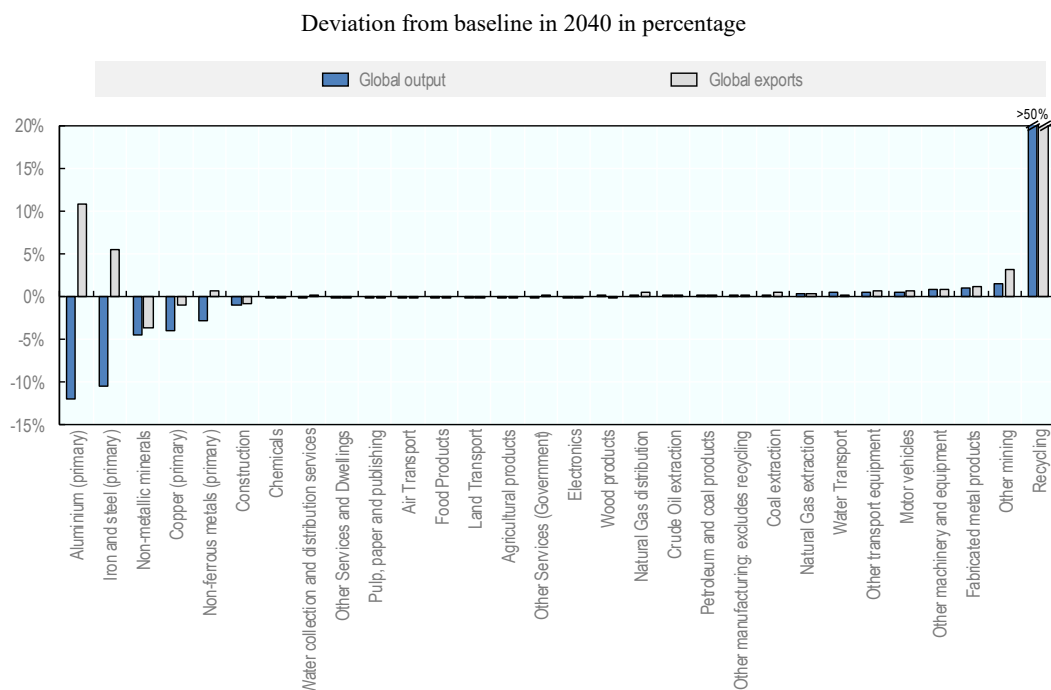
Note: Output is measured by activity, exports by commodity; thus exports of materials comprise both primary and secondary production, while output changes are presented only for primary production.
Source: OECD ENV-Linkages model.

In Chile, substantially reduced exports of copper (both unprocessed and processed) affect overall export volumes and hurt the domestic economy (and thus lowers GDP). Not surprisingly, the exchange rate vis-à-vis the USA also deteriorates (Figure 11).[11] Similar reductions in GDP, exports and exchange rates occur in other regions, not least the Caspian region, Sub-Saharan Africa (excl. South Africa; label "Other Africa" in the figure) and Indonesia. All of these regions have a more than average revealed comparative advantage in export of materials-related commodities.

Other regions, including Other OECD, Korea, China and India can combine a GDP loss with increased exports. These countries specialise in other commodities and benefit from the shift in global demand towards these commodities. South Africa is a special case: despite specialising in materials exports, and a deterioration of the exchange rate, it is projected to boost overall export levels. In contrast to Chile, the projections show that South Africa can boost its secondary copper production (see Section 3.2 below) and turn that into an export market.

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[11] A lack of refinement in the modelling of the associated economic processes, not least bilateral trade flows and the ease of switching between sources for imports, may overstate the impacts of the global policy package on specific countries that have very specialized trade patterns.

Figure 11. Effects of the policy package on regional exchange rates

Deviation from baseline in 2040 in percentage
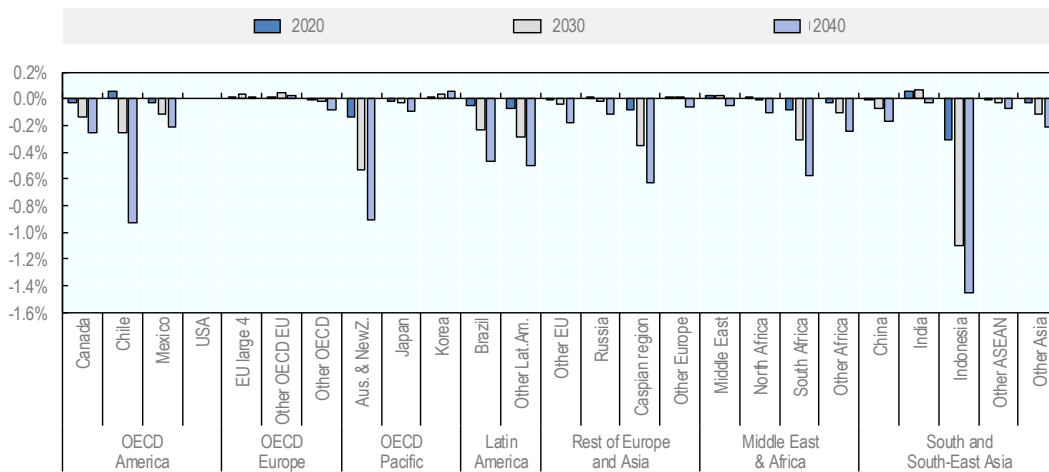
Note: Exchange rates vis-à-vis the USA are expressed in 2011 PPP USD.
Source: OECD ENV-Linkages model.

3.2. Consequences of the policy package for trade in materials-related commodities

In order to understand the changes in trade flows for the materials-related commodities, understanding of the changes in the activities that provide these commodities is helpful. As panel A of Figure 12 shows, the (stylised) policy package induces a significant drop in production of primary metals (compared to baseline, not compared to current levels), but the increase in secondary metals more than compensates that.[12] For example, global aluminium production increases by more than 10%, but the share of secondary production increases from slightly less than one-third of total production in the baseline projection for 2040 to slightly less than equal to primary production (i.e. slightly less than half of total production).[13] For iron and steel, a similar effect occurs, albeit a bit less strong. For copper and other non-ferrous metals, total production stays roughly unchanged, but with an increased share of secondary. Given the very small projected shares of secondary in the baseline, total secondary production of copper and other non-ferrous metals remains very limited. But in percentage terms, the increase in the share of secondary is larger in the sectors that do not already have well-established secondary production sectors (copper and other non-ferrous metals).

For the non-metallic minerals, mining and recycling sectors, the model does not distinguish a secondary production sector (OECD, 2019[4]). The processing of non-metallic minerals is projected to decline by 5% (panel B of Figure 12), while output of the mining sector stays roughly constant (+1% from baseline levels).[14] The biggest increase is observed for

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[12] Throughout the paper, terms such as "secondary metals" and "secondary production" are loosely used to reflect production methods using secondary materials as input.

[13] This result implicitly assumes that supply side constraints are reduced, and that higher effective rates of recycled content are achieved. OECD (2019[4]) discusses this in more detail.

[14] The mining sector provides inputs for metals and minerals processing sectors, but also encompasses other mining activities, such as uranium extraction.

recycling, which increases by around two-thirds; this growth of the recycling sector roughly matches that of the secondary metals production sectors.

Figure 12. Effects of the global policy package on global production of materials-related commodities

Value of global production in 2040 in bln USD

Panel A. Metals

Panel B. Non-metallic materials-related commodities
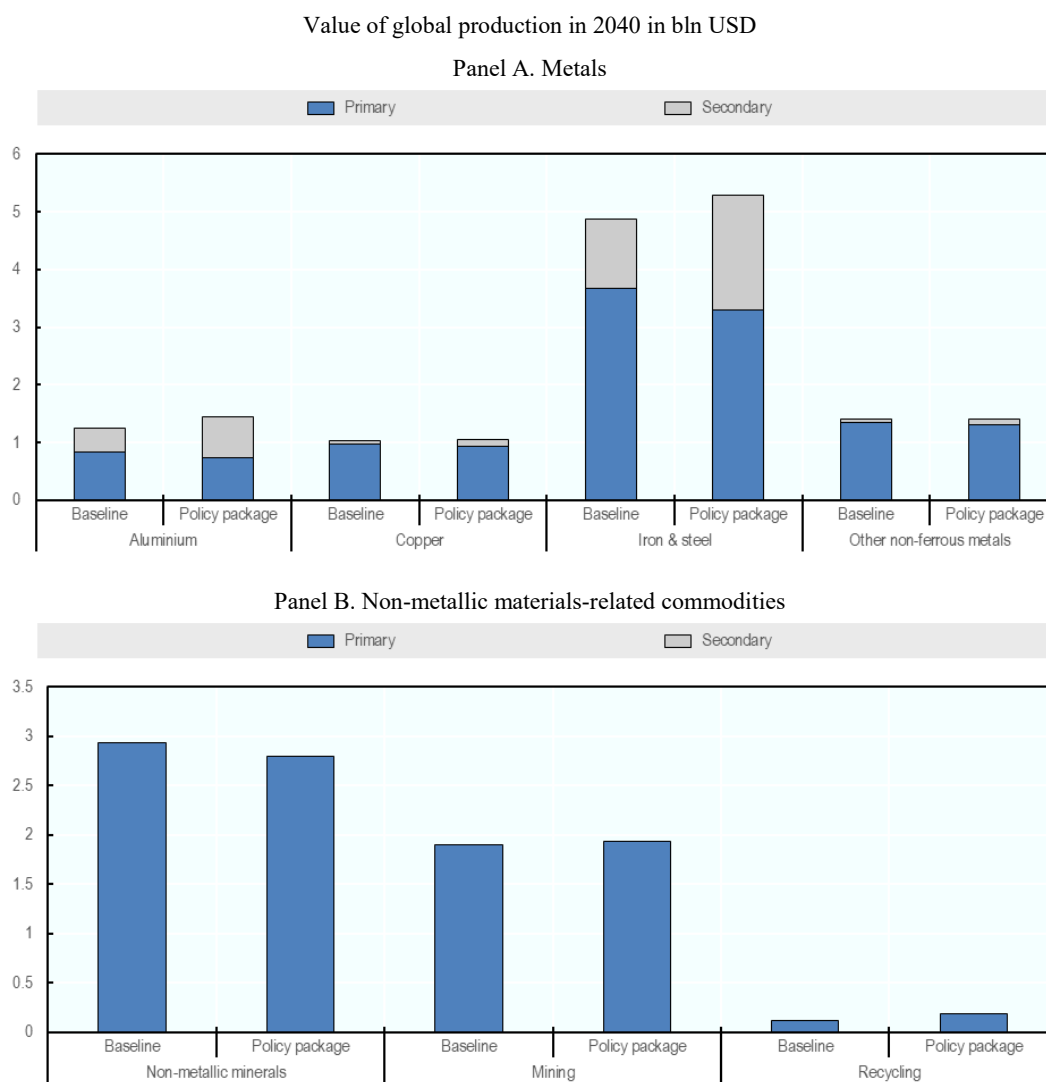
Source: OECD ENV-Linkages model.

OECD (2020, forthcoming[6]) teases out in detail what this policy package implies for physical materials use; Figure 13 shows more aggregated results. In most regions, reductions in metals use are stronger than reductions in the use of non-metallic minerals. This reflects higher tax rates as well as the availability of secondary materials. There are a few exceptions where overall demand increases and the need for primary metals as co-input for the reprocessing of scrap leads to an increase in primary metal demand; see OECD (2020, forthcoming[6]) for a detailed explanation. For non-metallic minerals, there are no substitutes and all reductions have to come from input substitution in the demand sectors, plus contraction of output of these sectors. At global level, the reductions in materials use are significant, but insufficient to completely reverse the baseline trend of increasing

materials use over time: metals and non-metallic minerals use in 2040 in the policy scenario is still 12% and 33% above 2017 levels, respectively.

Figure 13. Effects of the global policy package on materials use
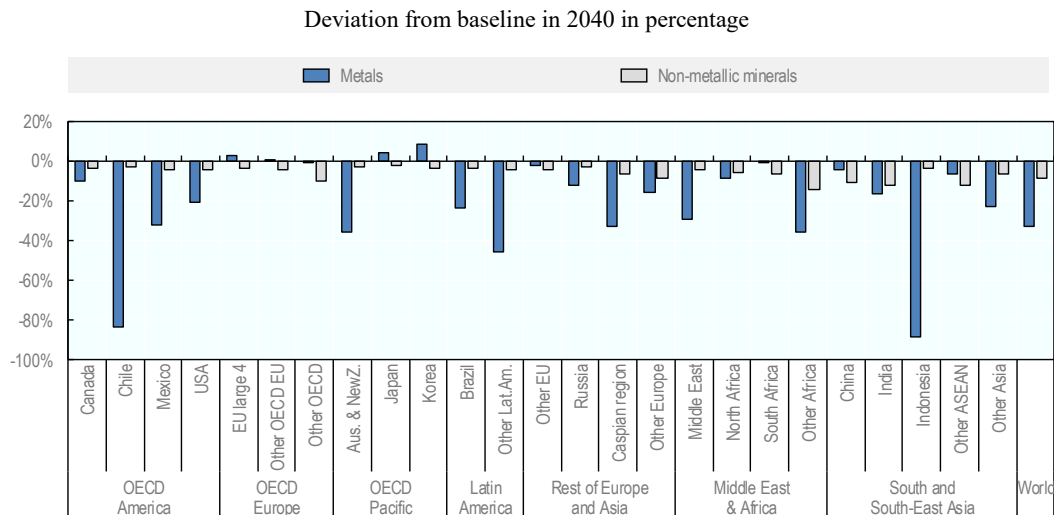
Deviation from baseline in 2040 in percentage

Note: *Metals* includes trade in iron and steel, aluminium, copper and other non-ferrous metals; *Minerals* includes non-metallic minerals and mining products.
Source: OECD ENV-Linkages model.

The increased production using secondary metals also boosts metal exports (Figure 14).[15] But as explained above, a globally implemented policy package does not leave competitiveness unchanged. In general, the materials tax rates will disproportionately affect materials processing sectors in regions with relatively low productivity, i.e. where materials input costs reflect a large share of total production costs. As a consequence, production will shift towards the more materials-efficient producers.

Thus, while global aluminium exports increase by around 10%, metals exports by the OECD America group of countries and by the European OECD countries are significantly higher.[16,17] This partially counteracts the declining share of OECD exports in the baseline projection. In the OECD Pacific group, increased exports from Japan and Korea are outweighed by reductions in exports from Australia and New Zealand.

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[15] As mentioned above, exports are measured at the commodity level (e.g. aluminium products), not at the level of the activities that produce them (e.g. primary aluminium processing and secondary aluminium reprocessing).

[16] The results are more diverse at the 25 region level: in OECD America, the largest increase is projected for the USA, with increases in the other countries in this group much closer to the global average.

[17] The time profile of the changes in global exports are presented in Figure C.3 Figure C.1 in Annex C, while Figure C.1Figure C.3 in Annex C reports changes in regional trade balances for metals and minerals for 2040.

Figure 14. Effects of the global policy package on metals trade flows

Deviation from baseline in 2040 in percentage
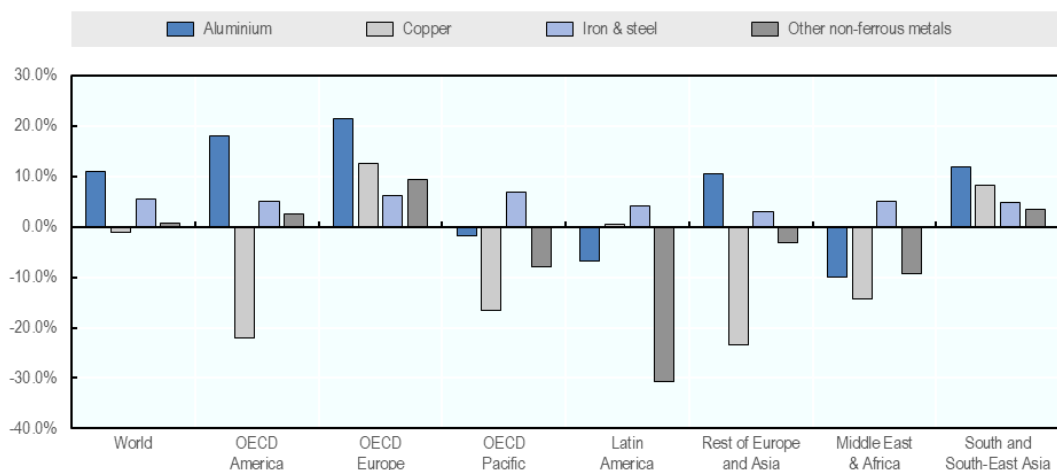
Panel A. Impacts on exports

Panel B. Impacts on imports
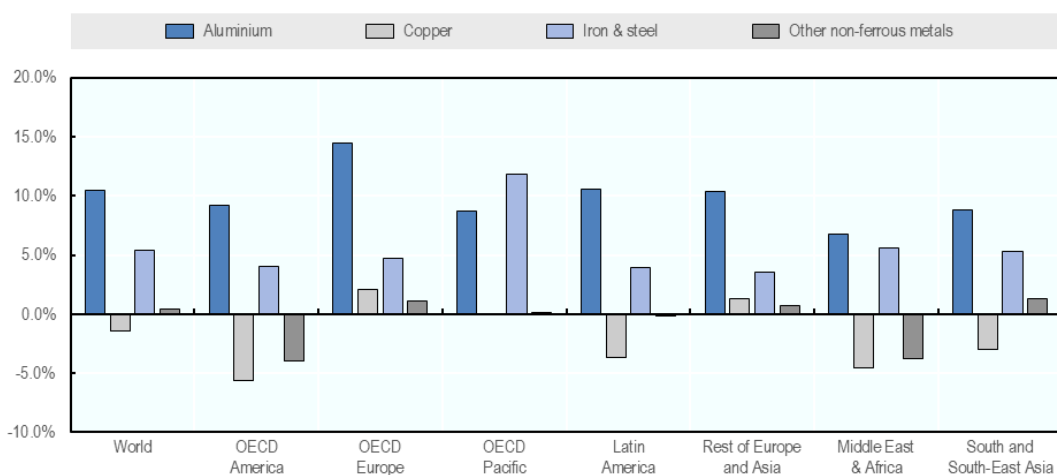
Note: Changes in trade flows are calculated at the 25 region level, then aggregated into the larger regional groups. Annex C provides the detailed 25-region results.

Source: OECD ENV-Linkages model.

Bigger reductions in aluminium exports (compared to the baseline) are projected for selected countries in Latin America and Middle-East and Africa, not least Brazil and Sub-Saharan Africa. The increase in South and South-East Asia comes primarily from China and India, while Indonesia sees a reduction in exports of metals. All the countries where the policy package erodes the aluminium market share (Australia and New Zealand, Brazil, Indonesia) are confronted with a decline in their exchange rate.

Global exports of copper and other non-ferrous metals remain roughly in line with the baseline projection, but this hides significant re-allocation of exports towards OECD Europe and South and South-East Asia, away from the other regions, including copper in Chile, and other non-ferrous metals in Latin America. These regional changes reflect the shift from primary to secondary metal production, which is much more evenly spread across countries. Furthermore, these figures represent processing industries, not extraction of the raw material (which is part of the mining industry). The model finds least-cost solutions depending on how relative prices and production costs shift between regions, with a fair degree of flexibility on international trade. For iron and steel, the shift in exports across regions is much less pronounced, reflecting the larger and more mature nature of this market, where the ratio between global exports and global production is significantly smaller than for the non-ferrous metals commodities.

As expected, the regional variations in imports are much smaller than those in exports. With some minor variations, imports of aluminium and iron & steel increase in all regions. For copper and other non-ferrous metals, where global changes in trade flows are very small, there are a few significant exceptions: an increase in copper imports in OECD Europe (as copper production uses copper as one of the inputs, the scaling up of copper production in this region also leads to increased demand for imported copper) and in Rest of Europe and Asia (specifically the Caspian region, where domestic production and exports decline significantly below baseline levels). In OECD America and Middle East & Africa, imports of non-ferrous metals decline. For the former group, reduced non-ferrous metal imports by the USA is dominant, while for the latter both the Middle Eastern and North African countries reduce their imports as domestic production gains competitiveness.

The non-metallic minerals commodities are generally less traded than metals: the ratio of global exports to global production is less than half that of the combined metals sector. This implies that more of the policy shock on non-metallic minerals is weathered domestically, and changes in export patterns are more uniform than for the more volatile metals (Figure 15, panel A). The boost in exports of mining and recycling products are also quite evenly spread across regions. The large increase in trade of recycling products should be seen in the context of the relatively small baseline trade volumes, and does not appear as dramatic when expressed in trade volumes. Not surprisingly, this extends to imports as well (Figure 15, panel B).

Figure 15. Effects of the global policy package on non-metallic materials-related trade flows

Deviation from baseline in 2040 in percentage

Panel A. Impacts on exports

Panel B. Impacts on imports

Note: Changes in trade flows are calculated at the 25 region level, then aggregated into the larger regional groups. Annex C provides the detailed 25-region results.
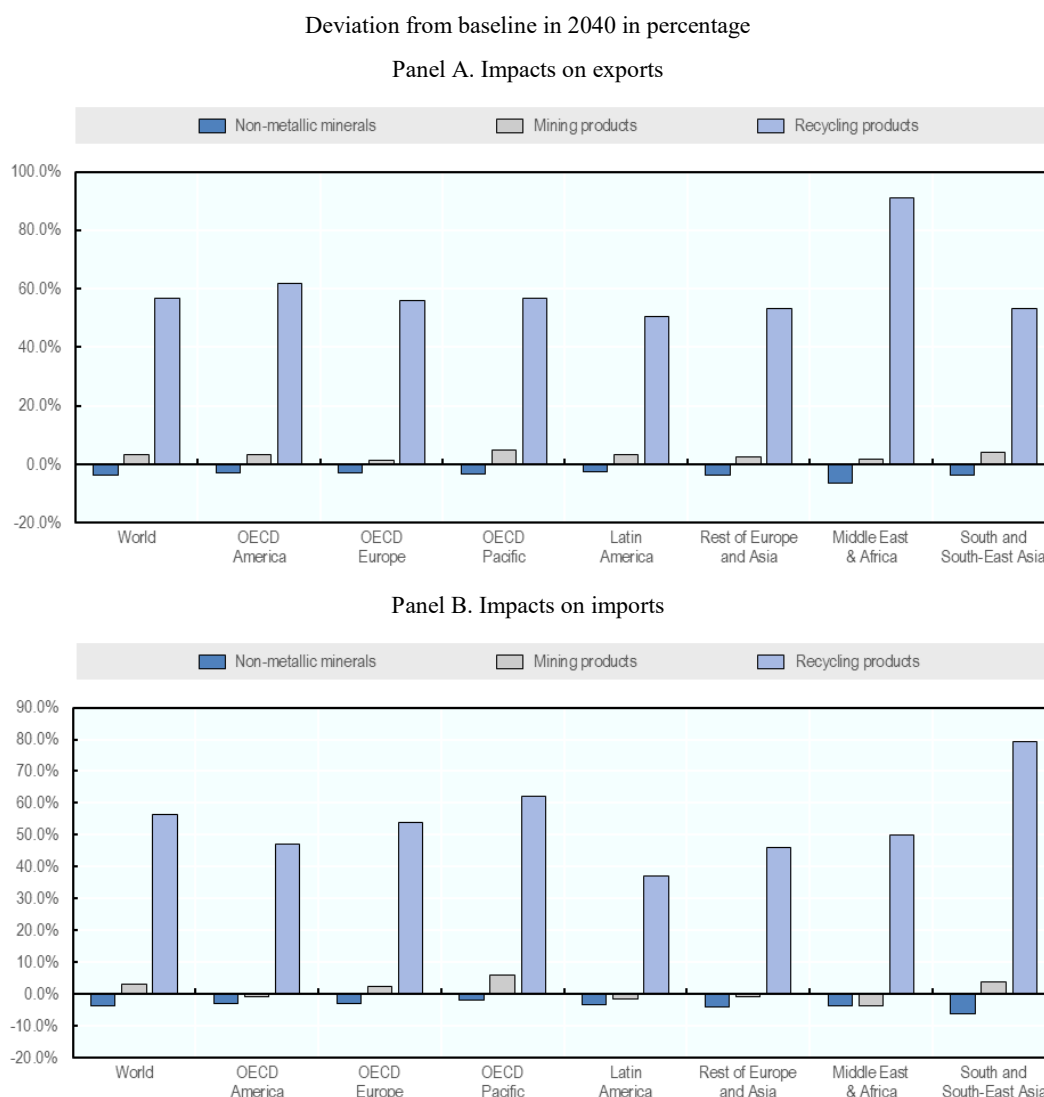*Source:* OECD ENV-Linkages model.

With one major exception, the regional correlation between exports and imports of materials-related commodities is about as strong as for total trade flows (Figure 16). This is not a priori expected, as the trade balance assumption that restricts divergence of total exports and imports does not apply at the sectoral level, although of course global exports should still equal global imports. As with total exports, most regions are in the upper right-hand quadrant, i.e. with increasing exports and imports. The regions in this quadrant generally see their economies – or at least their metal production sectors – boosting, with increased competitiveness on the international market and demand growth on the domestic market. There are several regions in the top left quadrant, with Indonesia as the outlier with

strong reductions in exports and strong increases in imports.[18] Regions in this quadrant are projected to have domestic materials-related production sectors that lose competitive position on both domestic and international markets. Countries in the bottom-left quadrant tend to have a contraction of the economy, with lower production and trade levels. Finally, in the bottom right quadrant are the regions where domestic producers gain competitive position on both domestic and international markets for materials-related commodities without significantly boosting overall demand levels. There are very few regions in this quadrant, as the boost that the improved competitiveness brings to the domestic economy tends to increase overall demand, which in turn boosts the level of imports; thus regions in the top-right quadrant may see a decline in the import share of demand but an increase in the level of imports.

Figure 16. Correlation between exports and imports of materials-related commodities
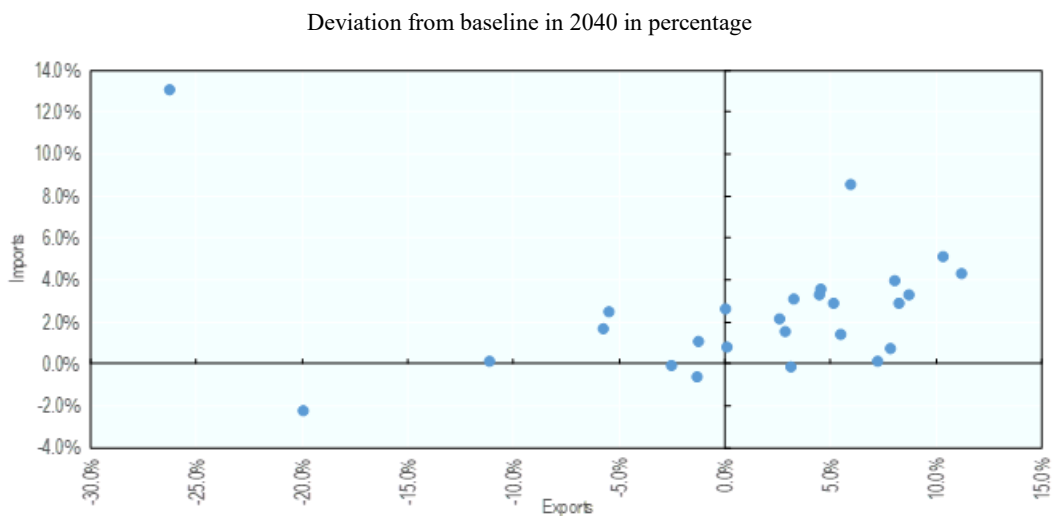
Deviation from baseline in 2040 in percentage

Notes:
- *Metals* includes trade in iron and steel, aluminium, copper and other non-ferrous metals; *Minerals* includes non-metallic minerals and mining products.
- Each dot represents a region.
Source: OECD ENV-Linkages model.

Indonesia is the clear outlier on the top left of the graph. It is a non-ferrous metals exporter (but iron and steel importer), and the domestic implementation of the policy package leads to a significant loss of competitive position on both the domestic and international markets for non-ferrous metals; see also the decline in the exchange rate that is required to balance the deviations in the value of exports and imports as reported in Figure 11.[19]

The importance of international trade in reducing materials use is further highlighted in Figure 17. The full reduction in global materials use that is induced by the policy package can be attributed to three distinct drivers: (i) a scaling of global production of processed

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[18] In fact, the result for Indonesia implies that the overall correlation coefficient between exports and imports is negative. Excluding this outlier brings the correlation coefficient to 0.6, close to the level of total exports and imports.

[19] Please note that the Indonesian ban on exports of unprocessed ores is not explicitly implemented in the model.

materials (*scale effect*); (ii) an improvement in the efficiency of materials inputs in this global production (*efficiency effect*); and (iii) regional shifts in production as well as shifts in the regional sourcing of the primary materials by the materials processing sectors (*trade effect*).

Figure 17. Effects of the global policy package on materials use by driver

Deviation from baseline in 2040 in percentage
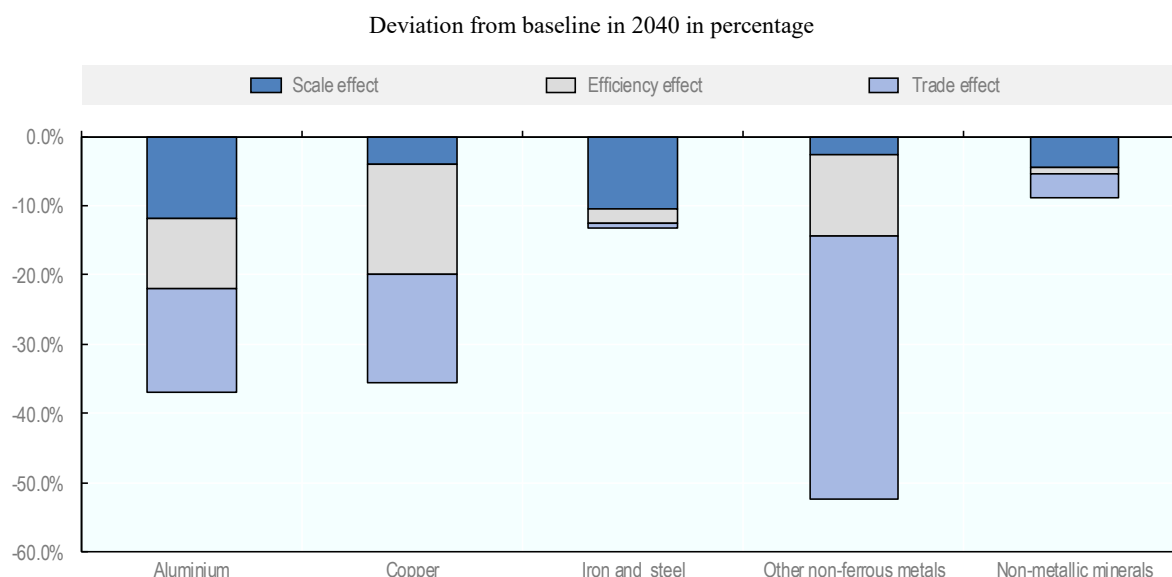
Note: The *scale effect* reflects the change in materials use resulting from a scale-down of global production of processed commodities; the *efficiency effect* reflects the change in materials use stemming from reduction in inputs of primary materials per unit of global production of processed commodities; the *trade effect* reflects the change in regional production of processed commodities plus the change in regional sourcing of primary materials inputs.
Source: OECD ENV-Linkages model.

The share of the trade effect – which comes from changes in the regional composition of production and from changes in input sourcing– is roughly one-third for aluminium and copper, much smaller for iron and steel and for non-metallic minerals, and substantially larger for other non-ferrous metals. The trade effect is small for iron and steel, as production technologies in this sector are more harmonised across countries, and thus the shift in competitive position between countries is much less pronounced (cf. Panel A in Figure 14). The possibilities to avoid paying for the materials taxes by shifting materials production (and the sourcing of inputs) towards less materials-intensive regions triggers a decoupling of materials use from production levels at the global level; this effect is especially strong for non-ferrous metals.[20]

3.3. Teasing out the international trade effects of the policy package

The results presented comprise the net effect of a range of different mechanisms. The international trade effects of the stylised policy package can be teased out further by decomposing the effects of the global implementation of the policy package into (i) a

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[20] A more detailed technical analysis at the level of specific non-ferrous metals may lead to more nuanced insights, especially if the aggregation of these metals in the analysis presented here implies an overestimation of the possibilities to substitute across regions for specific metals.

domestic policy effect, (ii) an international policy effect, and (iii) a trade interaction effect. The *domestic policy effect* is the effect on GDP of the respective region implementing the policy package, under the assumption that the other regions do not. Thus, domestic markets are affected but global trade is more or less unaffected. The second effect, the *international policy effect*, reflects the impacts of other countries implementing the policy package.[21] It is calculated through a simulation where all regions implement the policy package, except the respective region under consideration (e.g. for the international policy effect in Canada, all regions except Canada implement the policy package). Finally, the economic effects of joining both domestic and international policies will not equal the sum of these two effects, as they interact with each other through their effects on relative prices, which in turn affect the competitive position of all regions. This difference reflects the *trade interaction effect*.

The domestic policy effect tends to be dominant, and is in all regions negative for GDP (Figure 18): the taxes and subsidies implemented cause economic inefficiencies that reduce GDP below the baseline projection.[22] In contrast, the international policy effect tends to be positive: as other regions implement the policy package, their production costs decrease in most sectors – as a result of the reduced taxes on labour. This implies imports by the home country becomes cheaper, which is good for domestic demand. Furthermore, exporters of materials-related commodities in the home country can benefit from the production cost increases in the materials sectors in the other countries and thus reap a larger share of the global market. There are a few exceptions, though, especially for countries with a relatively low trade openness such as the USA (cf. Figure 2), where the foreign policies have negative spillover effects on the region that does not act.[23]

Finally, the trade interaction effects tend to be relatively small and positive. As these interaction effects primarily reflect the non-linearities in the economic system, they tend to increase with the stringency of the policy package; given the limited macroeconomic effects of the current policy package, these interaction effects are also very limited. They tend to be positive, as countries can adapt to both the domestic and international policy shocks simultaneously, exploiting the least-cost responses.

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[21] This effect is sometimes labelled as the "free rider incentive", but given that the policy package may boost the economy, that term could be misleading in this context.

[22] As argued above, and in more detail in OECD (2020, forthcoming[6]), this result is the consequence of not modelling the externalities that the policy package addresses.

[23] Close ties with the other EU countries can at least partially explain the negative international policy effect in the Other EU region. The assumption in this scenario that only the OECD members of the EU would implement the policy package – rather than the whole EU – is highly implausible, however.

Figure 18. Trade effects of the policy package on GDP
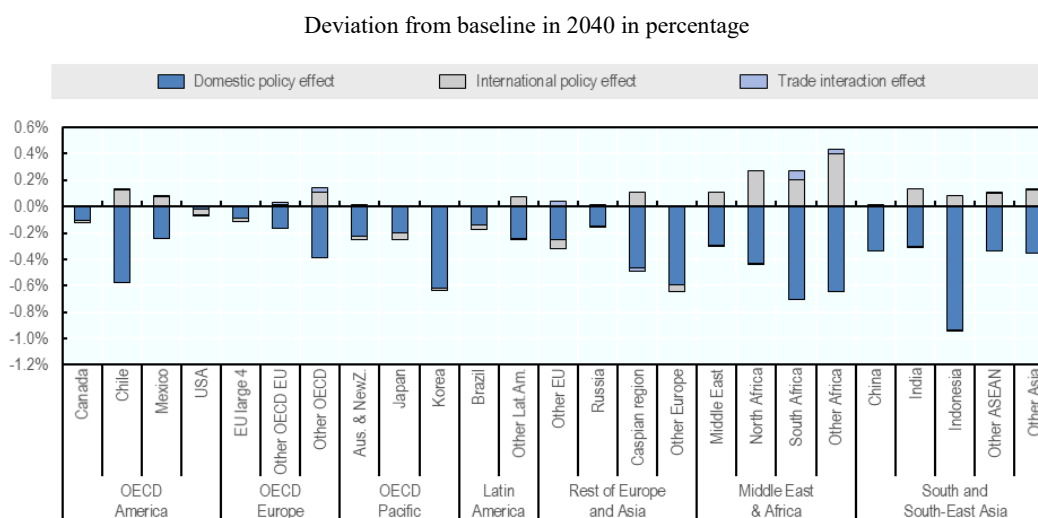
Deviation from baseline in 2040 in percentage

Note: The *domestic policy effect* reflects the effects of the respective region implementing the policy package alone; the *international policy effect* reflects the impacts of all other countries implementing the policy package; the *trade interaction effect* reflects the effects of combining both aspects simultaneously.
Source: OECD ENV-Linkages model.

The decomposition of the effects on trade flows is less straightforward (Figure 19). For materials importers, the policy package shifts global production to those sectors where the country has a comparative advantage (by lowering labour taxes in these sectors and increasing taxes on materials-related commodities), and the domestic policy package can boost exports. For countries that rely more on exports of materials-related commodities, the domestic policy package increases production costs and lowers competitiveness on the global market, leading to a reduction in export volumes.

Figure 19. Trade effects of the policy package on total trade flows
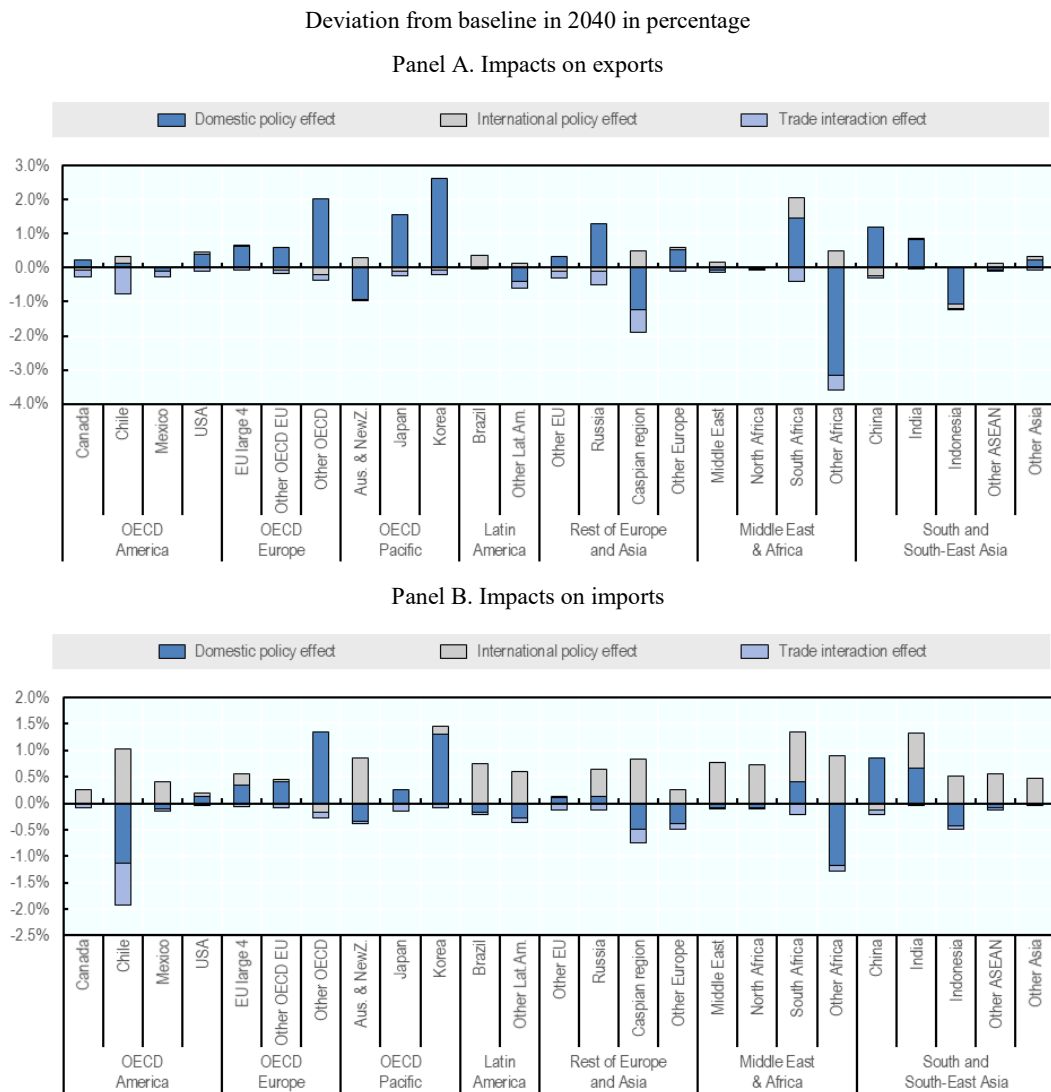
Deviation from baseline in 2040 in percentage

Panel A. Impacts on exports

Panel B. Impacts on imports

Note: The *domestic policy effect* reflects the effects of the respective region implementing the policy package alone; the *international policy effect* reflects the impacts of all other countries implementing the policy package; the *trade interaction effect* reflects the effects of combining both aspects simultaneously.
Source: OECD ENV-Linkages model.

The international policy effect on exports is limited in comparison with the effect of the domestic policy. Thus, even when all other countries implement the policy package, the export prospects of the country not acting remain rather undisturbed. In a few regions, notably those that export materials, the international policy effect is positive, indicating that the country can gain in competitiveness in materials-related commodities and expand its global market share.

The domestic policy effect on imports is similar to that of exports (panel B of Figure 19). Overall trade volumes are driven by macroeconomic consequences and the (strong) assumption on fixed trade imbalances, leaving little room for deviations between total exports and total imports (see Section 3.1). But the international policy effect is more

significant than for exports, and in most cases positive: as other countries implement the policy package, prices of most commodities become cheaper (not least through lower labour costs), boosting imports in the country that does not implement the policy. As imports of materials-related commodities represent only a small share of overall imports, the effect of higher costs in the primary materials-related sectors is outweighed by the lower costs in other sectors.

For both exports and imports, the trade interaction effect is negative, and in a few regions quite significant (Chile, the Caspian region, and Sub-Saharan Africa): having a global implementation of the policy package is worse for trade volumes than when the effects of the domestic and the international policy implementation are accounted for separately. This is most easily explained for imports: the positive international policy effect stems from the fact that cheaper imports are available, and domestic consumers shift somewhat from domestic to foreign providers. When the policy package is also implemented domestically, this shift in competitive position towards foreign producers vanishes, as domestic producers can also benefit from the lower labour taxes (and the relevant sectors benefit from the newly introduced subsidies). Thus, the global implementation partially takes away the positive international policy effect. As mentioned above, exports and imports must change together to maintain the exogenous trade imbalance; thus, the trade interaction effect for exports mimics that of imports.

Figure 20 takes this analysis deeper by looking at the changes in trade flows for materials-related commodities only. Many of the macroeconomic effects spill over to this sectoral level, with some positive and some negative domestic policy effects on exports, and largely negative trade interaction effects. The domestic policy effect is positive for imports of materials-related commodities in most regions (while it is mixed for overall imports); examples are Chile, Japan and Indonesia.

The more significant difference between the results for overall trade flows and materials-related commodities only is in the international policy effect. This effect is more positive for materials-related exports, highlighting the increased production costs for these commodities in the countries that implement the policy. The country that does not implement the policy can therefore grasp a larger share of the global market and boost its exports of these commodities. The positive international policy effect that occurs for total imports in many regions fails to materialise for imports of materials-related commodities. The same competitiveness story as for exports applies: domestic producers are at an advantage compared to foreign producers. But as the international policy effect has positive consequences for total domestic demand, and the lack of a domestic policy package does not steer demand away from the materials-related commodities, the smaller share of imports in total demand can be compensated by increased total demand, thereby leading to import levels that can – in some regions – still outstrip the baseline projection.

Figure 20. Trade effects of the policy package on materials-related trade flows
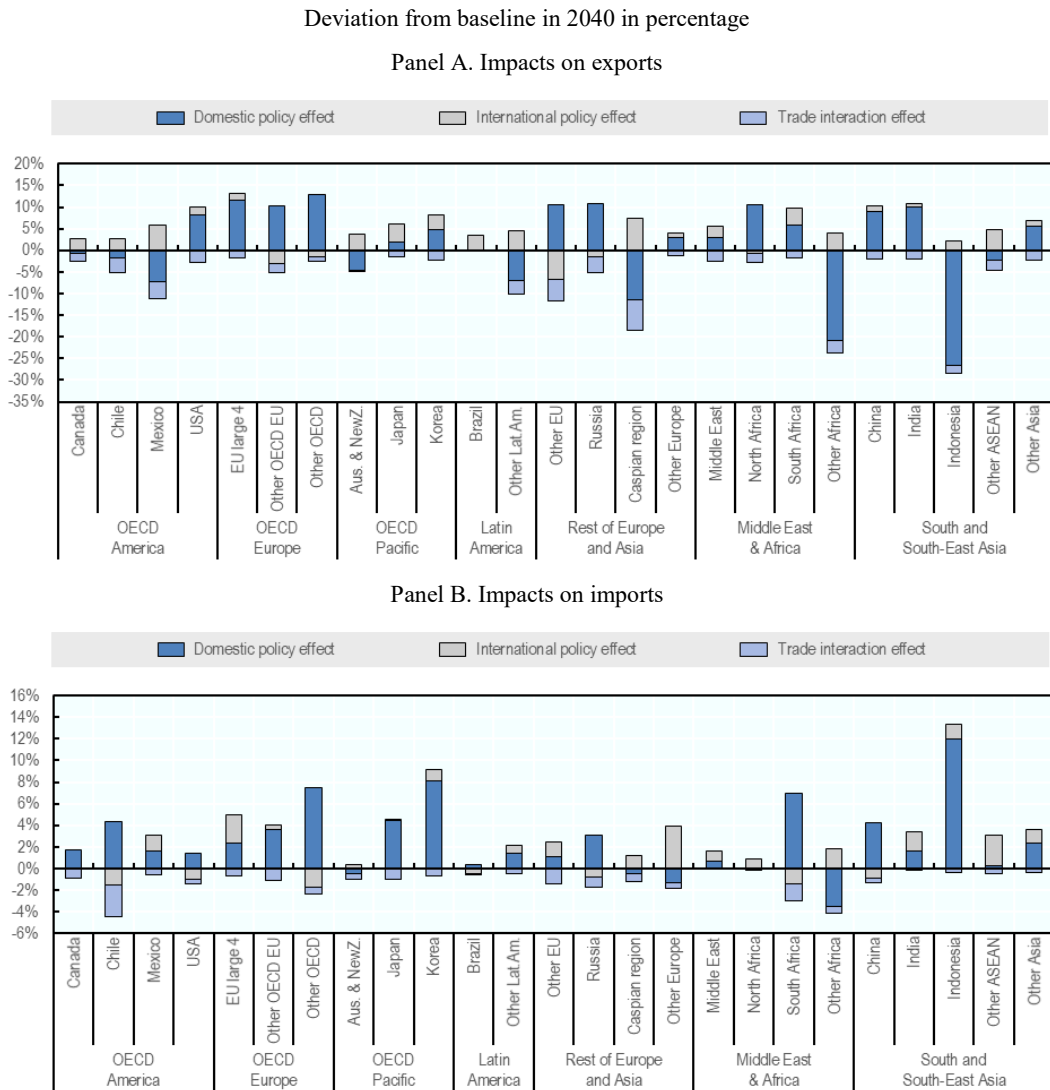
Deviation from baseline in 2040 in percentage

Panel A. Impacts on exports

Panel B. Impacts on imports

Note: The *domestic policy effect* reflects the effects of the respective region implementing the policy package alone; the *international policy effect* reflects the impacts of all other countries implementing the policy package; the *trade interaction effect* reflects the effects of combining both aspects simultaneously.
Source: OECD ENV-Linkages model.

This decomposition analysis clearly shows that the effects of a complex policy package on specific trade flows can only be understood through an analysis of the various underlying drivers, by teasing out the international trade effects, and by distinguishing between macroeconomic effects on GDP, effects on overall trade flows and sectoral effects on trade flows of materials-related commodities.[24]

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[24] Figure C.4 and Figure C.5 in Annex C highlight this by presenting the same graphs as in Figure 20, but with the macroeconomic, overall trade and sectoral trade effects separated.

4. Sub-global implementation of the policy package

The assumption in Section 3 that the stylised policy package will be implemented globally is a strong one; some countries have incentives to not implement the policy package. From a trade perspective, it makes sense to investigate a scenario where only countries that are net importers of materials implement the policy package. Specifically, the "Exporters excluded" scenario assumes that countries that are net exporters of materials (aggregated over the different materials) do not implement any part of the policy package described in Box 1. Table 2 shows which regions are net exporters of materials (for all materials together, aggregated in value terms).

A drawback of looking at the value of net trade flows is that a country may be a significant exporter of some materials, but importer of several others, with the value of imports outweighing the value of exports. Therefore, a second alternative scenario is constructed by looking at the revealed comparative advantage of countries in materials exports. Specifically, the "High RCA excluded" scenario assumes that countries which specialise in materials exports – more precisely those that have an RCA for all materials combined above 2 – are assumed not to implement the policy package. As shown in Table 2, the high RCA threshold is stricter than the net exporter threshold.

A third scenario of sub-global implementation of the policy package takes a finer granularity to identify net exporters. In this alternative scenario, net exporters of a specific material do not impose a tax on that material, but will impose the rest of the policy package. Specifically, the "Specific taxes excluded" scenario assumes that all countries implement the subsidies parts of the policy package, but the materials tax parts are only implemented when the country is a net importer of that material. This implies that in most countries, only some of the taxes on primary materials are implemented, while the subsidies to recycling and secondary metal production are implemented globally. The reduced labour taxes are also implemented globally, but for regions that exclude some of the primary materials taxes, the additional revenues raised will be smaller and hence the labour tax reduction will also be smaller.

Table 2. Overview of net materials exporters and countries with high RCA in materials

Projected net exports and RCA in 2040

		Net exporters of materials combined	High RCA for materials combined	Net exporter by material					
				Aluminium	Copper	Iron & steel	Other non-ferrous metals	Non-metallic minerals	Mining products
OECD America	Canada	+		+	+	+	+		+
	Chile	+	+	+	+			+	+
	Mexico	+			+	+		+	+
	USA					+			+
OECD Europe	EU large 4					+		+	
	Other OECD EU	+		+	+	+	+	+	+
	Other OECD	+	+	+	+		+	+	+
OECD Pacific	Aus. & NewZ.	+	+	+	+	+	+		+
	Japan	+		+	+	+	+	+	
	Korea					+			
Latin America	Brazil	+	+	+	+	+	+		+
	Other Lat.Am.	+		+	+		+		+
Rest of Europe and Asia	Other EU			+	+	+	+		
	Russia	+	+	+	+	+	+		+
	Caspian region	+		+	+		+		+
	Other Europe	+				+			+
Middle East & Africa	Middle East								
	North Africa								
	South Africa	+	+	+	+	+	+		+
	Other Africa	+	+	+	+		+		+
South and South-East Asia	China					+		+	
	India							+	
	Indonesia	+		+	+		+		+
	Other ASEAN								
	Other Asia								+

Note: The threshold for a high RCA is 2, i.e. a specialisation in materials exports that is twice the global average.

Countries with a high RCA in materials-related commodities can prevent major GDP losses by not implementing the policy package (Figure 21; scenario "High RCA excluded"). Especially Chile, South Africa and Other Africa (i.e. Sub-Saharan Africa excluding South Africa) can increase their projected GDP in 2040 beyond the baseline level. Others in this group see their GDP losses vanish. For this group of materials-specialised countries, the materials taxes disturbs their international competitive position, and thus their GDP, and opting out of the policy package implementation avoids the macroeconomic costs associated with the package.[25] The economies of other countries only very mildly affected; most benefit slightly from the reduced impacts in the high-RCA countries (and thus stronger demand for foreign products in these countries), while in other countries the negative impact on exports (as the high-RCA countries maintain their competitive position)

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[25] Obviously, any local environmental benefit from policy action is also foregone. The implications for regional and global welfare are thus unclear.

dominates. India shows the biggest response, with a further reduction of GDP of 0.1%-point below the baseline.

Figure 21. Effects of the sub-global policy packages on GDP

Deviation from baseline in 2040 in percentage

Notes:
- (1) denotes countries that are net exporters of combined materials; (2) denotes countries with a high RCA in combined materials exports.
- *Global policy* refers to the main scenario as presented in Section 3; *High RCA excluded* refers to an alternative scenario where countries that have a high RCA in combined materials do not implement any part of the policy package; *Exporters excluded* refers to an alternative scenario where countries that are net exporters of materials do not implement any part of the policy package; *Specific taxes excluded* refers to an alternative scenario where all countries implement the subsidies parts of the policy package, but net exporters of specific materials do not implement the tax part of the policy package on that material.

Source: OECD ENV-Linkages model.

The same mechanism extends to the scenario "Exporters excluded" where all net exporters of materials opt out of implementation of the policy package: the negative GDP impacts disappear in most cases, or even turn into a small GDP gain (e.g. for Mexico and Indonesia). Materials importers are hardly affected by this sub-global implementation of the policy package, even though 15 of the 25 regions, representing more than two-thirds of global GDP in 2040, opt out. This confirms the insight from Section 3.3 that the domestic policy effect dominates the overall GDP effect, especially in materials-importing countries.

The option to exclude those taxes from the policy package that affect materials that are exported (the "Specific taxes excluded" scenario) acts as a double-edged sword. On the one hand, it can prevent losses in these exporting sectors, with beneficial macroeconomic effects. On the other hand, it reduces the tax revenues available for reforming labour taxes. This hurts the other sectors in the economy. The former effect dominates in e.g. Korea (protecting the domestic iron and steel sector) and India (protecting the domestic non-metallic minerals sector), while the latter effect dominates in e.g. Chile, Other OECD and South Africa. The indirect effect of this specific policy scenario on the rest of the world can be best seen in the regions that are net importers of all materials-related commodities: Middle East, North Africa and the Other ASEAN region. All of these are worse off if their trading partners limit their policy package.

From a global perspective, the GDP losses are lowest when only specific taxes are excluded: this scenario prevents the most significant negative impacts of the policy package in all regions, and spreads costs more evenly across countries: the biggest loss is 0.8% of GDP in the Global policy scenario, and 0.4% in the Specific taxes excluded scenario.[26]

The associated changes in total exports and imports are shown in Figure 22. The effects on overall exports (panel A) are effectively driven by the trade-off between the cost-increasing effect of the taxes on materials and the cost-saving effect of lower labour taxes.

For example, the export gains in Other OECD projected for the Global policy scenario disappear when it opts out of the full policy package (in the "High RCA excluded" and "Exporters excluded" scenarios), but not when it only excludes some of the taxes and implements the rest of the policy package. Thus, in this region the cost saving effect of lower labour taxes dominates and allows the country to improve its competitive position.

In Korea, the macroeconomic losses could be dampened by the exclusion of specific taxes, but it comes at the expense of exports. Again, this is dominated by the labour cost effect, which is smaller when specific taxes are excluded from the policy package. Other Africa is another typical case: the global policy implementation depresses export volumes, and opting out prevents that. But opting out only on specific taxes, and implementing the rest of the package can boost overall export volumes.

Most countries that are net exporters of materials, such as Mexico, Other Latin America, the Caspian region, and Indonesia, can boost their exports when part of the policy package is implemented, but specific taxes are excluded. This is of course exactly the rationale for this policy scenario. An exception to this trend is Other Europe, where the partial implementation diminishes exports below baseline level. This can be attributed to the specific trade patterns of this region: in this "Specific Taxes excluded" scenario, it loses competitive position against their most important competitors.

The two countries that reduce their imports in the Global policy scenario and that have a high RCA for materials-related commodities (Chile and Other Africa), are both projected to boost imports when they opt out of the implementation of the policy package – and in the other sub-global scenarios as well (panel B of Figure 22). As shown in Figure 19 in Section 3.3, in these regions the domestic policy effect dominates in reducing imports below baseline levels. By opting out of the policy package, this domestic effect can be prevented.

The exclusion of specific taxes has contrasting effects on imports in other regions. At one extreme are Other OECD and India, where the exclusion of specific taxes but implementation of the remainder leads to a significant increase in imports. In both cases, the global policy package boosts imports, and the sub-global implementation lowers this effect. But when other countries implement parts of the policy, and only exclude specific taxes, most foreign products become cheaper, and these two regions can import more. At the other extreme is Korea, where the exclusion of its iron and steel sector – and thus the protection of its domestic economy – in the Specific Taxes Excluded scenario leads to lower imports as the competitive position of the domestic industry is less affected.

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[26] It may well be that the analysis of a broader policy package that can boost GDP levels beyond baseline, e.g. by including a materials efficiency improvement policy, reveals that this partial implementation of the policy dampens both costs and benefits.

Figure 22. Effects of the sub-global policy packages on total trade flows
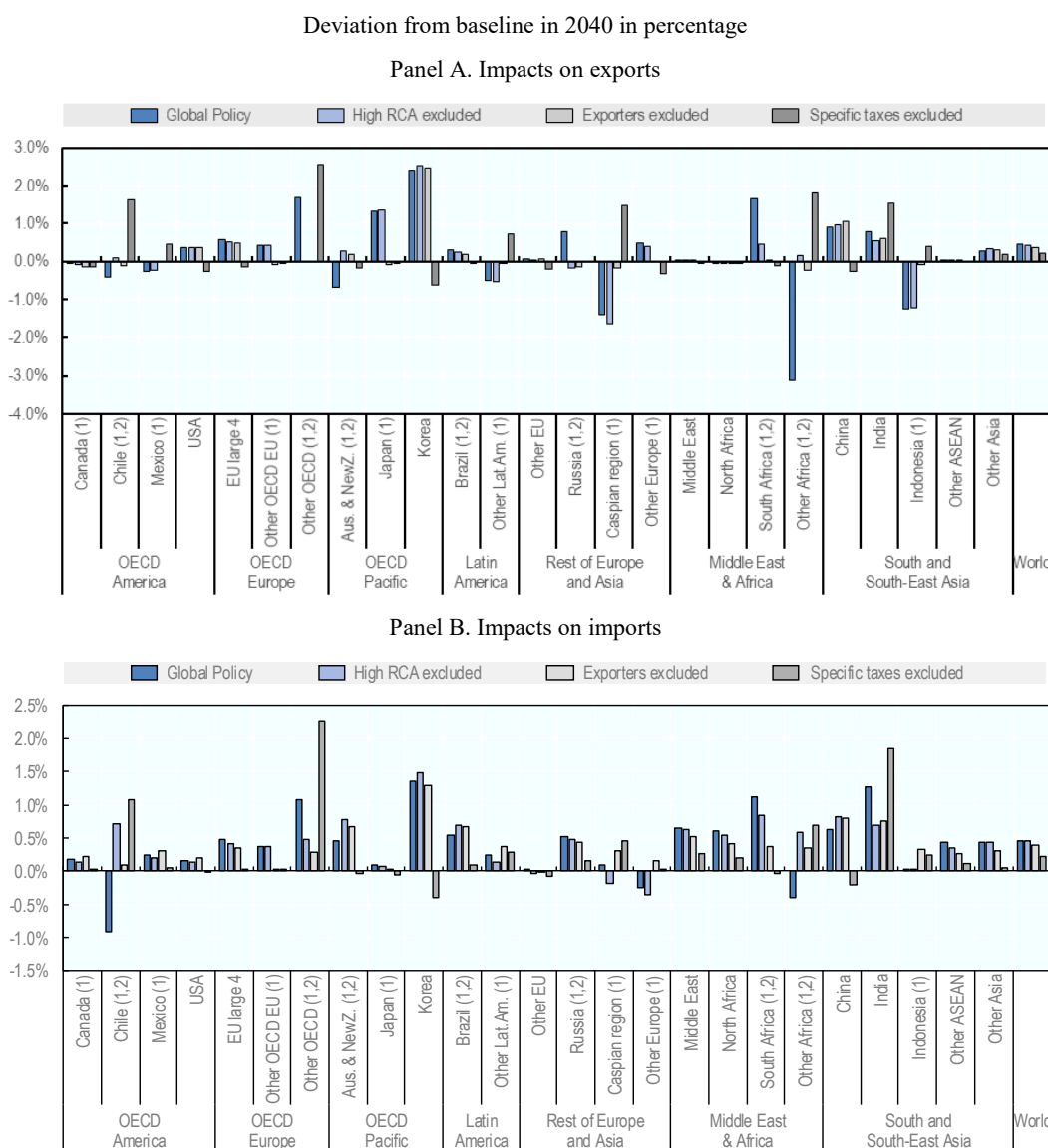
Deviation from baseline in 2040 in percentage

Panel A. Impacts on exports

Panel B. Impacts on imports

Notes:

- (1) denotes countries that are net exporters of combined materials; (2) denotes countries with a high RCA in combined materials exports. Exports reflect all goods and services, not only materials.
- *Global policy* refers to the main scenario as presented in Section 3; *High RCA excluded* refers to an alternative scenario where countries that have a high RCA in combined materials do not implement any part of the policy package; *Exporters excluded* refers to an alternative scenario where countries that are net exporters of materials do not implement any part of the policy package; *Specific taxes excluded* refers to an alternative scenario where all countries implement the subsidies parts of the policy package, but net exporters of specific materials do not implement the tax part of the policy package on that material.

Source: OECD ENV-Linkages model.

Figure 23 presents the results of the sub-global policy scenarios for the exports and imports of materials-related commodities. The results for exports largely resemble an amplified version of the total export effects (cf. panels A of Figure 22 and Figure 23). One striking example is the pattern for North Africa, where overall exports are hardly affected, but

materials-related exports can increase significantly. This effect is robust across scenarios. But as a net importer of materials, the volume of increased exports is rather small.

Figure 23. Effects of the sub-global policy packages on materials-related trade flows

Deviation from baseline in 2040 in percentage

Panel A. Impacts on exports

Panel B. Impacts on imports

Notes:
- (1) denotes countries that are net exporters of combined materials; (2) denotes countries with a high RCA in combined materials exports.
- *Global policy* refers to the main scenario as presented in Section 3; *High RCA excluded* refers to an alternative scenario where countries that have a high RCA in combined materials do not implement any part of the policy package; *Exporters excluded* refers to an alternative scenario where countries that are net exporters of materials do not implement any part of the policy package; *Specific taxes excluded* refers to an alternative scenario where all countries implement the subsidies parts of the policy package, but net exporters of specific materials do not implement the tax part of the policy package on that material.

Source: OECD ENV-Linkages model.

The effects on imports (panel B) are more ambiguous. Countries such as Chile may observe a more competitive domestic production sector and thus lower imports of materials-related commodities when they opt out of implementation of the policy package, to see materials-related imports boosted when only specific taxes are excluded. One intricate effect that plays a role here – and in other cases – is that the exclusion of specific taxes boosts production of the sectors that use processed materials as input: material input costs do not rise while lower labour tax rates and – in the relevant sectors – the subsidies on recycling and secondary metals reduce overall production costs. This implies that demand for domestically produced and imported materials-related commodities increases.

The regions with a high RCA in materials-related commodities are generally projected to increase their total imports when they opt out, but this does not extend to the imports of materials-related commodities, as the domestic sector can maintain its competitive position on the domestic market.

Finally, Figure 24 shows that opting out of the policy package, or even only opting out of specific taxes, significantly lowers the effectiveness of the policy package to decouple economic activity from materials use. Excluding the countries with a high RCA in materials exports already substantially reduces the effectiveness of the policy package at the regional level, but the impacts on global materials use are limited. If all net exports opt out, however, most of the metals use reductions of the policy package vanishes, and materials use reductions are largely limited to non-metallic minerals.

Figure 24. Effects of the sub-global policy packages on materials use

Deviation from baseline in 2040 in percentage

Panel A. Impacts on metals

Panel B. Impacts on non-metallic minerals

Notes:

- *Metals* includes trade in iron and steel, aluminium, copper and other non-ferrous metals; *Minerals* includes non-metallic minerals and mining products.
- *Global policy* refers to the main scenario as presented in Section 3; *High RCA excluded* refers to an alternative scenario where countries that have a high RCA in combined materials do not implement any part of the policy package; *Exporters excluded* refers to an alternative scenario where countries that are net exporters of materials do not implement any part of the policy package; *Specific taxes excluded* refers to an alternative scenario where all countries implement the subsidies parts of the policy package, but net exporters of specific materials do not implement the tax part of the policy package on that material.
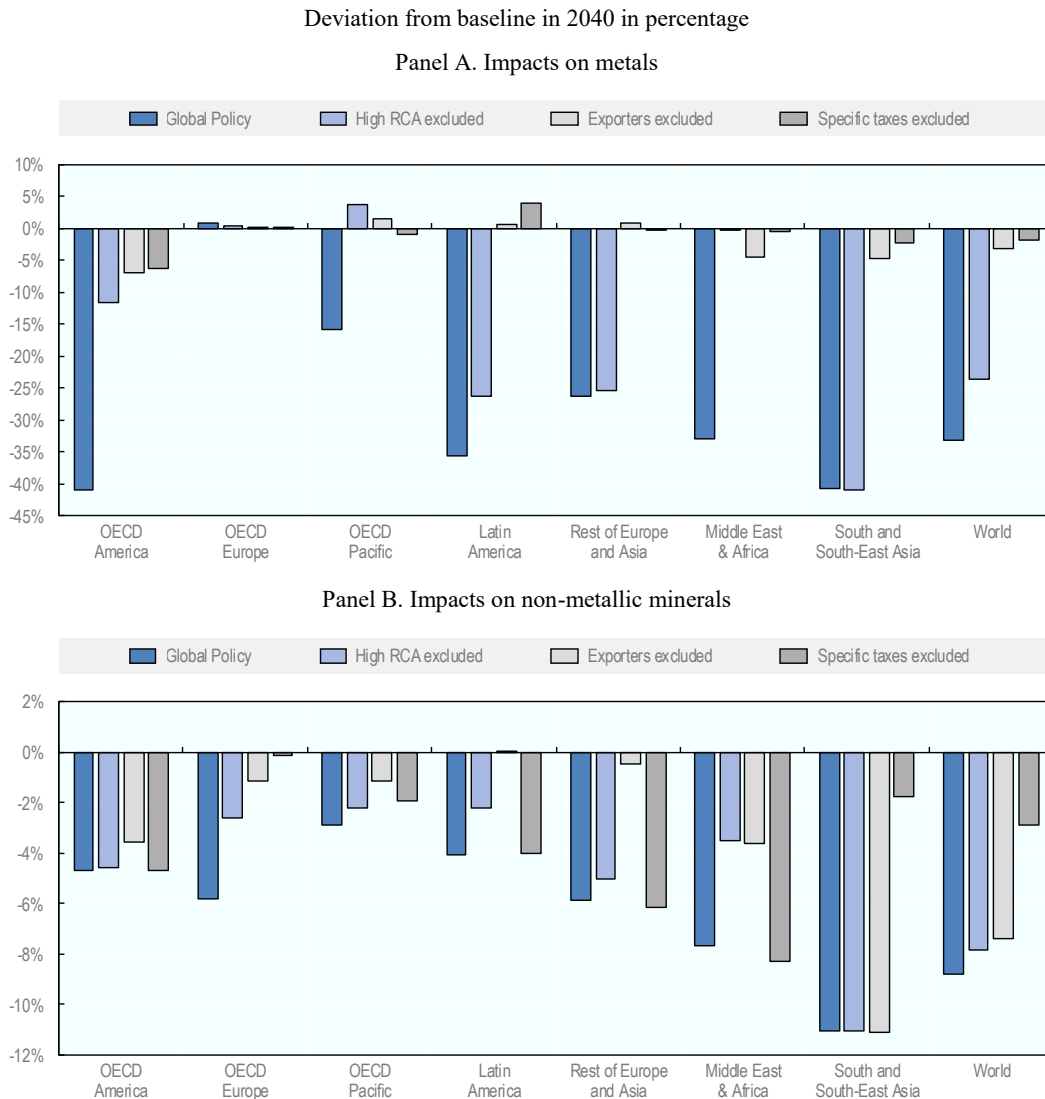
Source: OECD ENV-Linkages model.

The specific taxes excluded scenario is surprisingly even worse for total metals use reduction. The subsidies on recycling and reprocessing of secondary materials are by themselves not enough to induce a shift away from primary to secondary materials, and there is a complicating effect that primary materials are needed for reprocessing of secondary metals, and thus the boost to secondary metals results in a boost of primary metals as well. For non-metallic minerals, where the substitution to secondary materials is

not available (in the modelling framework at least), another effect dominates: by having the policy package partially implemented, production of the sectors that demand processed materials is boosted, which in turn boosts materials use in comparison to a full exclusion from the policy package.

All in all, the analysis in this section reveals that sub-global implementation of the policy package can be beneficial for some regions, and in all cases induces a shift in competitive position. But it comes at the expense of smaller reductions in materials use. In some cases it is a shift to restore the competitive positions of the baseline projections, but in others costs are transferred to other countries. Regional differences play a major role in what is the best policy option from a national perspective. From a global perspective, avoiding major losses in all regions by allowing countries to opt out of the most damaging taxes may protect global GDP, but also hampers the transition to a resource-efficient, circular economy.

5. Discussion

The analysis in this paper deals with a number of key international trade consequences of a transition to a more resource efficient, circular economy. Specifically, it investigates the effects of a hypothetical global materials tax reform, whereby metals and non-metallic minerals are taxed, recycling and secondary materials are subsidised and taxes on other commodities reduced, on the projected volume of exports and imports in the coming decades. It highlights how the domestic effects of the implementation of the stylised policy package tend to dominate not only in macroeconomic impacts, but also for exports and imports. At the sectoral level, a shift occurs away from primary materials towards recycling and secondary materials, and towards sectors that benefit from reduced labour taxes.

The effects on exports and imports of materials-related commodities rely on an interaction of a number of opposing effects, not least a change in competitive position on domestic and international markets for metals and minerals. The competitiveness effects are region-specific as even a uniform implementation of the policy package in all regions will have starkly different effects on regional economies. Furthermore, while individual countries may be able to avoid significant negative economic and trade consequences by opting out of – parts of – the policy package, this has negative consequences for the ability to stimulate the economy through lower labour taxes, hampers the transition to a resource-efficient, circular economy, leads to worse environmental outcomes and cannot prevent negative economic consequences at the global level.

There are many trade effects of a circular economy transition that cannot be addressed in this paper. First, the breadth of the policy package is limited, and excludes e.g. stimulus of resource efficiency, which could potentially boost GDP while reducing materials use. Better information on the costs to reduce damages associated with primary extraction and production would also allow for analysis of more targeted policy implementation, e.g. where tax revenues are earmarked to invest in reducing these damages. A broad policy package could also encompass measures that are directly aimed at trade flows. For example, many advocates of a circular economy emphasise the environmental burden from international transport and suggest that value chains could be closed locally. Such changes in value chains require a different type of scenario analysis.

Secondly, the granularity of the analysis is limited, and bilateral trade flows of specific materials in physical terms could not be assessed. This implies that the analysis cannot infer the Raw Material Consumption of countries, which calculates the materials use associated with consumption, taking into account the embedded materials throughout the value chain. A comparison of RMC with materials use projections as presented in OECD (2019[4]) can shed light on whether a regional decoupling of economic activity and materials use is accompanied by a shift in materials use elsewhere (e.g. when materials-intensive inputs in production and consumption are imported rather than domestically produced), which implies a smaller or perhaps even negative effect on global environmental quality. Other elements that could be included in a future research would be to dive into a case study for a specific material, for instance plastics, and to further refine the assessment of the regional differences in environmental pressures associated with the extraction and production of primary and secondary materials.

Thirdly, the policy instruments simulated in this paper are really stylised and hypothetical. In reality, the externalities associated with primary and secondary production vary

significantly across countries.[27] Such differences should be taken into account when designing policies to improve resource efficiency and facilitate the transition to a circular economy. Furthermore, while taxing different stages of the production process (e.g. extraction and processing) is consistent with economic theory when different externalities are associated with these different stages, policy design should avoid double taxation for a single externality and take tax interaction effects into account. Especially in case taxes on production already exist, these have to be accounted for when identifying the tax rates that ensure that prices equal social costs, i.e. the externalities are fully internalised.

Fourthly, changes in trade policies and trade agreements to facilitate the transition are not considered. Restrictions in the trade of waste and recycling products are part of an ongoing policy discussion, and analysis of the effects of potential changes in trade regimes on materials-related trade flows would be a welcome extension of the existing analysis.

Thus, the current analysis does not predict future trade flows in a circular economy. Rather, it focuses on highlighting how economic mechanisms influence future trade patterns when specific policies to boost resource efficiency and shift away from primary materials are implemented.

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[27] In principle, the extraction and processing of primary materials in technologically advanced countries could be less polluting than the recycling and reprocessing of secondary materials, and this would have to be reflected in the prices signals. OECD (2019[4]) clearly demonstrates that this is an extreme case and that on average, primary materials have much larger environmental consequences than secondary materials.

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Annex A. Details on the ENV-Linkages model

The OECD's in-house dynamic CGE model - ENV-Linkages - is used as the basis for the assessment of the economic consequences of environmental impacts until 2060 as well as to study the economic consequences of environmental policies.

ENV-Linkages is a multi-sectoral, multi-regional model that links economic activities to energy and environmental issues. It is the successor to the OECD GREEN model for environmental studies (Burniaux et al., 1992[11]). A more comprehensive model description is given in Chateau, Dellink and Lanzi (2014[12]); whereas a description of the baseline scenario construction procedure is given in Chateau, Rebolledo and Dellink (2011[13]).

Production in ENV-Linkages is assumed to operate under cost minimisation with perfect markets and constant return to scale technology. The production technology is specified as nested Constant Elasticity of Substitution (CES) production functions in a branching hierarchy. This structure is replicated for each output, while the parameterisation of the CES functions may differ across sectors. The nesting of the production function for the agricultural sectors is further re-arranged to reflect substitution between intensification (e.g. more fertiliser use) and extensification (more land use) of crop production; or between intensive and extensive livestock production. The structure of electricity production assumes that a representative electricity producer maximizes its profit by using the different available technologies to generate electricity using a CES specification with a large degree of substitution. The structure of non-fossil electricity technologies is similar to that of other sectors, except for a top nest combining a sector-specific resource with a sub-nest of all other inputs. This specification acts as a capacity constraint on the supply of the electricity technologies.

The model adopts a putty/semi-putty technology specification, where substitution possibilities among factors are assumed to be higher with new vintage capital than with old vintage capital. In the short run, this ensures inertia in the economic system, with limited possibilities to substitute away from more expensive inputs, but in the longer run this implies relatively smooth adjustment of quantities to price changes. Capital accumulation is modelled as in the traditional Solow/Swan neo-classical growth model.

The energy bundle is of particular interest for analysis of climate change issues. Energy is a composite of fossil fuels and electricity. In turn, fossil fuel is a composite of coal and a bundle of the "other fossil fuels". At the lowest nest, the composite "other fossil fuels" commodity consists of crude oil, refined oil products and natural gas. The value of the substitution elasticities are chosen as to imply a higher degree of substitution among the other fuels than with electricity and coal.

Household consumption demand is the result of static maximization behaviour which is formally implemented as an "Extended Linear Expenditure System". A representative consumer in each region– who takes prices as given– optimally allocates disposal income among the full set of consumption commodities and savings. Saving is considered as a standard good in the utility function and does not rely on forward-looking behaviour by the consumer. The government in each region collects various kinds of taxes in order to finance government expenditures. Assuming fixed public savings (or deficits), the government budget is balanced through the adjustment of the income tax on consumer income. In each period, investment net-of-economic depreciation is equal to the sum of government savings, consumer savings and net capital flows from abroad.

International trade is based on a set of regional bilateral flows. The model adopts the Armington specification, assuming that domestic and imported products are not perfectly substitutable. Moreover, total imports are also imperfectly substitutable between regions of origin. Allocation of trade between partners then responds to relative prices at the equilibrium.

Market goods equilibria imply that, on the one side, the total production of any good or service is equal to the demand addressed to domestic producers plus exports; and, on the other side, the total demand is allocated between the demands (both final and intermediary) by domestic producers and the import demand.

CO_2 emissions from combustion of energy are directly linked to the use of different fuels in production. Other GHG emissions are linked to output in a way similar to Hyman et al. (2003[14]). The following non-CO_2 emission sources are considered: (i) methane from rice cultivation, livestock production (enteric fermentation and manure management), fugitive methane emissions from coal mining, crude oil extraction, natural gas and services (landfills and water sewage); (ii) nitrous oxide from crops (nitrogenous fertilisers), livestock (manure management), chemicals (non-combustion industrial processes) and services (landfills); (iii) industrial gases (SF_6, PFCs and HFCs) from chemicals industry (foams, adipic acid, solvents), aluminium, magnesium and semi-conductors production

ENV-Linkages is fully homogeneous in prices and only relative prices matter. All prices are expressed relative to the numéraire of the price system that is arbitrarily chosen as the index of OECD manufacturing exports prices. Each region runs an exogenous trade balance, which is fixed in terms of the numéraire. One important implication from this assumption in the context of this paper is that real exchange rates immediately adjust to restore trade imbalances to the exogenous level when trade volumes shift.

As ENV-Linkages is recursive-dynamic and does not incorporate forward-looking behaviour, price-induced changes in innovation patterns are not represented in the model. The model does, however, entail technological progress through an annual adjustment of the various productivity parameters in the model, including e.g. autonomous energy efficiency and labour productivity improvements. Furthermore, as production with new capital has a relatively large degree of flexibility in choice of inputs, existing technologies can diffuse to other firms. Thus, within the CGE framework, firms choose the least-cost combination of inputs, given the existing state of technology. The capital vintage structure also ensures that such flexibilities are larger in the long run than in the short run.

The sectoral and regional aggregation of the model adopted in this report are given in Table A.1 and Table A.2, respectively.

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:

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.

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.

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

Annex B. Key macroeconomic results for the baseline projection

This Annex presents results for the baseline projection as presented in the *Global Material Resources Outlook to 2060* (OECD, 2019[4]). The text below is directly reproduced from that report.

World population has been increasing in recent decades and is projected to continue increasing in the coming decades. The central baseline scenario projects global population will reach more than 10 billion people by 2060 (see Figure B.1), drawing on the "medium scenario" of the World Population Prospects (UN, 2017[15]) and the central scenario of Eurostat projections for European countries (Eurostat, 2018[16]). The pace of population growth is slowing between 2011 and 2060, which contrasts with the past 40 years of strong growth. Over the next decades (between 2017 and 2060), global population is projected to grow by 0.7% per year on average, while the growth rate was 1.4% per year during the period 1980-2017.

Figure B.1. World population is projected to keep growing but less rapidly than in the past

Bln people
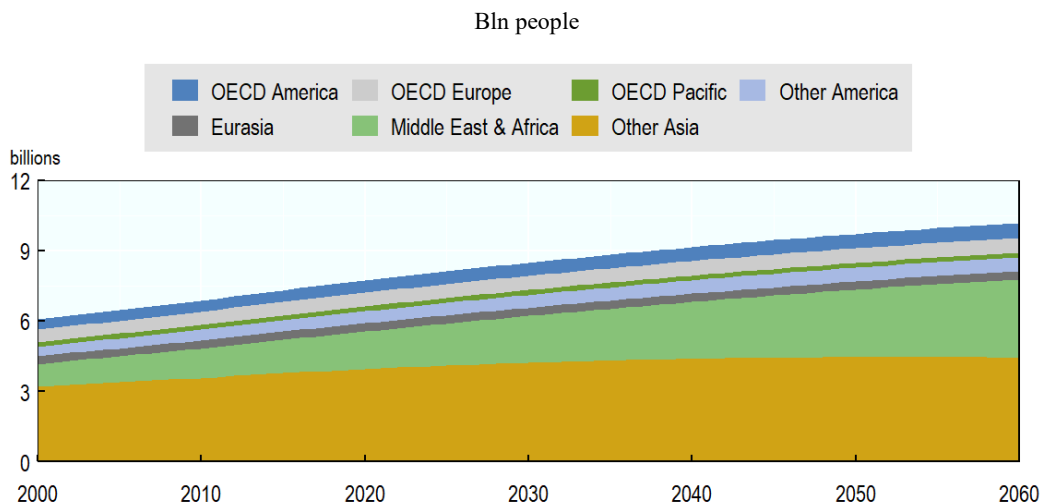
Source: Own calculation from The World Population Prospects: 2017 Revision (UN, 2017[15]) and Eurostat (Eurostat, 2018[16]).

This decline in population growth applies to all countries. However, population growth trends will vary across countries. Some countries with the most advanced demographic transition are projected to even face negative growth (many European countries, Japan, Korea, and China). At the other extreme, Sub-Saharan Africa (grouped with the other parts of Africa and the Middle East in the figure) is projected to experience very high population growth (over 2% per year over 2017-2060). As a result, more than 29% of world population in 2060 is projected to be settled in Africa, compared to 17% in 2017. In contrast, the OECD share shrinks from 14% in 2017 to 17% in 2060.

In the coming decades, the global population is projected to not only increase but also to become wealthier. Living standards (measured as GDP per capita) are projected to increase over the entire period, with most countries gradually converging towards OECD levels (Figure B.2). The improvements in living standards over the 2011-2060 projection period

(blue bars) are projected to be greater for countries that currently have lower levels of per-capita GDP (those to the right of the graph, since the figure is sorted by GDP per capita in 2011 in grey). The poorer countries at the beginning of the period are thus projected to show important gains in living standards (including Sub-Saharan African countries,[28] India, and other non-OECD Asian countries). Global income per capita is projected to reach the 2011 OECD level of living standards by 2060. The macroeconomic projections for OECD and G20 countries match the long-term macroeconomic projections of the OECD Economics Department (Guillemette and Turner, 2018[17]). For the remaining countries, projections are provided by the ENV-Growth model.

Figure B.2. Living standards are projected to gradually converge

Real GDP per capita in USD (2011 PPP), sorted by GDP per capita in 2011
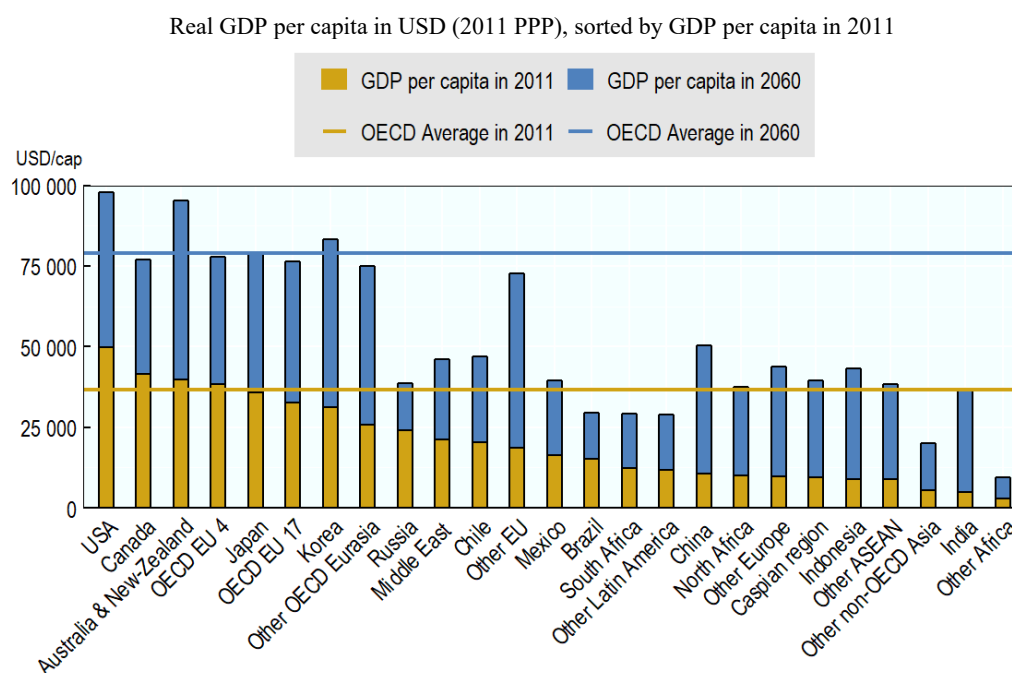
Note: See Annex A for regional definitions. In particular, OECD EU 4 includes France, Germany, Italy and the United Kingdom. OECD EU 17 includes the other 17 OECD EU member states. Other OECD Eurasia includes the EFTA countries as well as Israel and Turkey. Other EU includes EU member states that are not OECD members. Other Europe includes non-OECD, non-EU European countries excluding Russia. Other Africa includes all of Sub-Saharan Africa excluding South Africa; in the text, the term Other Africa is replaced with Sub-Saharan Africa to improve readability. Other non-OECD Asia includes non-OECD Asian countries excluding China, India, ASEAN and Caspian countries.
Source: OECD ENV-Growth model (OECD Environment Directorate) and OECD Economics Department (Guillemette and Turner, 2018[17]).

Two categories of countries deviate from this pattern. Countries that are fossil-fuel exporters are projected to underperform compared to the standard pattern, as fossil fuel revenues do not grow as rapidly as other contributing factors to GDP. Countries in this category include the Russian Federation (hereafter Russia), Brazil and Middle Eastern

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[28] In the simulations, South Africa is separated from the rest of Sub-Saharan Africa, which is labelled "Other Africa". In the text, the term Other Africa is replaced with Sub-Saharan Africa to improve readability.

countries. In contrast, European countries that are currently in a phase of integration to the European Union (EU), especially those labelled as "Other EU",[29] are projected to overperform.
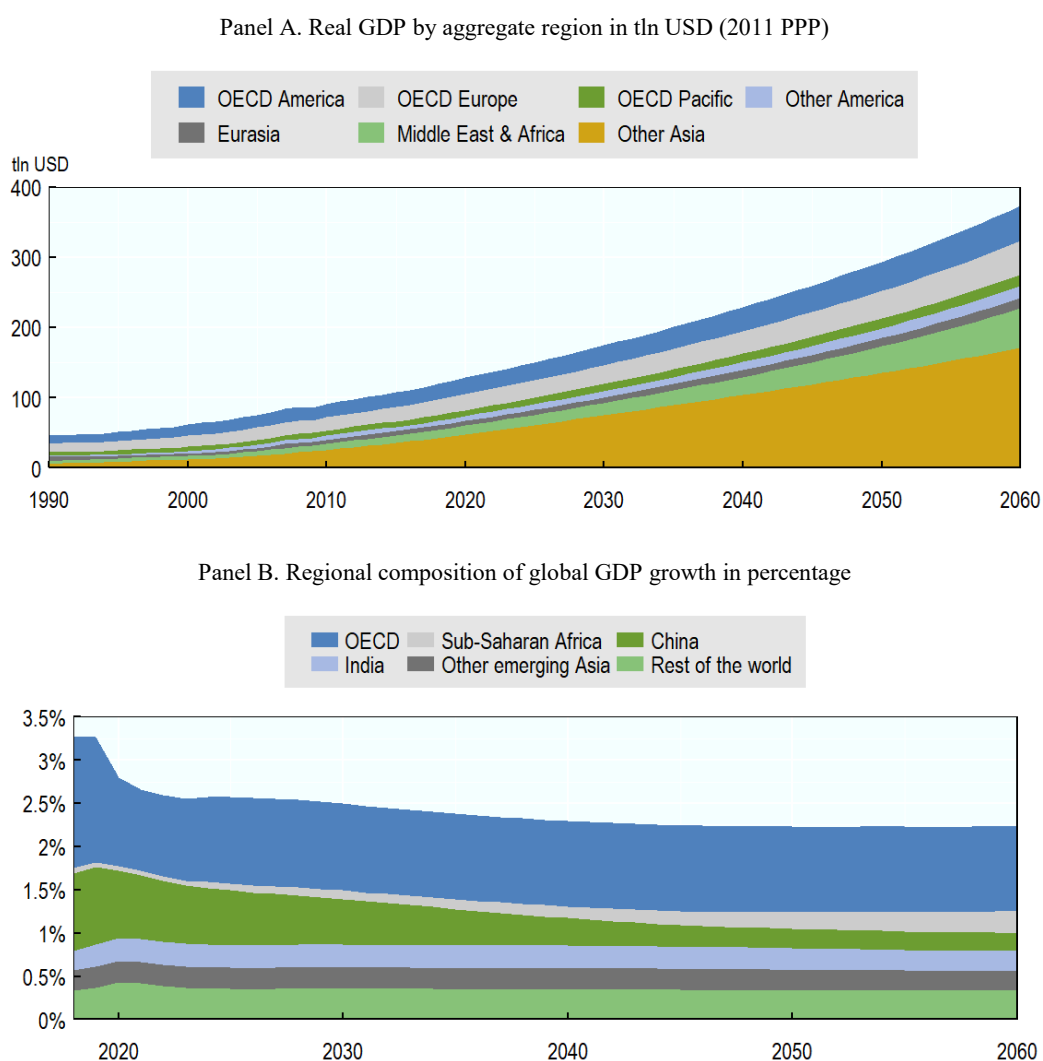
Living standards in developing economies will still be far from those of OECD economies at the end of the time horizon, despite this convergence process. This can be seen in Figure B.2, which presents real GDP per capita in 2060 by region (shown as stacked bars in 2060, while the OECD average is presented as a horizontal line). Some countries are projected to not even have reached 2011 OECD levels by 2060; these include countries in Latin America, Other non-OECD Asia, and Sub-Saharan Africa. Mexico, North Africa, Russia and India are projected to reach in 2060 a level close to the 2011 OECD living standards.

As a result of increasing population and living standards, global GDP increases, as shown in Panel A of Figure B.3. GDP increases in all regions, even in countries where population is declining, since the growth of GDP per capita has a larger impact than population changes.

The share of OECD countries in global GDP in 2060 is projected to fall to 31% from 48% in 2011 (from 61% in 2000). This is explained by the large increase in the share of the Asian developing economies, and – to a lesser extent – Sub-Saharan African countries. Other regions, such as the Middle East, Other America (i.e. non-OECD Latin America) and the Eurasia group of countries are not projected to see their share in global GDP increase significantly. This pattern results from the fact that countries with more dynamic demographic changes, especially faster growing populations, are also countries with high gains in GDP per capita, so their shares in world total GDP increase substantially. It therefore appears that projected trends of GDP per capita and population growth generally move together.

The central baseline scenario projects that the global GDP growth rate will slow down and stabilise just below 2.5% after 2030, as shown in Panel B of Figure B.3. While India and large parts of Sub-Saharan Africa are projected to record high growth rates and then become important drivers of world growth in the 2020-2040 period, the projected slowdown of the Chinese economy after 2025 dominates. From around 2040, the most dynamic region is projected to be Sub-Saharan Africa, but its increasing share in world GDP growth is not sufficient to counterbalance the slowdown of China's economic growth in this scenario.

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[29] Other EU includes the non-OECD EU countries (see Table A.2).

Figure B.3. Emerging economies drive the projected global GDP growth

Panel A. Real GDP by aggregate region in tln USD (2011 PPP)

Panel B. Regional composition of global GDP growth in percentage

Note: Panel B uses a custom aggregation of regions to highlight the contribution of China and India.
Source: OECD ENV-Linkages model; short-term forecasts by OECD Economics Department (as of Summer 2018) and IMF (as of Spring 2018).

An increase in GDP does not mean that the proportion of each good produced and consumed remains constant. The structure of the economy evolves because living standards transform preferences; because society is changing with increasing ageing and urbanisation, and also because the nature of production is evolving, relying more on research and development (R&D) and services[30] expenses. In particular, the model projects an increasing demand for services by households, government and firms.

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[30] In the ENV-Linkages model, services are split into several sectors (see Annex A): business services, three transport service sectors (land, air, water), and other services (which include all government services, education, health, waste management).

As income per capita increases, final demand patterns change. The share of necessary commodities (food and agricultural products) in total expenditure decreases, while the share of luxury goods – such as recreational and leisure activities and *other services* (including health and education) – increases. This conventional effect is reinforced in the central baseline scenario by the assumption that in emerging and developing economies preferences gradually shift towards OECD standards. This includes changes in the size and direction of government expenditures, as well as shifts in household expenditures towards services. These preference shifts are partially driven by income growth, but also reflect the projected further digitalisation of the economy.

The share of manufacturing goods in households' total expenditures is projected to decline slightly, but more importantly, expenditures on durable and equipment goods are projected to change. For example, they will shift away from equipment and paper, towards more electronics and vehicles.

Similar trends in the composition of government and investment expenditures are also projected, which include increasing shares of education and R&D expenditures.

Ageing also induces a shift of household and government demand towards more services, not least for health and other long-term elderly care expenditures. Even if public and private spending on health and long-term care vary considerably across countries, they are all projected to increase in the future (de la Maisonneuve and Oliveira Martins, 2014[18]). The projected increase of health and long-term care spending is driven by a combination of ageing and other demographic factors, as well as the increase in income per capita and technical progress (de la Maisonneuve and Oliveira Martins, 2014[18]). Regardless of the drivers, the result is an increase in the demand for the "other services" category, which includes health care as well as education and public services.

The changes in demand patterns are not only driven by modifications of final demand by households and governments, and for investment, but also by changes in intermediate demand, i.e. demand for produced goods and services by firms. This is reflected in an intensification of services as inputs to all sectors (including manufacturing processes), known as the "*servitisation of manufacturing*" (Pilat and Nolan, 2016[19]). Both servitisation of manufacturing and service digitalisation result from the Information and Communication Technology (ICT) revolution, the intensification of R&D expenses, and the growth of the sharing economy.[31]

This intensification of services in the economy goes further: it includes the shift in business models towards more and more services. The business of car companies for instance is increasingly geared towards services such as insurance, credit, and maintenance.

The main consequence of this structural transformation is that the services sectors, and especially the business services sector, are projected to grow faster than the rest of the economy in all countries over the period 2011-2060 (Figure B.4).

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[31] To illustrate these trends, Miroudot and Cadestin (2017[21]) showed that in 2015 in OECD countries between 25% and 60% of employment in manufacturing firms was in service support functions such as R&D, engineering, transport, logistics, distribution, marketing, sales, after-sale services, IT, management and back-office support.

Figure B.4. Demand for services is projected to increase more than the economy-wide average

Panel A: OECD aggregate (sorted by total growth over 2011-2060)
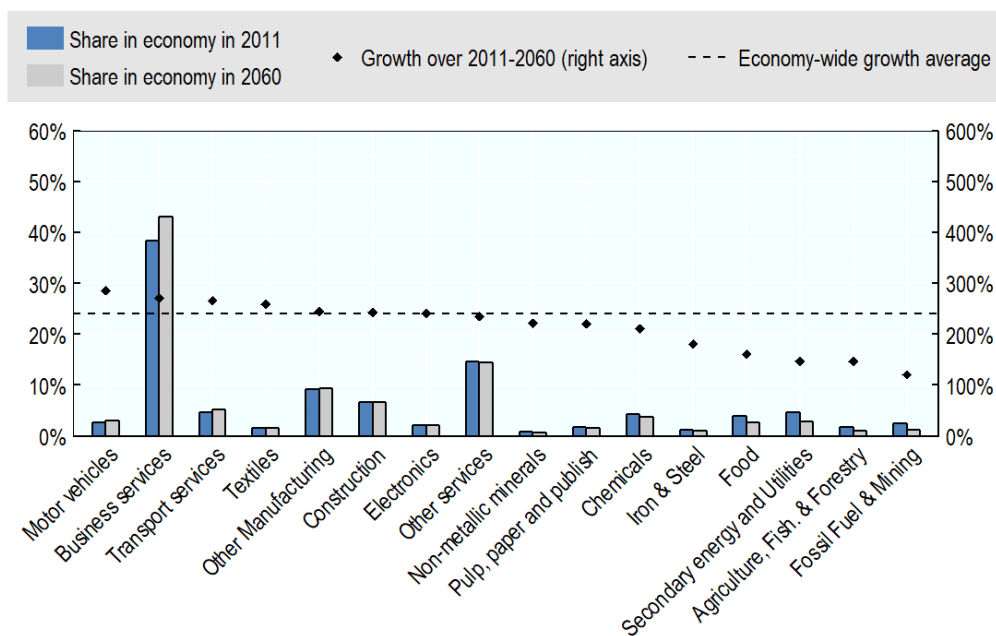
Panel B: Non-OECD aggregate
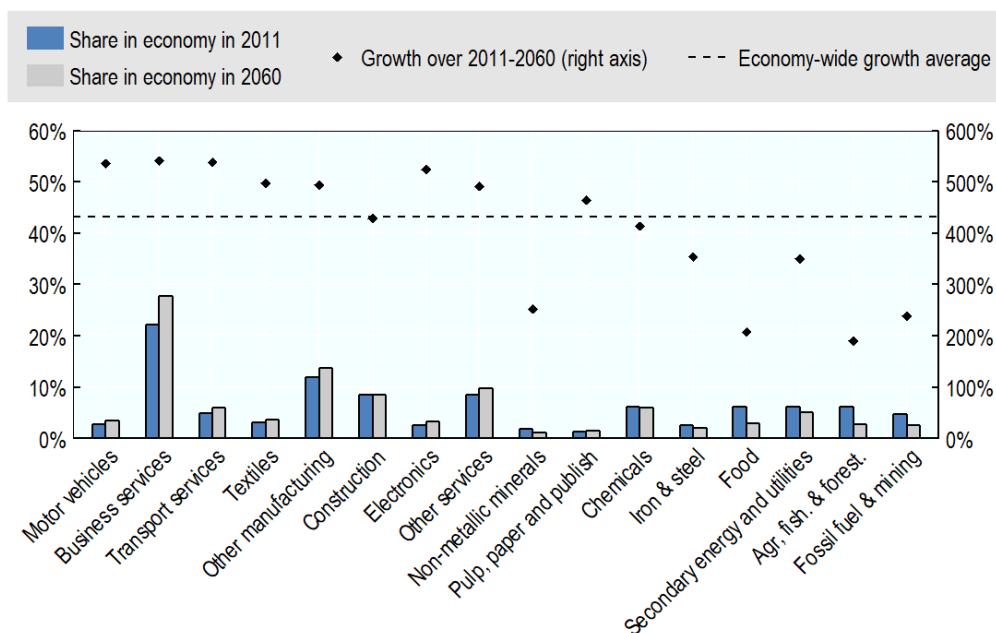
Source: OECD ENV-Linkages model.

In contrast, the output of the fossil fuel and mining sectors, as well as of energy intensive industries[32] is projected to increase less than the economy-wide average, mainly in OECD countries but also in emerging economies. Similarly, the share of food and agricultural goods in total expenditures is projected to diminish significantly. However, the global demand for these goods is still projected to increase by almost 80% by 2060 compared with 2011 levels: agricultural and food expenditures increase, but less rapidly than expenditures on other goods and services.

The GDP changes described above are largely driven by the evolution of the main primary factors of production (capital and labour) as well as by technical progress. These changes can come from a wide range of drivers, including continued efforts to optimise existing production processes, adopting new business models, and the spreading of best available techniques. The change in GDP per capita can be broken down into changes in employment levels, in labour efficiency and in the amount of capital per worker (Figure B.5).

Changes in labour efficiency have the strongest influence on per-capita GDP growth. Long run labour efficiency gains are assumed to be driven by country-specific progress in education levels, investment in innovation, and improvement in the quality of institutions and market regulations, as well as other determinants.[33] As shown in Figure B.5, and in accordance with traditional growth theory,[34] in the long run the gains in living standards (diamond marks) converge.

However, in the short and medium run (2011-2030), the process of catching up through increases in capital-to-output ratios plays a non-negligible role. This mechanism is visible in Figure B.5 as a high contribution to GDP by increases in capital per worker. A relative shortage of capital implies that investments are the major source of economic growth, especially in emerging economies. In contrast, investment is slowing down in more advanced economies, not only because equipment and infrastructure expenditures have largely already been undertaken, but also due to the reduction of saving rates that characterise these ageing societies.

Furthermore, in the short and medium term employment rates fluctuate and influence the dynamics of GDP per capita. In many regions, employment growth makes a positive contribution to growth, but in countries with significant ageing, employment changes become a drag on economic growth, as the share of the working age population in the overall population declines.

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[32] Energy intensive industries include the sectors producing chemicals, iron & steel, pulp, paper publishing and mon-metallic minerals.

[33] The methodology for projecting labour efficiency has been developed by the OECD Economics Department. Guillemette et al. (2017[22]) describe this methodology as well as the projection for the underlying determinants of long run efficiency. For the remaining 180 countries, the OECD Environment Directorate adopts a similar methodology but with fewer determinants in the long run efficiency: indicators for institutional quality as well as rule of law are not included in ENV-Growth model due to lack of data.

[34] For standard growth models (e.g. the Solow-Swan growth model), the capital-to-output ratio and the employment rate stabilise in the long run following the convergence towards a balanced growth path where capital supply growth matches labour efficiency growth.

Figure B.5. Labour efficiency and capital supply drive per-capita GDP growth

Annual growth rates in percentages
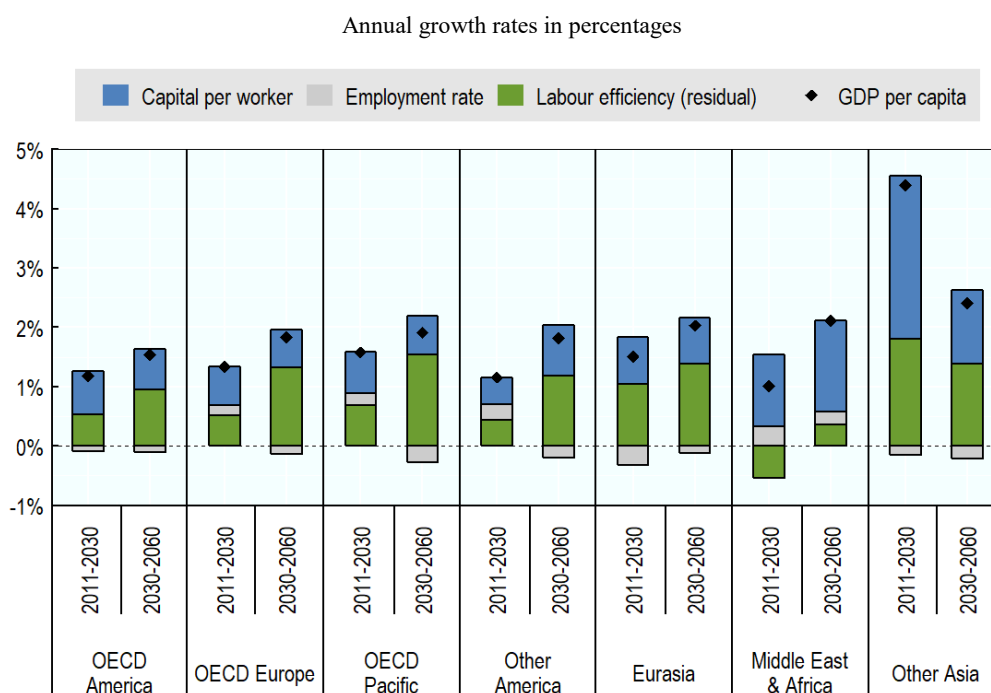
Note: The changes in the GDP per capita in market exchange rates (y) are decomposed in three components: (i) the change in employment rate (ER), (ii) the change in capital per worker (where capital is defined in a broad way including land and natural resources) (k), and, as a residual factor, (iii) the change in labour efficiency (A). Changes in GDP (in market exchange rates) can be decomposed as in the following formula:
, where α is the share of labour income in GDP. The GDP per capita growth rate in market exchange rates differs from the one in PPP exchange rates as the weights of different countries in regional aggregates differ.
Source: OECD ENV-Growth model (OECD Environment Directorate) and OECD Economics Department (Guillemette and Turner, 2018[17]).

Economic growth is thus characterised by changes in production technologies, which drive changes in the input structure (e.g. substitution of production inputs, labour or capital).[35,36] Such shifts in the input structure of production are not new – during the industrial revolution, for example, machines used to automate production reduced the need for labour. More recently, the increasing efficiency of cars has led to a lower use of fuel to travel the

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[35] These effects are driven by changes in relative costs and in factor productivity that affect the mix of inputs and technologies used to produce the final goods. The input substitution effect occurs as the price of one input changes relative to other inputs. In particular, if different inputs can serve as substitutes in the production of a specific commodity, then the mix of inputs that are used for the production of this commodity will depend on their relative prices. Further, if production inputs become more efficient through increases in total factor productivity, then more output can be generated with the same amount of inputs.

[36] In the modelling framework, smooth production functions are used to represent the production choices of many individual firms. Individual production technologies are only specified for selected sectors, notably those related to energy production and materials processing.

same distance, as well as a substitution between different types of fuels (e.g. ethanol instead of gasoline).

The production of manufacturing goods is an interesting example of these production changes. Table B.1 illustrates changes over time in the cost structure of aggregate manufacturing good production, for OECD and non-OECD countries. Inputs of services increase, reflecting the servitisation phenomenon described above, while other inputs of goods and services –including extracted materials – decrease. Labour costs also increase, due to wage increases relative to the marginal cost of production (not shown here).

In both OECD and non-OECD countries, unit production costs are projected to decline, reflecting higher productivity resulting from technical progress. However, this effect is stronger in non-OECD countries, where a higher rate of convergence also leads to more marked changes in productivity over time. In all regions, production costs shift away from industrial inputs towards more services.[37]

Table B.1. Input composition for the production of manufacturing goods

Share of components in production costs of manufacturing goods

|		OECD			Non-OECD		
		2011	2030	2060	2011	2030	2060
Price evolution (index 2011 = 1)		1.00	1.00	0.99	1.00	0.91	0.84
Input Composition of production	Capital and resources	12%	11%	12%	12%	9%	10%
	Labour	18%	19%	17%	11%	14%	14%
	Agricultural inputs	3%	4%	3%	7%	7%	8%
	Industrial inputs	48%	46%	40%	56%	54%	49%
	Services inputs	19%	21%	27%	14%	15%	21%

Source: OECD ENV-Linkages model.

As new technologies emerge, are adopted and become cheaper, they will be more widely used for the production of goods. An example is electricity generation as electricity can be produced with different technologies. Over time renewable technologies are projected to become cheaper and easier to access so that they will be more widely used to produce electricity. In the central baseline scenario, which projects a gradual shift towards renewables, the percentage of electricity produced with renewable technologies is projected to increase at the global level from 24% in 2016 to 31% in 2040, while fossil fuel electricity is projected to decline from 65% in 2016 to 61% in 2040 (IEA, 2017[10]).

The projections of primary and secondary metals use are driven by demand. The different metals processing sectors depicted in the model can produce the same good using two types of material inputs: (i) primary materials, from the processing of mined, extracted metals, and (ii) secondary metals, from the recycling of waste scrap. The process that uses primary metals is usually more energy and capital intensive and less labour intensive than the process using secondary metals. The secondary metal production is projected to increase at roughly the same pace to 2060 than primary, as seen in Figure B.6.

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[37] The decline in capital costs in non-OECD countries mostly reflects an observed decline in the price of capital between 2011 and 2018; in real terms capital costs are projected to grow more rapidly than other primary production factors in the coming decades.

Figure B.6. The share of secondary metal production is projected to remain roughly unchanged until 2060

Panel A. Share of the secondary production in total metal production, measured as the relative sizes of secondary to total in USD
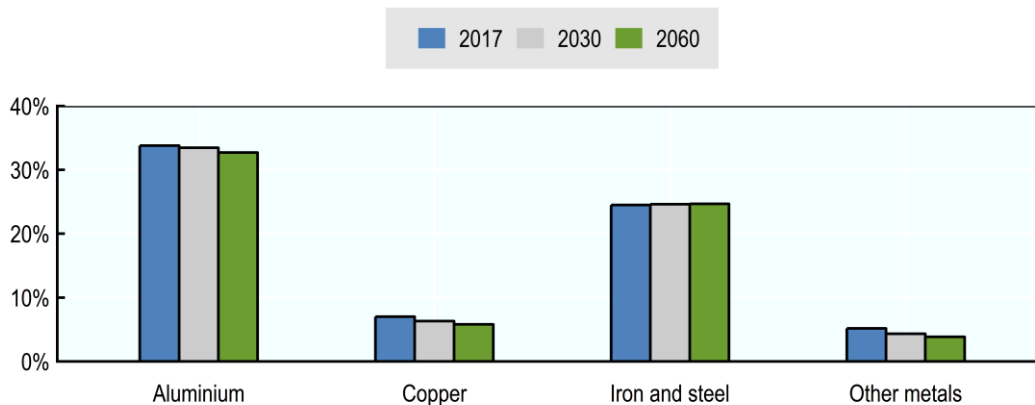
Panel B. Size of the metal sectors, index 1 in 2017
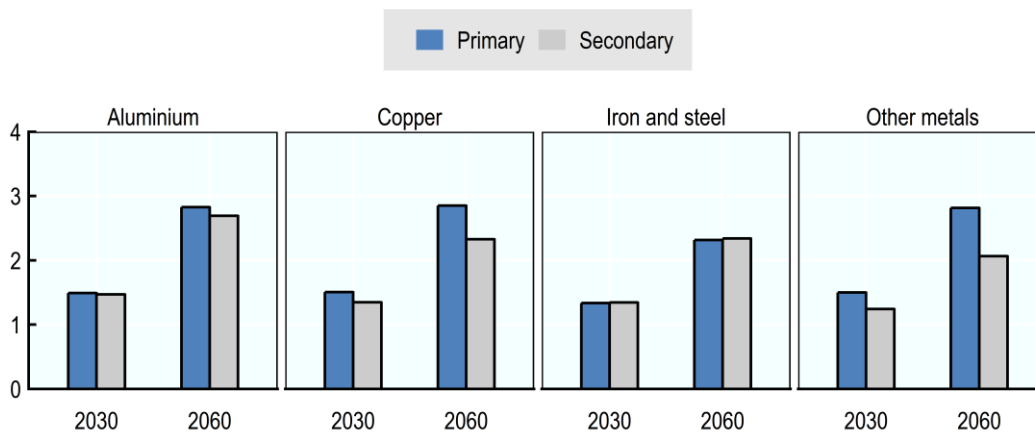
Source: OECD ENV-Linkages model.

Annex C. Background results on the projections for the policy package scenarios

1.   This Annex presents more detailed results of the projections in the main text.

Table C.1. Revealed comparative advantage for selected commodities in 2017

Ratio of the share of a commodity in a region's exports to the share of that commodity in global exports

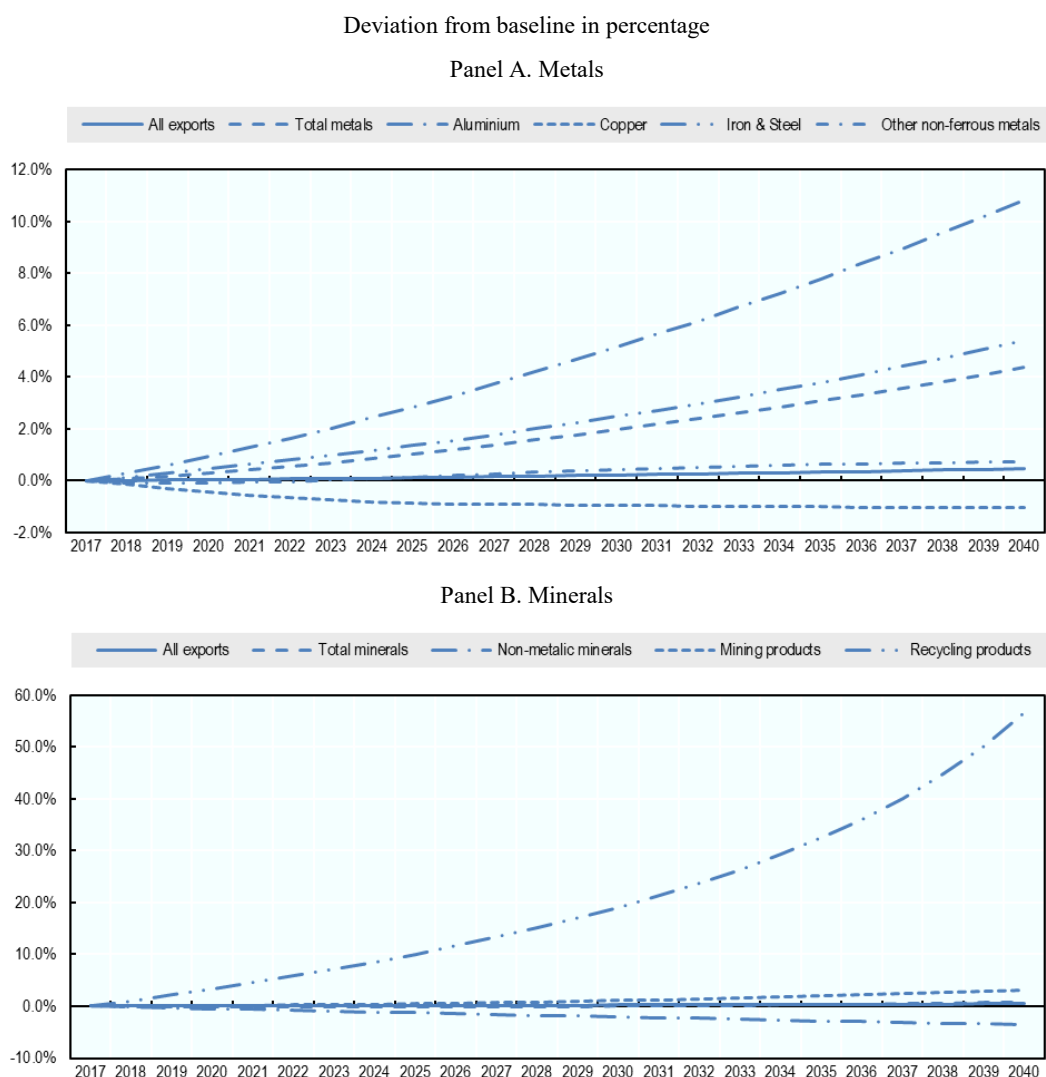|		Aluminium	Copper	Iron & Steel	Non-ferrous metals	Non-metallic minerals	Mining products
OECD America	Canada	2.5	2.4	0.8	2.5	-	1.9
	Chile	9.0	8.8	-	9.7	-	14.6
	Mexico	1.5	1.6	0.7	1.6	1.0	0.9
	USA	0.8	0.8	0.6	0.8	0.8	0.3
OECD Europe	EU large 4	0.8	0.8	1.0	0.8	1.2	0.2
	Other OECD EU	0.7	0.7	1.3	0.7	1.2	0.5
	Other OECD	3.3	3.3	0.8	3.2	1.0	0.7
OECD Pacific	Austr. & New Z.	2.1	1.9	-	1.9	-	14.1
	Japan	0.8	0.8	1.8	0.8	1.2	-
	Korea	0.7	0.6	1.7	0.6	0.5	-
Latin America	Brazil	-	-	1.7	-	-	11.6
	Other Latin Am.	1.5	1.4	0.7	1.5	-	2.7
Rest of Europe and Asia	Other EU	1.0	1.0	1.4	1.0	1.0	-
	Russia	0.9	0.9	1.6	0.9	-	1.0
	Caspian region	1.9	1.7	-	1.7	-	-
	Other Europe	-	-	5.5	-	-	3.1
Middle East & Africa	Middle East	0.3	0.3	0.3	0.3	0.3	0.5
	North Africa	-	-	-	-	-	-
	South Africa	7.3	9.6	3.2	9.6	-	6.7
	Other Africa	3.3	3.5	-	3.9	-	3.5
South and South-East Asia	China	0.5	0.5	1.0	0.5	2.1	0.1
	India	0.4	0.4	0.8	0.4	0.7	1.5
	Indonesia	1.3	1.2	-	1.2	-	3.2
	Other ASEAN	0.6	0.6	0.3	0.6	0.7	0.3
	Other Asia	0.7	0.7	1.2	0.6	0.8	0.6

Note: RCA values for exports that reflect less than 1% of global exports of that commodity are represented with a mark ("-"). Values above unity denote a relative specialisation of the region in that commodity. Recycling products are excluded from the table as export volumes are too small to create meaningful indicator values.

Figure C.1. Change in global exports of materials-related commodities over time

Deviation from baseline in percentage

Panel A. Metals

Panel B. Minerals

Source: OECD ENV-Linkages model.

Table C.2. Changes in regional exports of materials-related commodities

Deviation from baseline in 2040 in percentage

		Aluminium	Copper	Iron & Steel	Non-ferrous metals	Non-metallic minerals	Mining products	Recycling products
OECD America	Canada	16.3%	-22.6%	3.9%	-3.8%	-3.0%	2.4%	50.0%
	Chile	11.9%	-86.6%	3.7%	21.1%	-1.7%	3.9%	45.8%
	Mexico	14.7%	-20.1%	5.2%	-27.7%	-2.4%	4.6%	47.3%
	USA	22.8%	4.7%	5.3%	9.8%	-3.3%	2.4%	63.7%
OECD Europe	EU large 4	23.2%	24.7%	6.6%	15.0%	-2.8%	1.3%	53.1%
	Other OECD EU	13.2%	9.8%	6.0%	10.4%	-2.7%	1.2%	56.8%
	Other OECD	23.3%	7.2%	5.8%	6.4%	-4.3%	1.7%	59.1%
OECD Pacific	Austr. & New Z.	-39.1%	-28.2%	2.1%	-33.6%	-3.2%	5.0%	53.2%
	Japan	7.9%	-14.2%	7.0%	6.1%	-3.4%	2.3%	57.6%
	Korea	23.2%	-8.4%	7.3%	-4.5%	-3.6%	2.7%	57.6%
Latin America	Brazil	-19.1%	17.6%	3.2%	20.0%	-3.1%	3.1%	46.7%
	Other Latin Am.	-2.9%	-4.2%	5.6%	-43.9%	-2.6%	3.5%	51.5%
Rest of Europe and Asia	Other EU	13.8%	-43.6%	2.0%	8.5%	-2.7%	-2.4%	50.3%
	Russia	12.3%	19.8%	4.0%	4.6%	-4.9%	2.0%	54.5%
	Caspian region	7.8%	-50.8%	-1.3%	-14.3%	-4.0%	3.0%	59.5%
	Other Europe	3.6%	-13.1%	3.3%	0.5%	-3.9%	3.6%	50.3%
Middle East & Africa	Middle East	-2.7%	-11.1%	6.0%	17.0%	-3.8%	1.3%	102.4%
	North Africa	22.4%	54.5%	8.1%	24.7%	-3.2%	-0.2%	53.7%
	South Africa	-1.4%	25.6%	3.9%	8.1%	-6.4%	2.2%	49.1%
	Other Africa	-17.0%	-44.0%	2.9%	-26.0%	-13.0%	2.1%	54.2%
South and South-East Asia	China	24.7%	29.8%	6.4%	16.7%	-3.9%	0.0%	53.0%
	India	15.3%	34.5%	-0.4%	23.1%	-4.4%	3.6%	51.8%
	Indonesia	-62.8%	-60.3%	4.4%	-98.7%	-1.3%	6.1%	57.7%
	Other ASEAN	11.5%	-16.2%	5.4%	-2.5%	-4.5%	3.4%	58.8%
	Other Asia	13.4%	-12.3%	5.7%	11.2%	-3.7%	3.4%	53.6%

Source: OECD ENV-Linkages model.

**Table C.3. Changes in regional imports of materials-related commodities**

Deviation from baseline in 2040 in percentage

		Aluminium	Copper	Iron & Steel	Non-ferrous metals	Non-metallic minerals	Mining products	Recycling products
OECD America	Canada	13.2%	-9.4%	4.0%	-2.9%	-2.9%	0.9%	43.3%
	Chile	18.2%	-28.0%	3.7%	3.6%	-3.1%	-1.1%	29.7%
	Mexico	11.0%	-1.2%	4.9%	2.8%	-3.3%	-1.3%	39.7%
	USA	7.9%	-5.0%	3.9%	-5.2%	-3.2%	-1.4%	48.1%
OECD Europe	EU large 4	13.2%	5.7%	4.1%	2.2%	-2.3%	3.0%	50.6%
	Other OECD EU	9.9%	1.1%	5.0%	0.5%	-3.1%	2.1%	50.8%
	Other OECD	17.3%	0.0%	5.4%	0.6%	-3.8%	1.2%	64.7%
OECD Pacific	Austr. & New Z.	9.5%	-6.2%	-2.3%	-1.0%	-2.4%	-4.5%	33.1%
	Japan	7.7%	0.2%	10.8%	-2.6%	-1.8%	4.4%	65.5%
	Korea	9.3%	2.4%	13.9%	3.1%	-1.6%	8.5%	91.5%
Latin America	Brazil	12.0%	-7.4%	2.1%	-5.1%	-2.8%	-0.2%	20.5%
	Other Latin Am.	9.2%	-0.2%	4.4%	4.5%	-3.5%	-2.4%	41.0%
Rest of Europe and Asia	Other EU	9.4%	-2.4%	3.2%	0.3%	-3.6%	-0.5%	45.4%
	Russia	9.3%	-5.9%	4.7%	-2.1%	-2.3%	3.9%	57.1%
	Caspian region	15.0%	20.4%	2.0%	6.8%	-5.3%	-5.4%	30.6%
	Other Europe	9.7%	2.1%	5.4%	0.2%	-5.1%	0.3%	59.3%
Middle East & Africa	Middle East	7.1%	-5.8%	6.5%	-4.4%	-3.1%	-0.7%	51.1%
	North Africa	2.8%	-9.1%	5.5%	-5.5%	-4.8%	-0.9%	47.6%
	South Africa	9.0%	10.6%	2.8%	1.0%	-1.8%	4.0%	47.6%
	Other Africa	8.3%	-4.2%	3.3%	-1.6%	-4.8%	-12.0%	37.9%
South and South-East Asia	China	4.6%	-12.8%	6.2%	-4.8%	-5.7%	5.4%	44.0%
	India	10.2%	0.3%	4.6%	0.5%	-9.3%	1.3%	129.7%
	Indonesia	28.7%	10.6%	1.7%	117.1%	-4.5%	-19.1%	67.1%
	Other ASEAN	8.6%	-2.0%	5.3%	1.4%	-7.8%	-1.3%	75.0%
	Other Asia	9.6%	-0.2%	6.7%	0.3%	-3.4%	-0.2%	49.5%

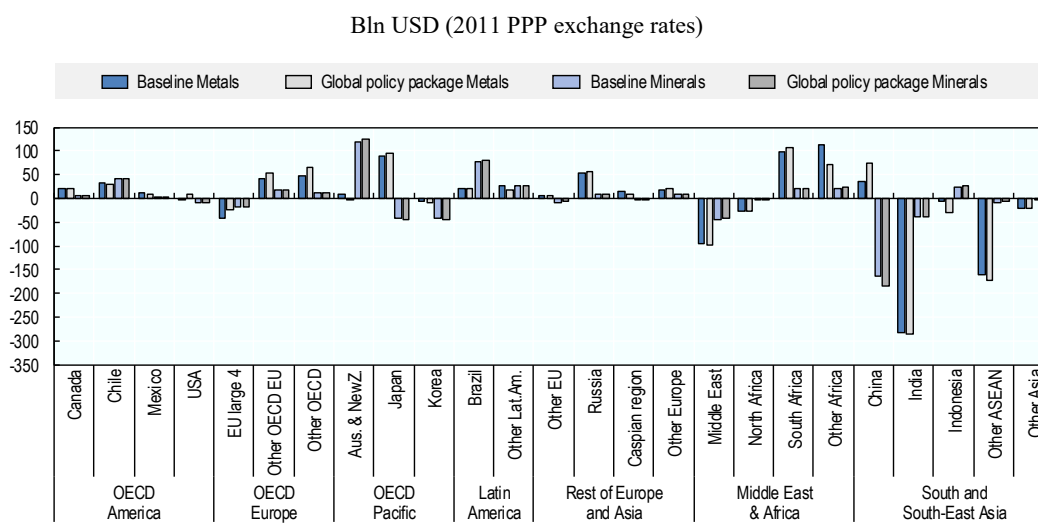*Source:* OECD ENV-Linkages model.

Figure C.2. Correlation between total exports and imports

Deviation from baseline in 2040 in percentage
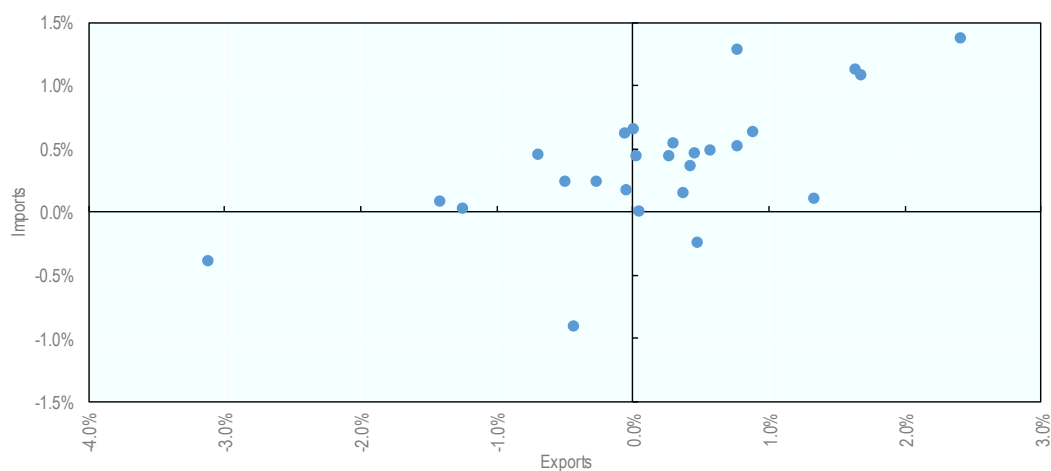

Source: OECD ENV-Linkages model.

Figure C.3. Regional trade balances for metals and minerals commodities

Bln USD (2011 PPP exchange rates)

Note: "Metals" includes trade in iron and steel, aluminium, copper and other non-ferrous metals; *Minerals* includes non-metallic minerals and mining products.
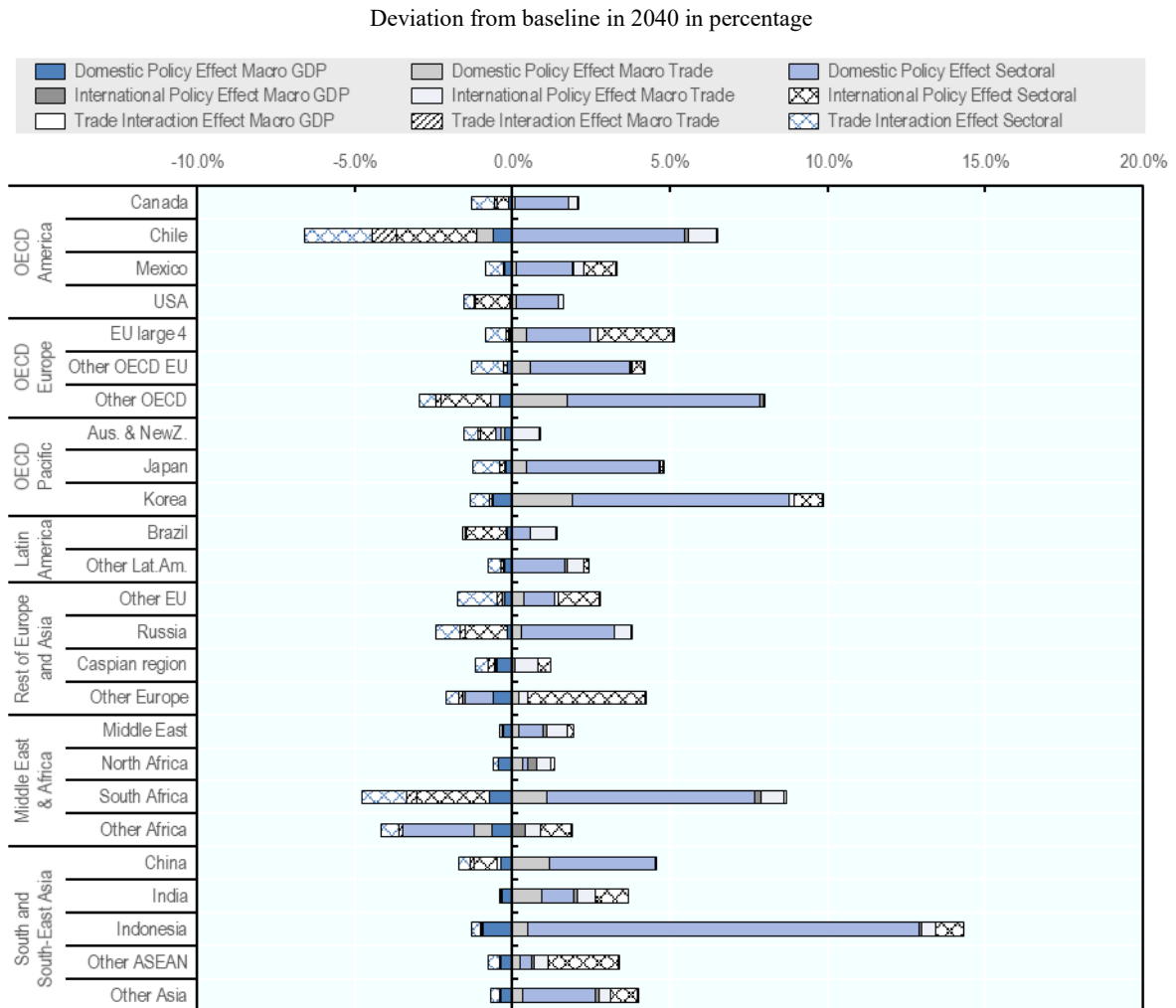*Source:* OECD ENV-Linkages model.

Figure C.4. Decomposition of the trade effects of the policy package on exports of materials-related commodities
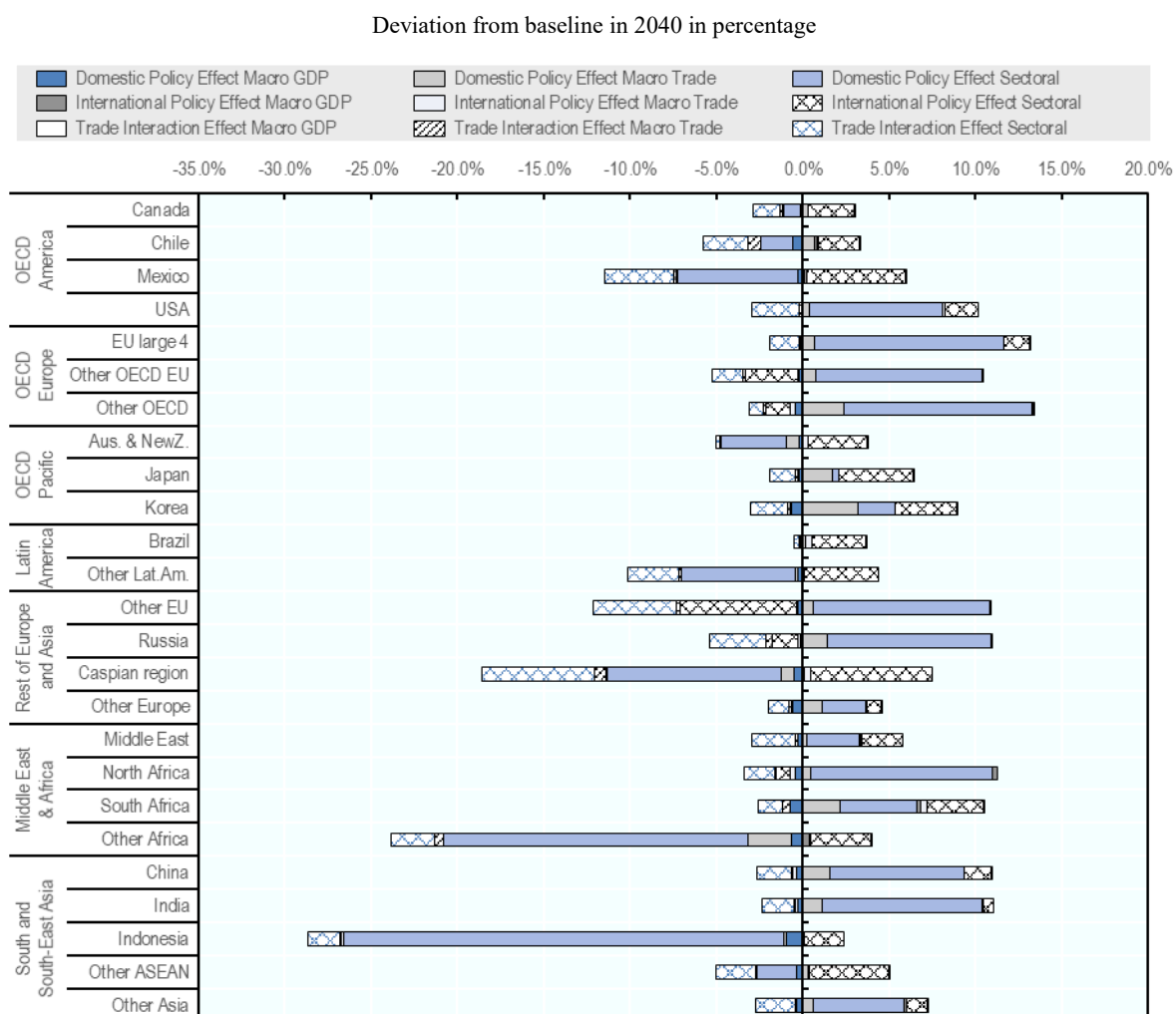
Deviation from baseline in 2040 in percentage

Note: The "Macro GDP" effects reflect the impact on GDP; the "Macro trade" effects reflect the additional impact on total exports in excess of the impact on GDP; the "Sectoral" effects reflects the additional impact on materials-related exports in excess of the impact on total exports.
Source: OECD ENV-Linkages model.

Figure C.5. Decomposition of the trade effects of the policy package on imports of materials-related commodities

Deviation from baseline in 2040 in percentage

Note: The "Macro GDP" effects reflect the impact on GDP; the "Macro trade" effects reflect the additional impact on total exports in excess of the impact on GDP; the "Sectoral" effects reflects the additional impact on materials-related exports in excess of the impact on total exports.
Source: OECD ENV-Linkages model.