The effects of EU Green Deal policies on world resources management & climate change: a CGE assessment with integrated material flows

Xinyu Li[2], Julie Metta*[1], Corjan Brink[2], Reyer Gerlagh[1] and Etienne Lorang[1]

[1]TiSEM, Tilburg University, The Netherlands
[2]PBL
*Corresponding author

October 15, 2024

Work in progress. Please do not distribute

Abstract

We study the synergies and conflicts between climate and circular economy policies and provide an enhanced CGE tool for such analysis. We examine the implications of the European Union's Green Deal policies on global resource management and climate change mitigation through an innovative Computable General Equilibrium model, Green-R. The enhanced CGE incorporates endogenous material intensity and integrates balanced Physical Input-Output Tables with (monetary) Social Accounting Matrices, providing a comprehensive view of both the economy and material flows. We analyze the effects of various fiscal instruments on iron and carbon material flows from extraction, to consumption and disposal, and CO_2 emissions. Our findings confirm the effectiveness of the Carbon Border Adjustment Mechanisms (CBAM) for both circular economy goals and climate mitigation, as they reduce leakages. We also identify a substantial tradeoff between circular economy and climate policies, as single-targeted policies inevitably lead to leakages in non-targeted areas.

Keywords : environmental policies, circular economy, CO_2 emissions, Input-Output, CGE modeling, material flows

1 Introduction

The European Union's (EU) Green Deal policies represent a watershed moment in environmental governance, marking a shift by a global economic power towards more sustainable resource management and climate change mitigation efforts. These policies aim to transform the EU's economy by decoupling economic growth from resource use and environmental degradation. Central to this transformation is the reduction of material use and reduction of CO_2 emissions. However, these reductions may entail trade-offs, as the energy transition essential to decrease emissions may require increased metal consumption.

The complexity of the EU Green Deal necessitates a thorough understanding of the interplay between policy interventions, geopolitical considerations, resource use, emissions, and economic outcomes. To address these complexities, we employ a Computable General Equilibrium (CGE) model, Green-R, which is specifically enhanced to incorporate material flows and intensities as an endogenous factor. This approach, based on Gerlagh and Lorang (2024) is innovative in its integration of Physical Input-Output Tables (PIOT) alongside Social Accounting Matrices (SAM) within a general equilibrium framework. By doing so, our model provides a comprehensive assessment that goes beyond mere economic implications to include the real volumes of materials affected by the EU Green Deal policies.

A critical aspect of our study is the analysis of resource policies, such as upstream and downstream material taxation, and their effects on material extraction, consumption patterns, and CO_2 emissions. By focusing on pivotal materials like iron (steel), and carbon, we delve into the multifaceted implications of the EU Green Deal. Our investigation explores whether climate imperatives align or diverge from circular economy strategies, providing valuable insights into the potential synergies and conflicts between these two policy areas.

In this context, it is important to understand the synergies between policies for materials like iron (steel), which is central to climate debates. By tracking iron in our model, we can discern the differences in labour share decomposition versus technological changes for decarbonising the steel industry.

The applied literature on the impact of climate policies underscores the importance of integrating economic and environmental considerations in policy analysis. Blackburn and Moreno-Cruz (2021) emphasize the significance of energy efficiency within a general equilibrium framework, highlighting the interconnectedness of economic activities and environmental outcomes. Böhringer and Rosendahl (2022) assess the economic and climate effects of Europe's transition beyond coal, providing valuable insights into the challenges and opportunities associated with decarbonization efforts, which enhance our understanding of the EU Green Deal's implications. Fischer and Fox (2012) offers a comparative analysis of policies aimed at combating emissions leakage, contributing to our evaluation of resource policies within the EU Green Deal, albeit without incorporating material balances. Holladay et al. (2018) investigates emissions leakage and its relationship with environmental policy and trade frictions, underscoring the complexities of addressing global environmental

challenges from a CO_2 emissions perspective. Liu (2013) delves into tax evasion and its implications for optimal environmental tax policies, informing discussions on resource taxation within the EU Green Deal framework.

We also contribute to the existing literature on the integration of material balances and flows in economic modeling. Historical contributions to this field include early work on material constraints in general equilibrium models by Ayres and Kneese (1969), andNoll and Trijonis (1971). More recent representations, such as those by Hassler and Krusell (2012) and Barrage (2020), have focused on fossil fuel products with detailed upstream flows. Studies on waste and the circular economy, like those by Pittel et al. (2010) and Zhou and Smulders (2021), further highlight the importance of incorporating material intensity into economic models. Early inclusion of material accounting in large economic models include the work of Ibenholt (2003), Sjöström and Östblom (2010) and Masui (2005) who already examine policies aimed at reducing waste generation and GHG emissions. However, such approaches usually consist in ex-post calculations of material flows from economic output. Our work also complements the contribution of applied circular economy policy analysis by Winning et al. (2017), Nechifor et al. (2020) or Dellink (2020).

This work combines theses two fields of climate and circular policies analysis and material flow modeling by investigating how policies complement each other and can help achieve CO_2 reduction and resource efficiency. To do so, we adapt the model from Gerlagh and Lorang (2024) to a larger scale with two regions (the EU and the rest of the world), we demonstrate that circular economy and climate policies have different effects on iron (steel) extraction and use, and CO_2 emissions. They developed a general equilibrium framework with endogenous representation of material flows, With their model, the impact of taxing material extraction or waste depends on hypothesis made on the firms behavior. Contrary to Gerlagh and Lorang (2024), our findings indicate that a waste tax is more efficient than an extraction tax in reducing both emissions and resource extraction, as our model captures leakages when policies are implemented in the EU but not globally.

This paper is structured as follows: In Section 2, we detail the methodology underpinning our model, including the construction of Green-R and its innovative features. We explain how incorporating material intensity into CGE models allows for a more nuanced understanding of the effects of resource use reduction efforts. Our model's ability to capture international trading patterns and regional inequalities is particularly important for evaluating the global effects of the EU Green Deal. In Section 3, we illustrate the application of our model in assessing the effects of EU Green Deal policies on world resources, focusing on iron, steel, and CO_2 emissions. We provide insights into the debate on circular economy and climate policies. Our findings suggest that material balances and flows offer deeper insights into the effectiveness of different policy mechanisms, such as waste taxes versus extraction taxes. In Section 4, we highlight key findings and potential caveats of our analysis. We address the limitations of our model and suggest areas for further research, emphasizing the need for a coherent framework for economic analysis that includes material balance and consistency. Finally, Section 5 concludes with overarching insights from our analysis and outline

avenues for future research and policy action. We argue that the integration of climate and circular economy policies is needed for achieving both CO_2 reduction and resource efficiency. Our research demonstrates that waste taxes are more effective than extraction taxes in reducing both emissions and resource extraction, but even best combined with ETS and CBAM policies, providing important insights for economists and governments. By showcasing the capabilities of the material embedded CGE models, we contribute to the ongoing debate on the (non) efficiency and limits of circular economy policy instruments for emissions reduction.

2 Model

This section outlines the framework and specifications of the Computable General Equilibrium (CGE) model used in this study, emphasizing its application to analyze decarbonization and circular economy policies with a particular focus on material flows, especially iron and steel. This model builds on the MATCGE framework but complements it by capturing leakages, an aspect that Gerlagh and Lorang (2024) were not able to fully address. It is important to note that the results from Gerlagh and Lorang (2024) and this model are not fully comparable. Green-R provides a more complete analysis using existing data, in a setting with two regions (Europe and the Rest of the World ROW) and different policy instruments, highlighting the different marginal Effects of the same instruments in different regions.

2.1 Green-R: a Computable General Equilibrium (CGE) model with material flows

The Green-R framework (a CGE model) employed in this study is a multi-regional, multi-sectoral framework designed to capture the complex economic interactions and trade relationships across different regions and sectors. It includes several features that enhance its capability to model material flows and trade. This framework offers additional features compared to the MATCGE developped by Gerlagh and Lorang (2024), such as a nested Constant Elasticity of Substitution (CES) production structure and more detailed material flow tracking. The model divides the world into two regions: Europe (EUR) and the Rest of the World (ROW). This regional differentiation allows for an in-depth analysis of regional policy Effects and trade dynamics. International trade is explicitly modeled to reflect the flow of key materials, including iron, steel, and carbon (CO_2, between these regions. By incorporating trade, the framework assesses how regional policies affect global markets and vice versa.

Here we describe the model with generic equations. We do not aim to specify all economics details, but we need to explicate the material balances. To do so conveniently we save on notation and will frequently abstract from country subscripts, and differences between factors and goods. Below we explain our notation.

We consider countries c, sectors (firms) producing goods i, consumers h, and institutions (government) g. We assume profit maximization with constant returns to scale technologies, so that we identify sectors and firms with their technology. An advantage of this approach is that we can treat trade Armington structures on equal footing as sectors, i.e. as a technology. The split of domestic output in supply for the domestic market and exports, and the aggregation of domestic and imported goods into domestic supply are each represented through a specific i. We don't need to separately specify the Armington structure, and we subsume the country label. That is, we consider i the broad set of all technologies for production and defining composite goods, where firms of any country are a subset of I. Similary, consumers in a specific country are considered a subset

of the set of all consumers H, and institutions are also considered a subset $g \in G \subset H$. Finally, we broaden our notation by considering the set $f \in F$ for production factors not produced, and $J = I \cup F$ for the set of goods and factors.

Thus good i is produced according to linearly homogeneous technology $y_i = f_i(\mathbf{x}_i)$, $\mathbf{x}_i \in \mathbb{R}^J$. We write $X_{ji} = (\mathbf{x}_i)_j$ for the input-output matrix describing factors and goods. Using this compact notation, we can describe the *economics* goods and factor balances through one equation. Supply equals demand for all $j \in J$:

$$\sum_{h \in H} \omega_{hj} + y_j = \sum_{h \in H} C_{hi} + \sum_{j \in I} X_{ij} \tag{2.1}$$

where typically enodowments are zero, $\omega_{hj} = 0$, for produced goods $j \in I$, output is zero, $y_j = 0$, for factors $j \notin I$. Firms maximize profits which are zero. Consumers maximize utility given a budget constraint. An institution g may levy taxes on technology i and household h; the mapping $t : I \cup H \to G$ describes the recipients of taxes. Zero profits for firms, budget equations for consumers and institutions are thus described through:

$$\forall i \in I : (p_i - \tau_i^y) y_i = \sum_{j \in J} (p_j + \tau_{ji}^X) X_{ji} \tag{2.2}$$

$$\forall h \in H : \sum_{j \in J} (p_j - \tau_{hj}^\omega) \omega_{hj} + T_h = \sum_{j \in J} (p_j + \tau_{hj}^C) C_{hj} \tag{2.3}$$

$$T_h = \sum_{h'j : h \in t(h')} \tau_{h'j}^\omega \omega_{hj} + \sum_{i : h \in t(i)} \tau_i^y y_i + \sum_{h'j : h \in t(h')} \tau_{h'j}^C C_{h'j} + \sum_{ij : h \in t(i)} \tau_{ji}^X X_{ji} \tag{2.4}$$

The model is completed by the FOCs

$$p_j + \tau_{ji}^X = \mu_i \frac{\partial f_i}{\partial (\mathbf{x}_i)_j} \tag{2.5}$$

$$p_j + \tau_{hj}^C = \mu_h \frac{\partial u_h}{\partial C_{hj}} \tag{2.6}$$

with $u_h(C_{hj})$ the utility function.

2.2 Incorporating material intensity endogenously

The integration of material flows into a Computable General Equilibrium (CGE) model represents an advancement in analyzing the interplay between economic activities and their environmental consequences. This approach, building on the work of Gerlagh and Lorang (2024), incorporates material flows to assess the effects of resource extraction and waste generation. The model is underpinned by the principle of mass balance, ensuring that the total mass of materials entering the system equals the total mass leaving it, thus providing a reliable representation of material flows.

Material intensity is modeled endogenously within the CGE framework, meaning that the con-

sumption of materials is driven by economic activities within each sector, for several materials (i.e., iron, CO_2 and steel). Details on the sectoral breakdown can be found in Appendix C. A key feature of this model is the endogenous adjustment of material intensities, which allows changes in resource use efficiency in response to economic conditions and policy interventions. This dynamic adjustment reflects real-world feedback mechanisms between economic and environmental systems. By disaggregating the economy into distinct sectors, the model captures variations in resource intensity and environmental Effects across different industries. This sectoral analysis is critical for understanding how specific policies affect material use and waste generation within various economic activities.

Our model places a particular focus on iron, steel, and carbon due to their roles in industrial processes and substantial environmental effects. We disaggregate the steel sector into primary, secondary, and recycling subsectors to capture the differences in production processes and material flows. This approach enables the model to accurately capture the demand for materials based on sectoral outputs and technological choices.

The integration of material flows into the CGE model also involves the use of Physical Input-Output Tables (PIOTs) alongside Social Accounting Matrices (SAMs). This dual approach enables a comprehensive assessment of material volumes affected by economic transactions, enhancing the model's accuracy. The calibration process involves deriving material intensities and balances, ensuring that the model accurately reflects the flow of materials through the economy. Taxes such as extraction, waste, and material taxes are incorporated to study their Effect on supply and demand prices, further elucidating the economic and environmental outcomes of different policy scenarios.

The integration of material flows in the CGE model involves several key features:

- **Material balances Tracking and Mass Conservation:** This principle ensures the accuracy and reliability of the model's representation of material flows throughout the economy. The model tracks material flows from extraction to waste management, ensuring a comprehensive understanding of environmental implications.

- **Endogenous adjustment:** The model considers endogenous adjustments in material intensities, meaning that changes in resource use efficiency can occur in response to economic conditions and policy interventions.

- **Sectoral analysis:** Material flows are tracked across different economic sectors, allowing for a detailed examination of resource use and waste generation within specific industries.

For detailed information on the calibration process, material flow integration, and specific equations used, please refer to Appendix A.

Let θ_i be the material intensity of output produced by technology i, which is endogenous. We assume an baseline intensity $\overline{\theta}_i$ and an endogenous adjustment $\theta_i = \lambda_i \overline{\theta}_i$. Let θ_{hj} be the exogenous material intensity for endowment hj. Let $\theta_{hj} = \lambda_j \overline{\theta}_{hj}$ be the endogenous material intensity of good i consumed by h. We assume the material intensity scales proportionally over all users of the good. Thus we have $\theta_{ij} = \lambda_i \overline{\theta}_{ij}$ the endogenous material intensity of intermediate delivery from i to j.

Let ρ_i be that material inflow intensity for producing good i, and ϵ_i the waste ratio. Gerlagh and Lorang (2024) show that the intra-firm material balances identify the (unique) endogenous change in material intensity λ_i through

$$\forall i \in I : \lambda_i \overline{\theta}_i y_i = (1 - \epsilon_i)(\rho_i y_i + \sum_{j \in J} \lambda_j \overline{\theta}_{ji} X_{ji}). \tag{2.7}$$

Note that Multiplication of the commodity balance per good with material intensities, and summation, then provides the law of material conservation. Overall gross material extraction equals gross waste:

$$\sum_{hj} \theta_{hj} \omega_{hj} + \sum_{i} \rho_i y_i = \sum_{i} \epsilon_i (\rho_i y_i + \sum_{j \in J} \lambda_j \overline{\theta}_{ji} X_{ji}) + \sum_{hj} \lambda_j \overline{\theta}_{hj} C_{hj} \tag{2.8}$$

When we subtract material recycled through use in secondary steel production, we get net material extraction and net waste production.

When calculating the waste footprint, we allocate all waste produced during production to the user of the good. Technically, we set $\epsilon_i = 0$.

2.3 CES tree and model specification

The CES production structure is a core component of our model. Figure 1 shows the production tree for steel, illustrating the hierarchical relationships between inputs and outputs in the production process. The CES tree allows us to model the substitution possibilities between different inputs, such as capital (K), labor (L), energy (ENE), and intermediate goods (INT), with specified elasticity values at each node.

The elasticity of substitution values, denoted by σ, indicate the ease with which one input can be substituted for another. For example, the substitution elasticity between capital and labor (KL) is $\sigma = 0.8$, reflecting moderate substitutability. The elasticities are different between sectors and the assumptions made were validated during workshop and through results from interviews with steel stakeholders. The overall structure enables us to examine how changes in input prices and policies affect the production of primary steel.

2.4 Policies and their implementation

The Green Deal policies analyzed in this paper include a range of policies aimed at reducing carbon emissions and promoting circular economy. These policies are designed to influence both the supply and demand sides of the market, targeting different stages of the production and consumption cycle to achieve decarbonisation adn circular economy goals. Different types of taxes are modeled to analyze their Effect on material flows and environmental outcomes.

The study considers several scenarios to analyze the Effect of different tax policies on the steel

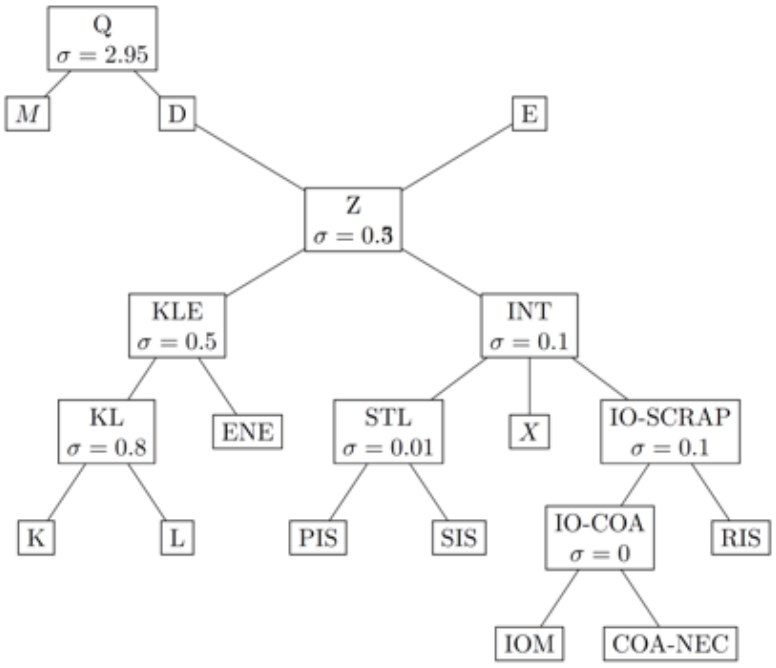


Figure 1: Production tree for primary steel

sector and its associated material flows. These scenarios include a CO_2 tax on steel, a CO_2 tax on steel with the Carbon Border Adjustment Mechanism (CBAM), a raw (extraction) tax, a raw (extraction) tax with CBAM, a raw (extraction) tax with CBAM plus an import tax on steel, and a waste tax.

In the first scenario, a CO_2 tax is imposed on the steel sector. This tax is intended to internalize the environmental costs of carbon emissions, providing an economic incentive for reducing greenhouse gas emissions within the steel production process. By increasing the cost of carbon-intensive activities, the tax aims to encourage more sustainable production practices and the adoption of cleaner technologies.

The second scenario extends the CO_2 tax by incorporating the Carbon Border Adjustment Mechanism (CBAM). CBAM is designed to prevent carbon leakage by applying the same carbon cost to imports as those faced by domestic producers. This ensures a level playing field between domestic and foreign steel producers, mitigating the risk of relocating production to countries with less stringent climate policies. The combination of the CO_2 tax and CBAM aims to enhance the effectiveness of carbon pricing in reducing global emissions.

The third scenario introduces a raw (extraction) tax. This tax targets the extraction of natural

resources, specifically iron ore in the context of steel production. By imposing a financial charge on the extraction process, the tax aims to promote the conservation of raw materials and reduce the environmental Effect associated with resource extraction. It encourages producers to improve resource efficiency and explore alternative, less resource-intensive production methods.

In the fourth scenario, the raw (extraction) tax is combined with CBAM. Similar to the second scenario, this combination aims to prevent resource extraction from shifting to countries with lower environmental standards. By applying the extraction tax uniformly to both domestic and imported raw materials, CBAM ensures that the tax effectively promotes sustainable resource use on a global scale.

The fifth scenario further extends the previous one by adding an import tax on steel. This additional tax on imported steel is intended to protect domestic steel producers from unfair competition and incentivize the use of locally produced steel. By combining the raw (extraction) tax, CBAM, and the import tax, this scenario aims to comprehensively address environmental Effects throughout the supply chain, from raw material extraction to final steel production.

Finally, the sixth scenario examines the implementation of a waste tax. This tax is imposed on the generation of waste materials within the steel sector. By financially penalizing waste generation, the tax encourages the adoption of waste reduction measures and more efficient waste management practices. It aims to minimize the environmental footprint of steel production by promoting the recycling and reuse of materials, ultimately contributing to a circular economy.

These scenarios provide a comprehensive framework for evaluating the potential economic, resource and decarbonisation effects of various tax policies on the steel sector. The tax mechanisms included are:

2.4.1 Extraction Tax

The extraction tax is imposed on the extraction of raw materials, aimed at promoting sustainable resource use and reducing the environmental Effect of resource extraction. This tax increases the supply price by:

$$\sum_{m} \tau^{R}_{(m,s,r)} \rho_{(m,s,r)}$$

where $\tau^{R}_{(m,s,r)}$ is the extraction tax rate for material m in sector s and region r, and $\rho_{(m,s,r)}$ is the resource extraction intensity for material m in sector s and region r.

2.4.2 Waste Tax

The waste tax is a financial charge imposed on the generation of waste materials, aimed at incentivizing waste reduction and promoting more efficient waste management practices. This tax

increases the demand price by:

$$\frac{\sum_m \tau^W_{(m,sa,r)} \epsilon_{(s,sa,r)} \text{MFL}_{(m,s,sa,r)}}{X_{(s,sa,r)}}$$

where $\tau^W_{(m,sa,r)}$ is the waste tax rate for material m in sector sa and region r, $\epsilon_{(s,sa,r)}$ is the waste intensity, $\text{MFL}_{(m,s,sa,r)}$ represents the material flow for material m in sector s, sub-sector sa, and region r, and $X_{(s,sa,r)}$ is the total output in sector s, sub-sector sa, and region r.

2.4.3 Import/Material Tax

The material tax is levied on the use of specific raw materials within the production process, aimed at encouraging the efficient use of resources and reducing environmental Effects. This tax increases the demand price by:

$$\frac{\sum_m \tau^M_{(m,sa,r)} \text{MFL}_{(m,s,sa,r)}}{X_{(s,sa,r)}}$$

where $\tau^M_{(m,sa,r)}$ is the material tax rate for material m in sector sa and region r, $\text{MFL}_{(m,s,sa,r)}$ represents the material flow for material m in sector s, sub-sector sa, and region r, and $X_{(s,sa,r)}$ is the total output in sector s, sub-sector sa, and region r.

The tax rates applied in the scenarios are:

- CO_2 tax: \$75 per ton. This tax is designed to internalize the environmental costs of carbon emissions, providing an economic incentive to reduce greenhouse gas emissions.
- Extraction tax: \$35 per ton. This tax targets the extraction of natural resources, encouraging the conservation and sustainable use of raw materials.
- Import tax on steel: \$35 per ton. This tax is imposed on imported steel to protect domestic industries and encourage the use of locally produced steel, potentially reducing the environmental Effect associated with transportation.

2.5 Data and assumptions

The model is based on the Global Trade Analysis Project (GTAP) database, specifically GTAP-11 (2017), which provides a detailed representation of global economic activity. This dataset provides comprehensive information on the total volumes of materials (expressed in USD monetary terms). In addition to the GTAP data, information on the volumes (in tons) of the extraction sector for steel is sourced from various reputable organizations, including the International Resource Panel (IRP), the United States Geological Survey (USGS), and the World Steel Association. Further specification can be found in Appendix B.

It is assumed that iron ore is exclusively delivered to the steel sector and that there is a single global price for iron ore, approximately 75 USD per ton. The revenue from iron ore mining equals

the expenditure, and it is assumed that iron ore mining has the same cost structure as the aggregate Mining sector.

The steel sector of GTAP is divided into three subsectors: primary, secondary, and recycling. The cost structure for these subsectors follows the GTAP-CE framework. The material flows are linked to the value of deliveries as follows: iron ore is converted to steel in the steel production process, which is then used in other manufacturing processes and ultimately reaches the customers. Waste rates are assumed to be 100% at the end of the product life cycle, with no stocks, except for iron ore at steel production, which has a waste rate of 50%, steel in steel production with a waste rate of 10%, and steel in other manufacturing with a waste rate of 5%.

Several challenges are associated with the data. Firstly, the available dataset pertains only to the year 2014, with an update to 2017 anticipated later this year. This temporal limitation constrains the applicability of the data to more recent economic conditions and trends. Secondly, the data is primarily expressed in monetary terms (USD) for transactions, which poses a challenge for analyses that require physical volume data (in tons). The available volume data, although useful, is not highly detailed and is not specifically aligned with transaction data.

Furthermore, while the GTAP data provides a detailed and decomposed view of economic activities, it remains less mature compared to other datasets. The neatness and decomposition of GTAP data offer an advantage in analysis, but the maturity level indicates that further refinements and updates are necessary to enhance its robustness and applicability. This immaturity affects the reliability of the data, particularly for detailed sectoral analysis and policy evaluation.

3 Results

This section presents the results of the implemented policy schemes, illustrating how the model captures the effects of decarbonisation and resource policies both upstream (extraction) and downstream (waste management). We analyze the effects on material extraction, consumption patterns, and CO_2 emissions, considering the scenarios of CO_2 tax on steel (CO2Tax), CO_2 tax on steel with carbon adjustment mechanisms (CO2Tax+CBAM), extraction tax (RawTax), extraction tax with CBAM (RawTax+CBAM), extraction tax with CBAM plus import tax on steel (RawTax+CBAM+IMTaxSteel), and waste tax (WasteTax). The policy effects on emissions are summarized in Tables 1, 2 and 3.

Table 1: Policy Effect Compared to Baseline (Part 1)

Policy	**GDP EU**	**GDP ROW**	**GDP Global**	**Iron ore EU**	**Iron ore ROW**	**Iron ore Global**
CO2Tax	-3659.30	2543.12	-1116.19	-0.16	1.56	1.40
CO2Tax+CBAM	-2927.57	1824.06	-1103.51	-0.08	-0.14	-0.23
RawTax	-1216.76	601.29	-615.47	-30.74	25.34	-5.40
RawTax+CBAM	-3148.89	2391.69	-757.21	-20.67	14.03	-6.64
RawTax+CBAM+IMTaxSteel	-2702.94	1972.49	-730.46	-20.57	12.89	-7.68
WasteTax	-0.29	-1.90	-2.19	-2.74	4.28	1.54

Table 2: Policy Effect Compared to Baseline (Part 2)

Policy	**CO_2 EU**	**CO_2 ROW**	**CO_2 Global**
CO2Tax	-10.66	6.88	-3.78
CO2Tax+CBAM	-9.30	2.98	-6.32
RawTax	-0.57	0.44	-0.13
RawTax+CBAM	-2.93	4.76	1.83
RawTax+CBAM+IMTax	-2.07	2.48	0.41
WasteTax	-0.29	-1.90	-2.19

Table 3: Policy Effect Compared to Baseline (Part 3)

Policy	$Iron_{EU}GDP_{EU}$	$\mathbf{CO_{2EU}/GDP_{EU}}$	$\mathbf{Iron_{Tot}/GDP_{EU}}$	$\mathbf{CO_{2Tot}/GDP_{EU}}$	$\mathbf{Iron_{Tot}/GDP_{Tot}}$	$\mathbf{CO_{2Tot}/GDP_{Tot}}$
CO2Tax	0.000043	0.002912	-0.000383	0.001032	-0.001256	0.003384
CO2Tax+CBAM	0.000029	0.003177	0.000078	0.002158	0.000208	0.005724
RawTax	0.025267	0.000466	0.004441	0.000108	0.008780	0.000213
RawTax+CBAM	0.006563	0.000931	0.002109	-0.000581	0.008768	-0.002416
RawTax+CBAM+IMTax	0.007610	0.000767	0.002841	-0.000150	0.010511	-0.000555
WasteTax	0.000043	0.002912	-0.000383	0.001032	-0.001256	0.003384

The implementation of CO_2 taxes, both with and without CBAM, shows a negative effect on GDP for the EU, with CO_2 Tax leading to a decrease of approximately 3659.3 units and CO_2 Tax+CBAM showing a slightly smaller decrease of around 2927.57 units. The RawTax scenario results in a reduction in GDP for the EU by about 1216.76 units, which is less severe compared to the combined policies of RawTax+CBAM and RawTax+CBAM+IMTaxSteel, which show reductions of 3148.89 and 2702.94 units, respectively.

The mechanisms driving these results include changes in imports and trade flows, the direct and embedded materials in goods, and changes in the intensity of steel use per sector. Eco-design incentives also play a role, encouraging sectors to adopt more efficient production processes and reduce material and energy use.

3.1 Effect on iron ore extraction

Iron ore extraction in the EU decreases under all scenarios, with the RawTax scenario showing the largest reduction of 30.74 units. Adding CBAM reduces the extraction by 20.67 units, and further combining with import tax on steel (RawTax+CBAM+IMTaxSteel) shows a reduction of 20.57 units. Interestingly, the CO_2 Tax scenarios show a much smaller reduction in iron ore extraction, indicating that these taxes are less effective in reducing resource extraction compared to direct raw material taxes.

The results, depicted in Figure 2 show that the extraction tax is the most effective in reducing iron ore mining, increasing the supply price of iron ore in Europe by 50%. However, this policy also results in a leakage effect where extraction in the rest of the world increases, as Europe exports less and imports more iron ore, leading to a leakage rate of 82%. By taxing the import of iron ore and steel, the leakage can be reduced to 63%, as higher prices for imports decrease the overall demand for steel. It is important to note that the input of iron ore constitutes less than 3% of the total production cost of the steel sector, with energy (6%), capital and labor (20%), and services (25%) being larger.

3.2 Effect on primary steel production

Figure 3 illustrates that primary steel production in Europe decreases in all scenarios due to increased production costs or, in the case of WasteTax, increased consumption costs. With the RawTax scenario, production also decreases in the rest of the world due to higher iron ore prices. The increased demand in Europe for iron ore from the rest of the world causes a small price increase of iron ore globally, making primary steel production more expensive and reducing demand (Figure 3).

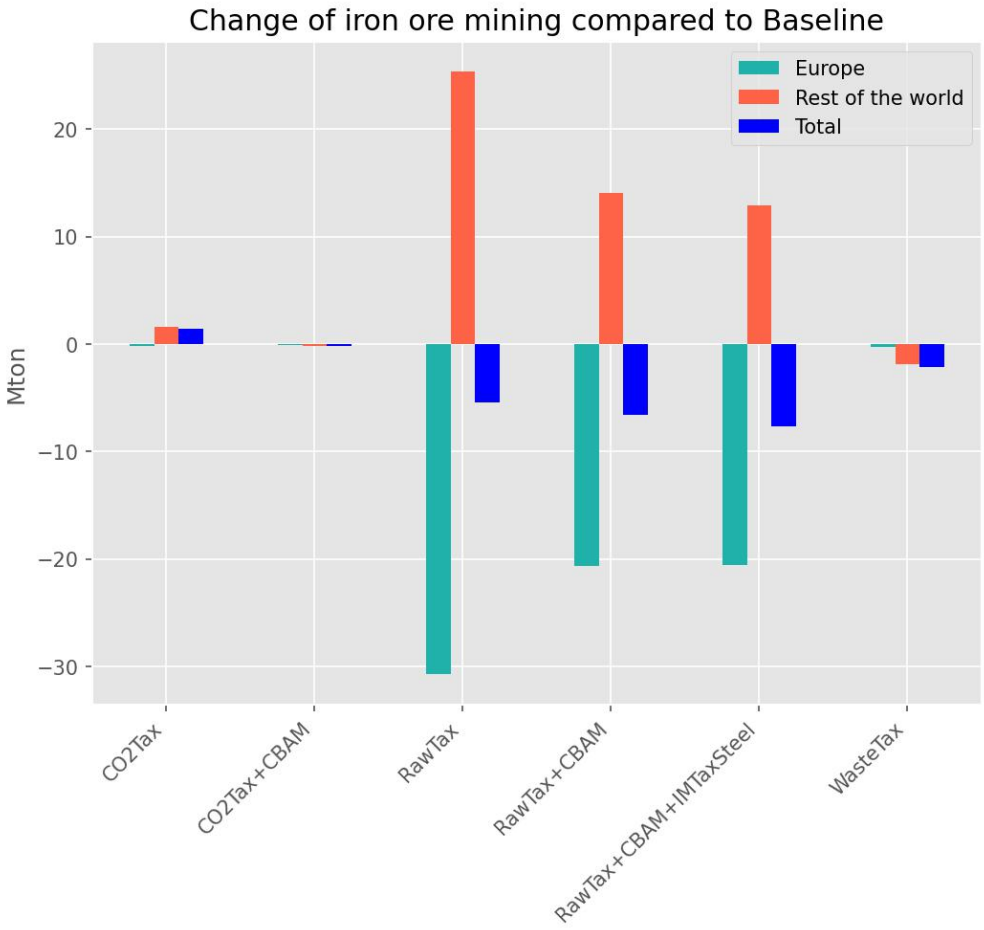


Figure 2: Effect on Iron Ore Mining

3.3 Effect on secondary steel production

The production of secondary steel in Europe is stimulated by the CBAM, as more expensive imports of primary steel from the rest of the world lead to a shift towards secondary steel. In the rest of the world, secondary steel production increases due to higher demand for steel imports from Europe, which results in higher prices for both primary and secondary steel (see Figure 4).

3.4 Effect on use of Recycling Steel

Scrap (recycling steel) is used in both primary and secondary steel production, so changes in scrap use result from changes in both production types. As depicted in Figure 5, in all scenarios, primary steel becomes more expensive compared to secondary steel, especially in the RawTax scenario, where cost increases are mitigated by importing iron ore. Global use of scrap increases in all scenarios except for the WasteTax scenario, where Europe imports less due to higher prices of goods, including steel. With RawTax, the overall demand for steel decreases and shifts from Europe to the rest of the world. This decrease is more pronounced in the RawTax+CBAM and WasteTax

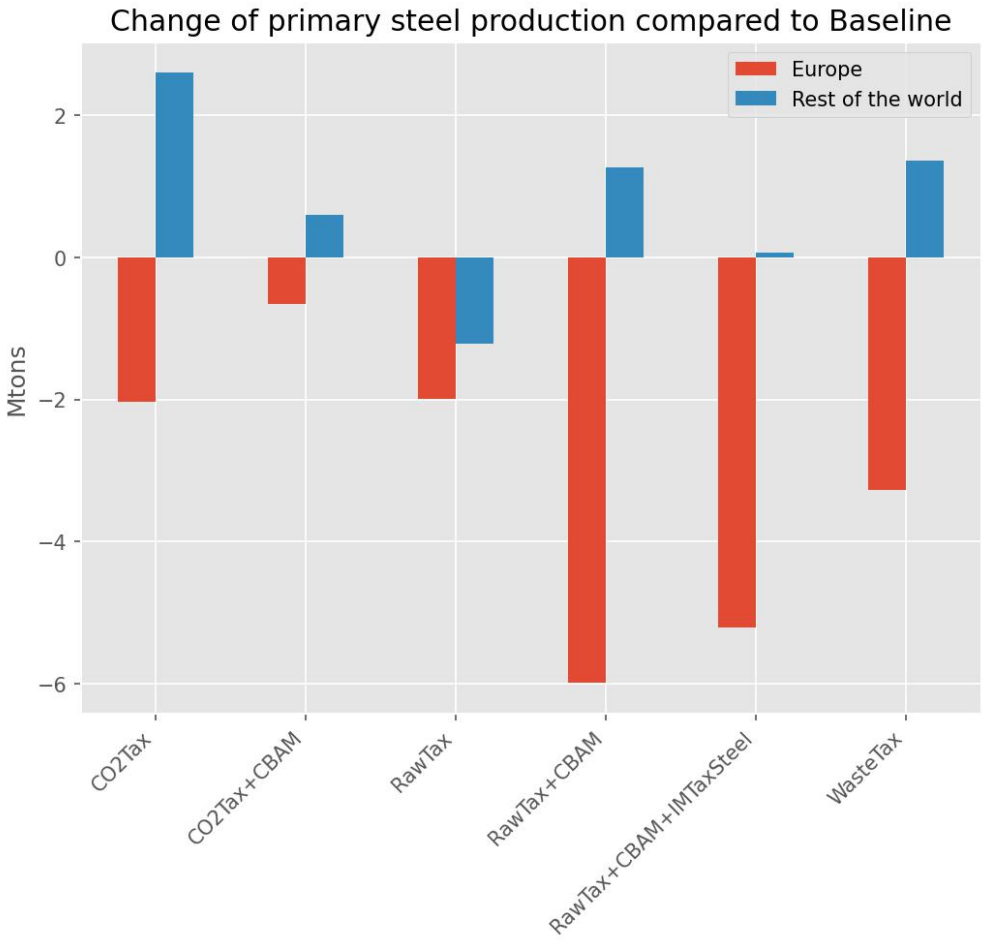


Figure 3: Effect on Primary Steel Production

scenarios.

3.5 Effect on CO_2 emissions

CO_2 emissions in the EU decrease under the CO_2 tax scenarios, with CO_2 Tax showing a reduction of 10.66 units and CO_2 Tax+CBAM showing a reduction of 9.30 units. RawTax results in a modest reduction of 0.57 units, whereas combining it with CBAM (RawTax+CBAM) increases the reduction to 2.93 units. Adding the import tax on steel (RawTax+CBAM+IMTaxSteel) shows a reduction of 2.07 units. Global emissions, however, increase under most scenarios due to the higher emission intensity of production in regions outside the EU.

The RawTax scenario has only a small Effect on emissions, mainly causing a shift of extraction from Europe to the rest of the world. Global emissions increase in the RawTax+CBAM, RawTax+CBAM+IMTaxSteel, and WasteTax scenarios due to the higher emission intensity of steel production in the rest of the world.

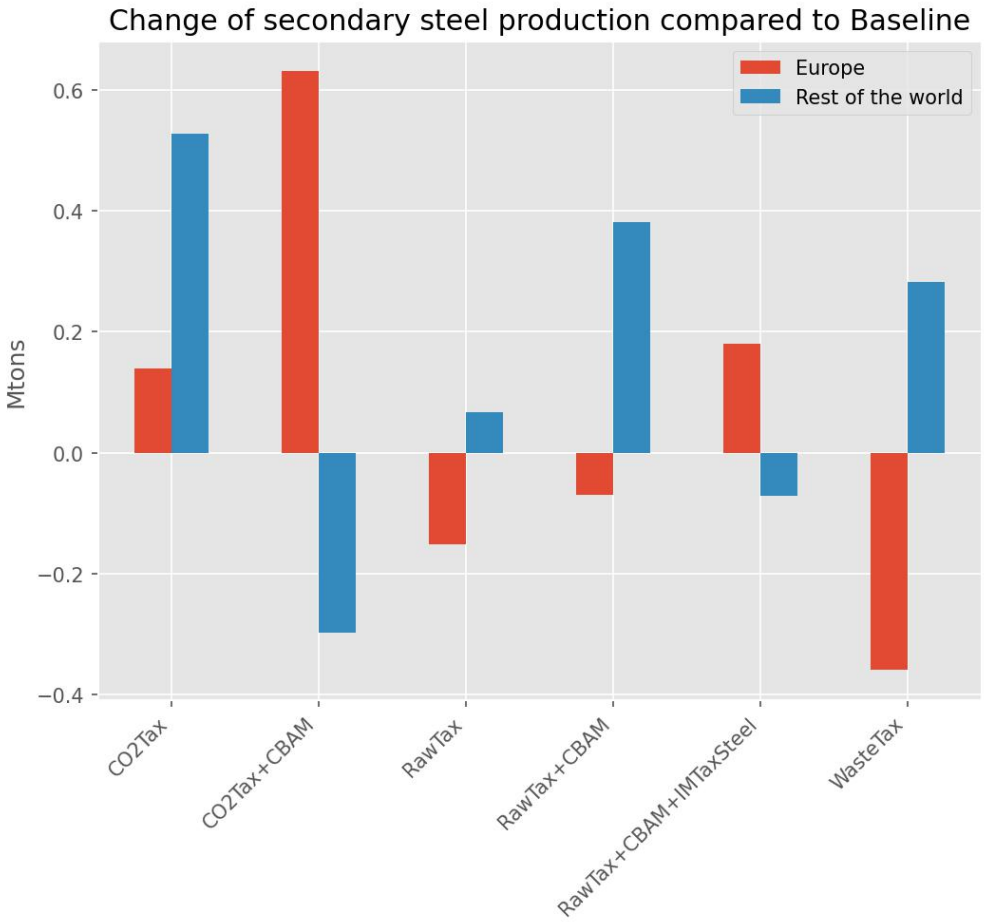


Figure 4: Effect on secondary steel production

3.6 Efficiency of the policies

When focusing on the cost implications and efficiency of these measures in reducing resource extraction and emissions, we see that the results are disparate. The three figures illustrate the same policies but in terms of GDP, capturing their efficiency for the same level of GDP invested.

Figure 7 illustrates the policy effects in the EU at the cost of units of EU GDP. The RawTax policy effectively reduces iron ore extraction in Europe with a relatively low effect on GDP. However, the effect on emissions is minor, primarily because the reduction in extraction in Europe is offset by an increase in extraction in the rest of the world. This leakage effect underscores the importance of considering global effects when implementing regional policies. Additionally, taxing imports enhances the efficiency of emission reductions, making this approach more effective than imposing a raw material tax alone.

Figure 8 depicts the policy effects in the world at the cost of EU GDP. The RawTax remains the most efficient measure for reducing iron ore extraction globally. However, when combined with an import tax, the reduction in extraction becomes larger but at a much higher GDP cost. The

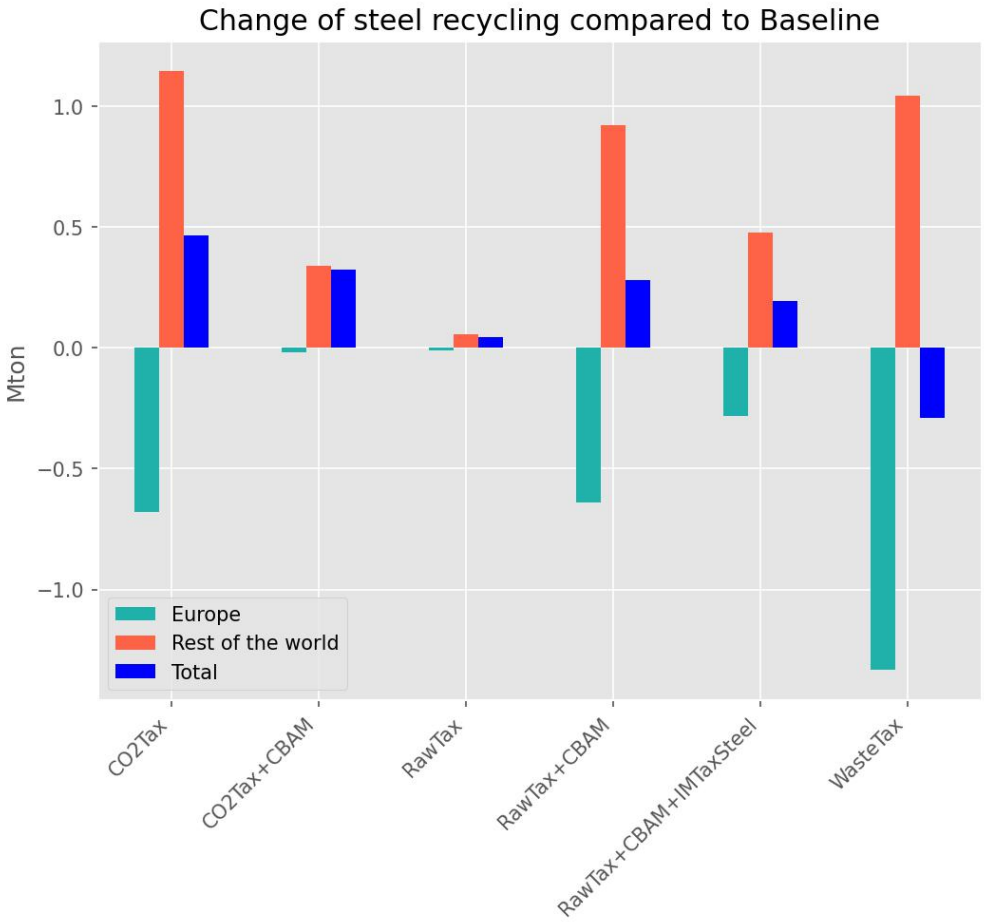


Figure 5: Effects on steel recycling Use

analysis shows that taxing the import of steel enhances the reduction efficiency for both emissions and iron ore. The loss in steel production has a more substantial effect on global GDP compared to the loss in iron ore extraction, indicating that policies need to balance between economic effects and environmental benefits.

The RawTax reduces extraction in Europe at a relatively low cost, but with only a small effect on emissions. However, this effect is mainly a shift of extraction to the rest of the world, combined with increased imports by Europe. Taxing imports increases the efficiency of emission reduction in Europe across all tax schemes.

Figure 9 shows the policy effects in the world at the cost of world GDP. At a global level, a tax on materials appears to be an expensive method to reduce emissions. The primary reason is the higher cost associated with shifting extraction and production activities globally. In contrast, a carbon tax provides a broader incentive for reducing emissions, not only by reducing the use of steel but also by encouraging lower emission intensities in steel production. This comprehensive approach suggests that carbon taxes might be more effective in achieving global emission reduction targets compared to material-specific taxes.

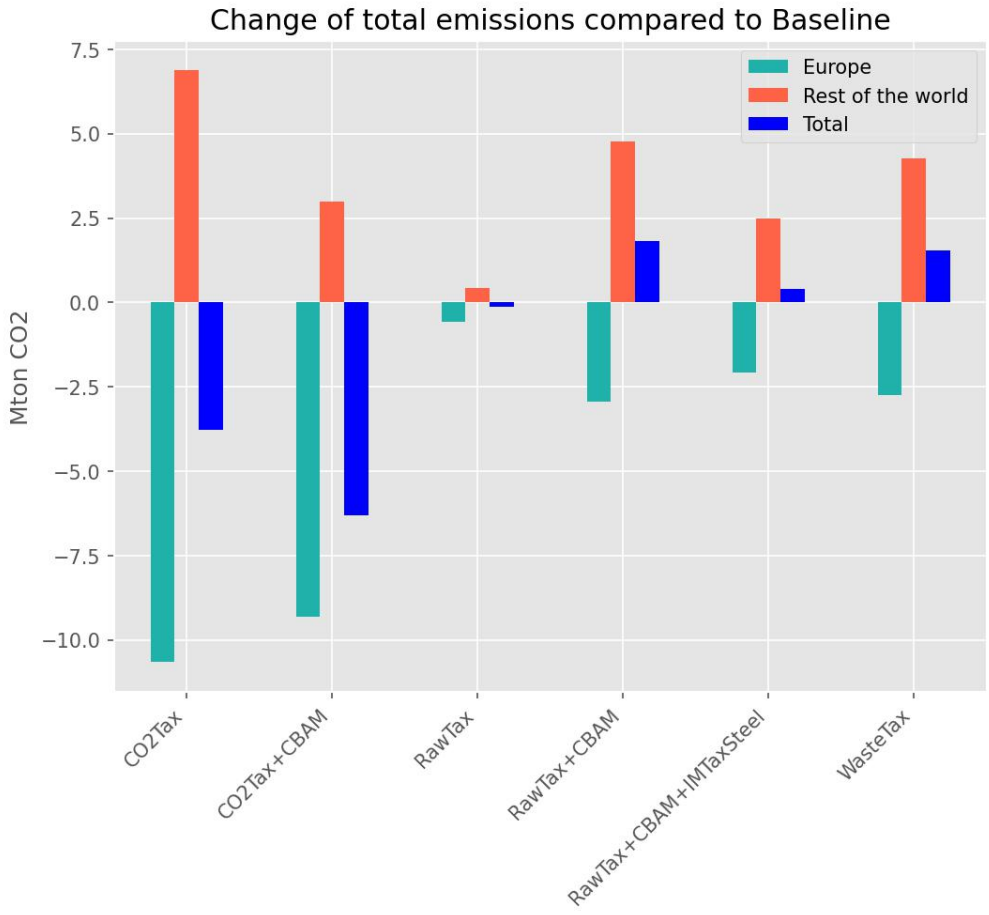


Figure 6: Effects on CO_2 emissions

At a global level, a tax on materials appears to be an expensive way to reduce emissions. A carbon tax provides a broader incentive for reducing emissions, not only through using less steel but also by reducing the emission intensity of steel production.

3.7 Material balance analysis

Figure 10 illustrates the material balance in Europe, showing the contributions of extraction, import, waste from production, waste from consumption, and export under different tax scenarios. It is evident that policies such as RawTax and RawTax+CBAM+IMTaxSteel reduce the extraction in Europe while increasing imports. The waste from production and consumption remains relatively constant across the scenarios, indicating that these policies mainly affect the extraction and import stages of the material lifecycle.

In contrast, Figure 11 provides a comprehensive view of the global material balance, including both Europe and the rest of the world. The figure highlights how the reduction in extraction in Europe is offset by an increase in extraction in the rest of the world. This leakage effect is particularly pronounced under the RawTax scenario. Moreover, the waste generated from production and

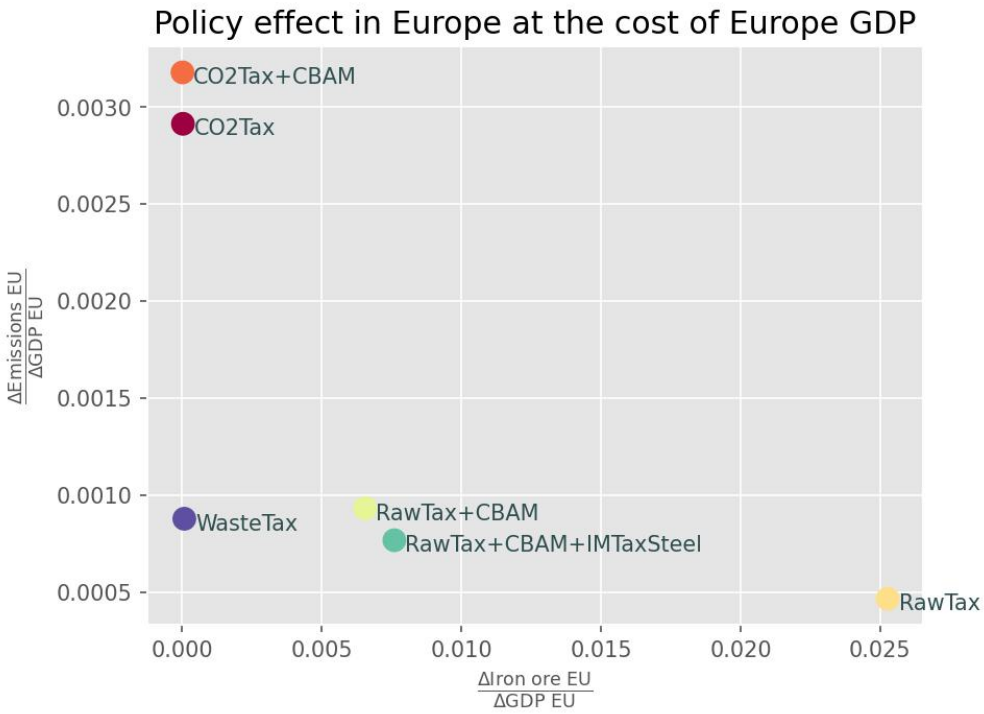


Figure 7: Policy effect in the EU at the cost of units of EU GDP

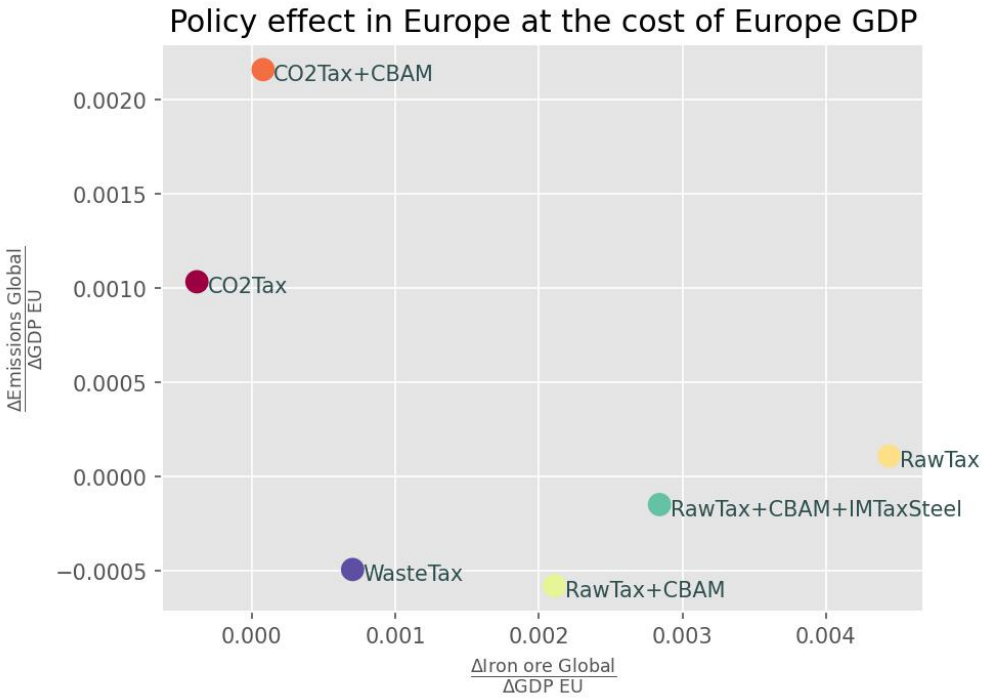


Figure 8: Policy effect in the world at the cost of EU GDP

consumption in both Europe and the rest of the world exhibits minimal variation across different

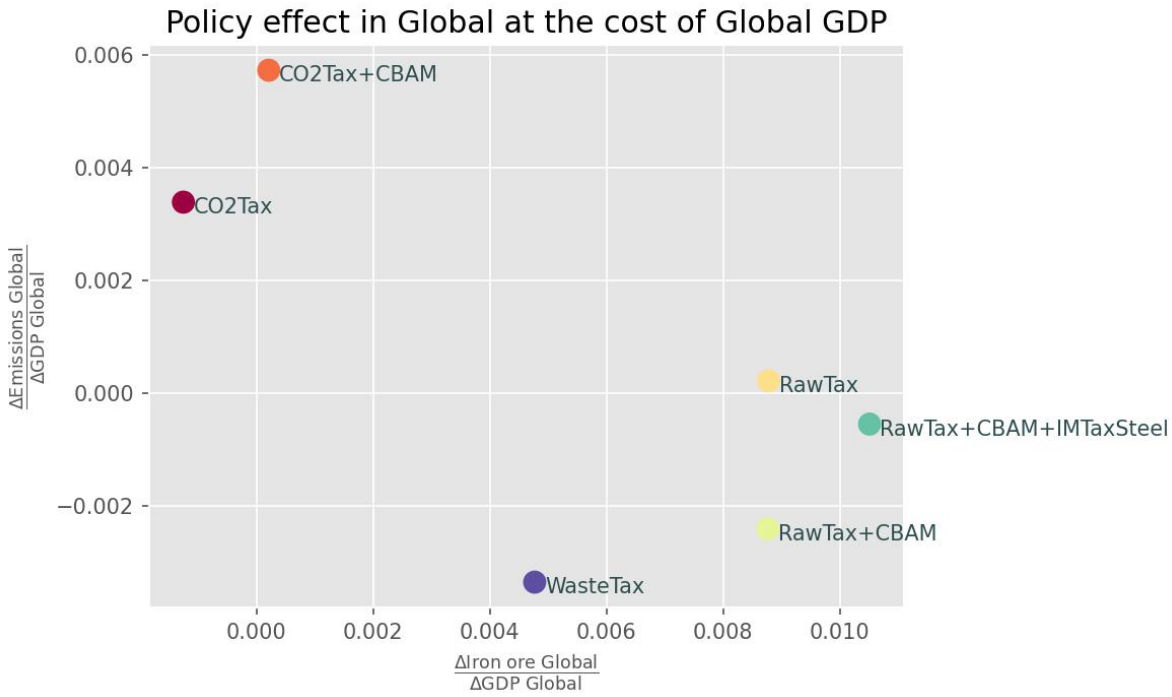


Figure 9: Policy effect in the world at the cost of world GDP

tax policies, suggesting that while regional policies can shift the burden of extraction, they have a limited effect on global waste generation patterns.

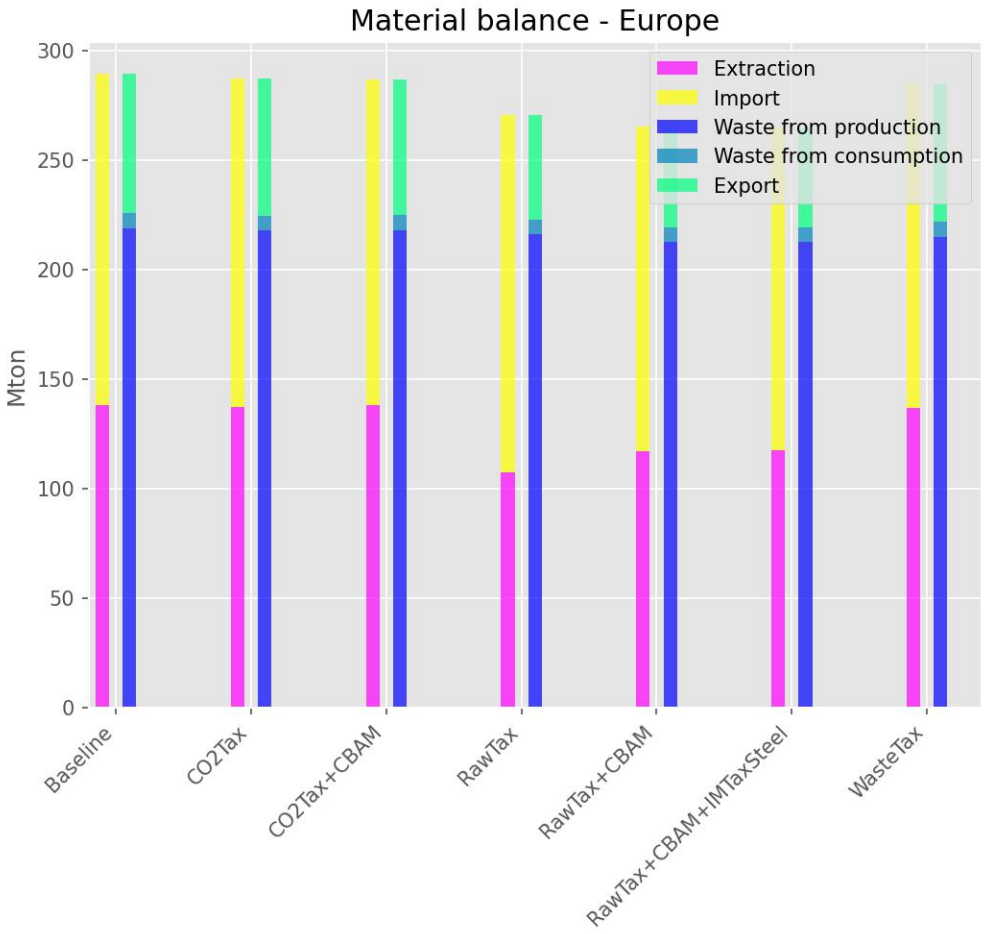


Figure 10: Material balance in Europe under different tax scenarios

4 Discussion and caveats

4.1 Climate change effects of resource policies

Resource policies have direct and indirect effects on climate change. Raw material taxes can reduce emissions by lowering the demand for resource-intensive products, but their effect on CO_2 emissions is less pronounced unless combined with measures like the Carbon Border Adjustment Mechanism (CBAM). CBAM ensures that imported goods face the same carbon costs as domestic products, preventing carbon leakage. For instance, the RawTax scenario combined with CBAM showed a reduced leakage rate, highlighting the importance of comprehensive policies in mitigating climate change. Additionally, CO_2 taxes and Emissions Trading Systems (ETS) provide broader incentives for reducing emissions by targeting the emission intensity of production processes. These mechanisms encourage industries to adopt cleaner technologies and improve energy efficiency, thus contributing to global emission reduction goals.

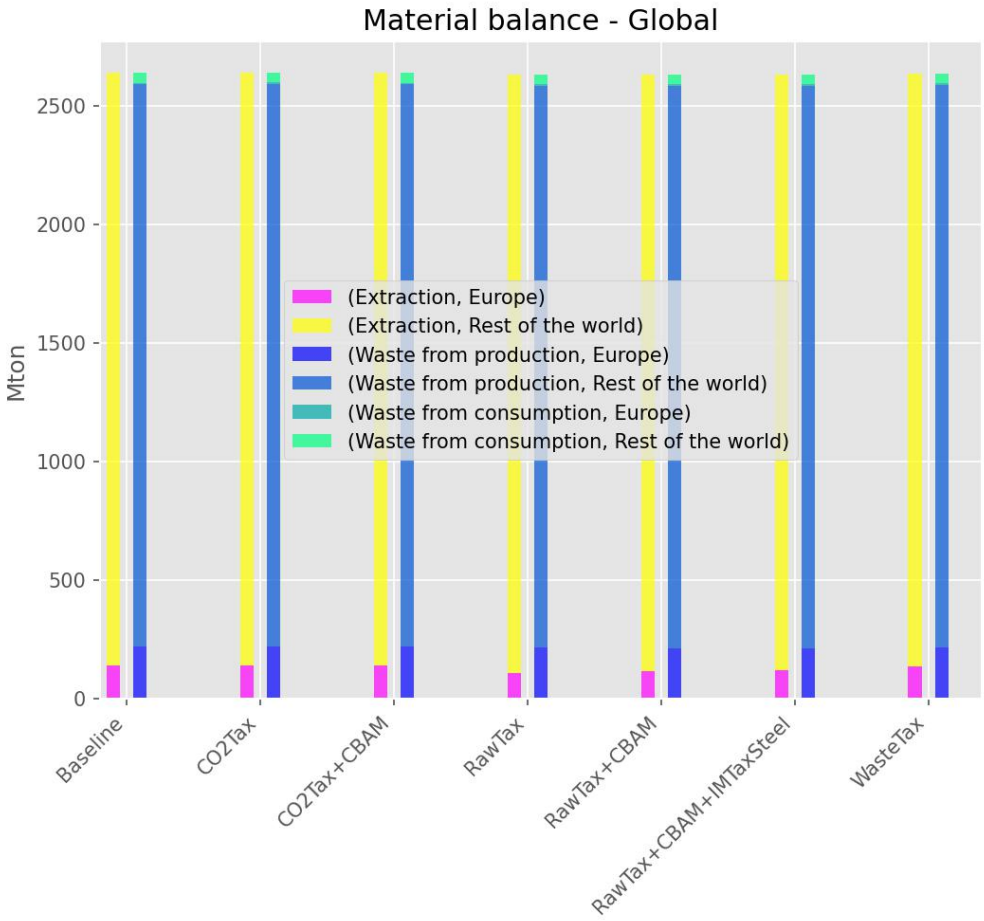


Figure 11: Global material balance under different tax scenarios

4.2 Implications of upstream versus downstream taxes on resource management

The distinction between upstream (extraction) and downstream (waste) taxes allows the understanding of their effect on resource management. Upstream taxes, such as raw material taxes, directly target the extraction phase, aiming to reduce the extraction of natural resources. This approach can lead to a reduction in resource use in the targeted region, as seen in the RawTax scenario, which effectively reduced iron ore extraction in Europe. However, the downside is the leakage effect, where the reduction in extraction in one region is offset by an increase in another region. Downstream taxes, like waste taxes, focus on the end-of-life phase of products, incentivizing better waste management and recycling practices. While these taxes do not directly reduce resource extraction, they can lead to a more sustainable use of resources by promoting recycling and reducing the overall demand for raw materials.

4.3 Leakages and trade-offs

Leakages occur when the reduction in resource extraction or emissions in one region leads to an increase in another region. Disparities between global and local taxation policies can lead to the phenomenon of exporting emissions, where stringent environmental policies in one region drive industries to relocate to regions with less stringent regulations, thereby exporting emissions rather than reducing them globally. This effect can undermine the global effectiveness of policies, as seen with the extraction tax, which shifted extraction from Europe to the rest of the world. Implementing global coordination mechanisms, such as the Carbon Border Adjustment Mechanism (CBAM), can help mitigate these disparities by applying the same tax rate to imports, ensuring that all products, regardless of origin, are subject to the same environmental standards.

There is also a noticeable trade-off between reducing resource extraction and minimizing CO_2 emissions. While raw material taxes effectively reduce iron ore extraction, their effect on CO_2 emissions is less pronounced unless combined with measures like CBAM. Single-target policies, such as a CO_2 tax or an extraction material tax alone, can lead to leakages, where reductions in one domain are offset by increases in another. For CO_2, an Emissions Trading System (ETS) proves to be the most effective. Combined policies offer a more holistic approach, reducing both resource extraction and emissions more effectively, highlighting the importance of integrated policy frameworks to address environmental sustainability comprehensively.

4.4 Disparities between global and local policies, and sustainability of policies

As discussed in the section on leakages, disparities between global and local taxation policies can lead to exporting emissions, as stringent policies in one region drive industries to relocate to less regulated regions. Global coordination mechanisms like the Carbon Border Adjustment Mechanism (CBAM) can mitigate these disparities by ensuring uniform environmental standards. This approach promotes global environmental sustainability by preventing the shifting of environmental burdens.

The sustainability of tax schemes depends on their design and implementation. Single-target policies, such as a CO_2 tax or material tax alone, often lead to unintended consequences, such as leakages into non-targeted domains. For example, a CO_2 tax may reduce emissions but increase material use elsewhere, while a material tax could have the opposite effect. Combined policies, which address multiple aspects of resource use and emissions, are more effective in achieving broader sustainability goals. However, these tax schemes can also lead to potential injustices. Higher production costs due to taxes may be passed on to consumers, disproportionately affecting lower-income households. Additionally, regions with industrial activities may face economic disadvantages compared to regions with less stringent environmental regulations. Policymakers must consider these potential injustices and strive to design tax schemes that are both effective and equitable.

5 Conclusion

This study provides an analysis of the European Union's Green Deal policies on global resource management and climate change mitigation using the enhanced Computable General Equilibrium model, Green-R. By incorporating material intensity as an endogenous factor and integrating Physical Input-Output Tables with Social Accounting Matrices, we assessed the material volumes affected by upstream and downstream taxation policies, focusing on iron, steel, and carbon.

The analysis reveals that raw material taxes, while effective in reducing iron ore extraction in Europe, tend to shift the burden globally, leading to minimal net reductions in emissions. Leakage effects are particularly large in scenarios involving raw material taxes, with iron ore extraction increasing in the rest of the world by 25.34 units under the RawTax scenario. Introducing Carbon Border Adjustment Mechanisms (CBAM) reduces this leakage, limiting the increase to 14.03 units, and further combining CBAM with import taxes on steel mitigates the leakage effect to 12.89 units.

While upstream taxes directly target resource extraction, downstream taxes, such as waste taxes, promote recycling and reduce waste generation but have a limited direct effect on resource extraction. These findings underscore the trade-offs between reducing resource extraction and minimizing CO_2 emissions. Single-target policies, such as a CO_2 tax alone, may reduce emissions but lead to higher material use elsewhere, whereas a material tax could have the opposite effect.

Combined policy measures, particularly those incorporating CBAM, are shown to be more effective in reducing both resource extraction and CO_2 emissions. CBAM helps mitigate leakage effects by applying equivalent taxes on imports, ensuring that emission reductions in one region are not offset by increases elsewhere. This makes CBAM a potential policy for achieving circular economy goals and climate mitigation within the context of unilateral policies.

The study also addresses the disparities between global and local taxation policies. Localized policies, while effective within their jurisdictions, can lead to the phenomenon of exporting emissions, thus undermining global environmental sustainability. Harmonized global policies are essential to ensure that local actions contribute positively to global sustainability objectives.

Resource policies, particularly those targeting CO_2 emissions, play a critical role in mitigating climate change. The Emissions Trading System (ETS) proves to be the most effective for CO_2 reductions, as it provides a broader incentive for reducing emissions not only through reduced steel use but also by encouraging lower emission intensities in steel production.

The sustainability and potential injustices associated with these tax schemes are critically examined. While taxes on resource extraction and emissions are necessary for promoting sustainability, they can disproportionately affect lower-income populations if not implemented thoughtfully. Ensuring that tax schemes include measures to mitigate these socioeconomic effects is vital for achieving equitable sustainability. Transparent and inclusive policy-making processes can help address potential injustices and garner broader support for sustainability initiatives.

The enhanced Green-R model offers valuable insights into the synergies and conflicts between climate and circular economy policies. Policymakers are encouraged to adopt combined policy

measures that address both resource management and climate change mitigation effectively. By considering the global effects of local actions and incorporating mechanisms like CBAM, it is possible to design more holistic and sustainable policies.

References

R. U. Ayres and A. V. Kneese. Production, Consumption, and Externalities. *The American Economic Review*, 59:282–97, 1969.

L. Barrage. Optimal Dynamic Carbon Taxes in a Climate–Economy Model with Distortionary Fiscal Policy. *The Review of Economic Studies*, 87:1–39, 2020. ISSN 0034-6527, 1467-937X. doi:10.1093/restud/rdz055.

C. J. Blackburn and J. Moreno-Cruz. Energy efficiency in general equilibrium with input–output linkages. *Journal of Environmental Economics and Management*, 110:102524, Oct. 2021. ISSN 0095-0696. doi:10.1016/j.jeem.2021.102524. URL https://www.sciencedirect.com/science/article/pii/S0095069621000887.

C. Böhringer and K. E. Rosendahl. Europe beyond coal – An economic and climate impact assessment. *Journal of Environmental Economics and Management*, 113:102658, May 2022. ISSN 0095-0696. doi:10.1016/j.jeem.2022.102658. URL https://www.sciencedirect.com/science/article/pii/S0095069622000365.

R. Dellink. The consequences of a more resource efficient and circular economy for international trade patterns: A modelling assessment. Technical report, OECD, Paris, June 2020.

C. Fischer and A. K. Fox. Comparing policies to combat emissions leakage: Border carbon adjustments versus rebates. *Journal of Environmental Economics and Management*, 64(2):199–216, Sept. 2012. ISSN 0095-0696. doi:10.1016/j.jeem.2012.01.005. URL https://www.sciencedirect.com/science/article/pii/S0095069612000186.

R. Gerlagh and E. Lorang. Material source and waste taxes in competitive equilibrium. 2024. URL https://www.cesifo.org/DocDL/cesifo1_wp11091.pdf.

J. Hassler and P. Krusell. Economics and climate change: Integrated assessment in a multi-region world. *Journal of the European Economic Association*, 10(5):974–1000, Oct. 2012. ISSN 15424766. doi:10.1111/j.1542-4774.2012.01082.x.

J. S. Holladay, M. Mohsin, and S. Pradhan. Emissions leakage, environmental policy and trade frictions. *Journal of Environmental Economics and Management*, 88:95–113, Mar. 2018. ISSN 0095-0696. doi:10.1016/j.jeem.2017.10.004. URL https://www.sciencedirect.com/science/article/pii/S0095069616301462.

K. Ibenholt. Material Accounting in a Macroeconomic Framework: Forecast of Waste Generated in Manufacturing Industries in Norway. *Environmental and Resource Economics*, 26(2):227–248, 2003. doi:10.1023/A:1026346119612.

A. A. Liu. Tax evasion and optimal environmental taxes. *Journal of Environmental Economics and Management*, 66(3):656–670, Nov. 2013. ISSN 0095-0696. doi:10.1016/j.jeem.2013.06.004. URL https://www.sciencedirect.com/science/article/pii/S0095069613000454.

T. Masui. Policy evaluations under environmental constraints using a computable general equilibrium model. *European Journal of Operational Research*, 166(3):843–855, Nov. 2005. ISSN 03772217. doi:10.1016/j.ejor.2004.07.002.

V. Nechifor, A. Calzadilla, R. Bleischwitz, M. Winning, X. Tian, and A. Usubiaga. Steel in a circular economy: Global implications of a green shift in China. *World Development*, 127:104775, Mar. 2020. ISSN 0305750X. doi:10.1016/j.worlddev.2019.104775.

R. G. Noll and J. Trijonis. Mass Balance, General Equilibrium, and Environmental Externalities. *The American Economic Review*, 61(4):730–735, 1971.

K. Pittel, J.-P. Amigues, and T. Kuhn. Recycling under a material balance constraint. *Resource and Energy Economics*, 32(3):379–394, 2010. doi:10.1016/j.reseneeco.2009.10.003.

M. Sjöström and G. Östblom. Decoupling waste generation from economic growth — A CGE analysis of the Swedish case. *Ecological Economics*, 69(7):1545–1552, May 2010. ISSN 09218009. doi:10.1016/j.ecolecon.2010.02.014.

M. Winning, A. Calzadilla, R. Bleischwitz, and V. Nechifor. Towards a circular economy: Insights based on the development of the global ENGAGE-materials model and evidence for the iron and steel industry. *International Economics and Economic Policy*, 14(3):383–407, July 2017. ISSN 1612-4804, 1612-4812. doi:10.1007/s10368-017-0385-3.

S. Zhou and S. Smulders. Closing the loop in a circular economy: Saving resources or suffocating innovations? *European Economic Review*, 139:103857, Oct. 2021. ISSN 0014-2921. doi:10.1016/j.euroecorev.2021.103857.

Supplementary Materials

A Appendix 1 - PIOT SAM

The theoretical framework underlying the integration of material flows into a CGE model involves several key features:

A.1 Integration of Material Flows in a CGE Model

The primary novelty lies in integrating material flows and balances into a CGE model. By incorporating material flows, the model becomes capable of analyzing the interaction between economic activities and their environmental consequences, particularly in terms of resource extraction and waste (emission) generation.

A.2 Material Balances and Mass Conservation

The foundation of the approach lies in the principle of mass balance, which dictates that the total mass of materials entering a system must equal the total mass leaving the system, accounting for any accumulation or depletion of stocks. This principle ensures the accuracy and reliability of the model's representation of material flows throughout the economy. The model tracks the flow of materials through sectors, from extraction to waste management, providing a comprehensive understanding of the environmental implications of economic activities.

A.3 Endogenous Adjustment

An essential feature of the integrated model is its consideration of endogenous adjustments in material intensities. This means that changes in resource use efficiency can occur in response to economic conditions and policy interventions, reflecting real-world dynamics and feedback mechanisms between economic and environmental systems.

A.4 Sectoral Analysis

Material flows are tracked across different economic sectors, allowing for a detailed examination of resource use and waste (emissions) generation within specific industries. By disaggregating the economy into distinct sectors, the model can capture variations in resource intensity and environmental effects across different economic activities.

A.5 Social Accounting Matrix (SAM) and Physical Input-Output Tables (PIOT)

A Social Accounting Matrix (SAM) contains data on economic transactions within a specific economic system. In addition to the economic data, PIOTs depict the physical flows of goods and services in terms of physical units, such as tons. The integration of SAMs and PIOTs ensures a holistic perspective on material usage, balancing both economic and physical flows.

A.6 Calibration of the PIOT

The calibration process starts with data on material extraction and production, followed by assumptions on waste rates and material intensities. For instance, iron ore extraction data provides input for the iron ore mining sector, with subsequent steps involving the calculation of material flows and balances for steel production and other sectors. This iterative process ensures balanced material accounts across all sectors.

A.7 Mathematical representations

A typical SAM in mathematical terms is represented as follows. Let S be the SAM matrix. For a square SAM matrix of size $n \times n$, where n is the number of agents:

$$\sum_{j=1}^{n} S_{ji} = \text{Income of agent } i$$

$$\sum_{i=1}^{n} S_{ij} = \text{Spending of agent } j$$

The SAM is balanced, meaning that for every agent j, their total spending equals their total income:

$$\sum_{i=1}^{n} S_{ij} = \sum_{j=1}^{n} S_{ji}$$

Similarly, a PIOT is represented as:

$$\sum_{l=1}^{k} P_{cl} = \sum_{c=1}^{k} P_{lc}$$

where $k = n + 2$ is the number of sectors, including extraction and waste accounts.

The extraction ratio ($\rho_{(m,s,r)}$) and material intensity ($\theta_{(m,s,sa,r)}$) are defined as:

$$\rho_{(m,s,r)} = \frac{RMX_{(m,r,s)}}{Z_{(m,s,r)}}$$

$$MFL_{(m,s,sa,r)} = \lambda_{(m,s,r)}\theta_{(m,s,sa,r)}Z_{(s,sa,r)} + \sum_{r'}\lambda_{(m,s,r')}\theta_{(m,s,sa,r')}M_{(s,sa,r',r)}$$

This appendix provides the necessary information for replicating and extending the methodology described in the main text, ensuring transparency and reproducibility of the research findings.

B Appendix 2 - Split GTAP sectors

This study focuses on the material of steel, however, GTAP-11 dataset does not provide too many details on the material chain of steel. In GTAP-11 dataset, iron ore mining is aggregated with other mining into a sector called “Other Extraction" (oxt), in addition, primary steel, secondary steel and recycled steel are put together into a sector called “Ferrous Metals" (i_s). To better describe the material flow of steel in the economy, we disaggregate “Other EXtraction" (oxt) into two sectors: iron ore mining and other mining; and disaggregate “Ferrous Metals" (i_s) into three sectors: primary steel, secondary steel and recycled steel.

C Appendix 3 - Sectoral breakdown for CGE Model

This appendix provides a detailed sectoral breakdown used in the Computable General Equilibrium (CGE) model. The sectors are categorized for both the Europe 27 and the Rest of the World (ROW), with three agents: Households (HH), Governments, and Investments.

Table 1: Sectoral Breakdown for CGE Model

Sectors
Agriculture, Forestry, and Machinery and other equipment
Other manufacturing
Construction
Transport
Services
Power sector
Coal energy consumption
Crude oil energy consumption
Gas energy consumption
Oil products energy consumption
Coal non-energy consumption
Crude oil non-energy consumption
Gas non-energy consumption
Oil products non-energy consumption
Fishing
Iron ore mining
Other mining
Coal mining
Crude oil extraction
Gas extraction
Oil products (refineries)
Chemical products
Primary steel production
Secondary steel production
Recycling of steel
Non-ferrous metal
Non-metallic minerals