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Summary

The paper explores the implications of achieving the EU27 Resource Efficiency target by 2030 for the future sustainability of the area. The target involves increasing by well over 30% within 2030 EU27 Resource Productivity, which would correspond to nearly double the annual growth rate of the pre-crisis period. The analysis uses a model-based index (FEEM Sustainability Index, FEEM SI) conceived to assess sustainability across time and countries. FEEM SI builds on the recursive-dynamic computable general equilibrium (CGE) model ICES-SI, which considers jointly variables belonging to the three sustainability dimensions (economy, society, and environment). The indicators produced in this framework are first normalized and then aggregated by using some elicited weights and a non-linear methodology. The 30% increase of EU27 Resource Efficiency by 2030 is achieved by applying an ad-valorem tax to the use of mining resources, and offsets the negative effects on the economy (slightly lower GDP and Investment rate) with considerable benefits for the environment. This implies a +1.02% increase in overall EU sustainability with respect to the reference "no policy" scenario.

Keywords: Material Productivity, Resource Efficiency, Sustainable Development Indicators, Computable General Equilibrium
JEL Classification: C68, D58, L61, O13

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Implications of the 2030 EU Resource Efficiency target on Sustainable Development

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Abstract

The paper explores the implications of achieving the EU27 Resource Efficiency target by 2030 for the future sustainability of the area. The target involves increasing by well over 30% within 2030 EU27 Resource Productivity, which would correspond to nearly double the annual growth rate of the pre-crisis period.

The analysis uses a model-based index (FEEM Sustainability Index, FEEM SI) conceived to assess sustainability across time and countries. FEEM SI builds on the recursive-dynamic computable general equilibrium (CGE) model ICES-SI, which considers jointly variables belonging to the three sustainability dimensions (economy, society, and environment). The indicators produced in this

framework are first normalized and then aggregated by using some elicited weights and a non-linear methodology.

The 30% increase of EU27 Resource Efficiency by 2030 is achieved by applying an ad-valorem tax to the use of mining resources, and offsets the negative effects on the economy (slightly lower GDP and Investment rate) with considerable benefits for the environment. This implies a +1.02% increase in overall EU sustainability with respect to the reference “no policy” scenario.

Introduction

Sustainable Development is one of the main topics on the EU's general agenda. Ever since the UN (Earth Summit[1]) conference in Rio de Janeiro in 1992, it has become a fundamental component of the EU's overall development strategy. The Europe 2020 strategy[2] aims to make a qualitative leap of progress towards a smart, sustainable and inclusive European Union by the end of this decade. The strategy's five main targets of sustainable development are employment and R&D (economy), climate change/energy sustainability (environment), and education and poverty/social inclusion (society). Progress will be monitored and recommendations[3] made to aid in achieving the national objectives and sub-objectives[4].

While these objectives may appear difficult to achieve in the aftermath of the financial crisis and the delay in recovery, especially for the Mediterranean countries such as Italy and Greece, they also represent an opportunity to radically re-think the strategy for development and the switch to a more sustainable economic future for the European Union. In fact, beyond the targets, the Europe 2020 strategy also identifies seven flagship initiatives for promoting qualitatively oriented growth. Among these, of particular interest is the focus on "resource efficiency"[5], which involves energy, land and raw materials (the latter often straggling behind energy and land).

Increasing material productivity and the recycling rate of the economic system is crucial for reducing the consumption of scarce natural resources as well as the discharge of harmful waste from chemical and/or technical transformations. Moreover, this is the necessary condition for coping with the increasing worldwide demand for non-basic commodities on the part of an increasing, upwardly mobile population.

The European Union also provides 2050[6] with a more ambitious vision relying on the concept of a circular economy[7], in which the rate of extraction of natural resources and waste discharge is minimized through a substantial increase in recycling rates.

Not many analyses have been made of the potential effects of increased resource efficiency related to the use of materials. The EU commission has recently broached the issue with an appreciable

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[1] http://www.un.org/geninfo/bp/enviro.html
[2] http://ec.europa.eu/europe2020/index_en.htm
[3] http://ec.europa.eu/europe2020/europe-2020-in-your-country/index_en.htm
[4] http://ec.europa.eu/europe2020/pdf/targets_en.pdf
[5] http://ec.europa.eu/resource-efficient-europe/index_en.htm
[6] http://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm
[7] http://ec.europa.eu/environment/circular-economy/index_en.htm

modelling effort[8] focusing on targets aimed for 2030. The technical report 2014-2478 *Study on modelling of the economic and environmental impacts of raw material consumption* (EC, 2014a) made a macro-econometric assessment of an increase in resource productivity, computed as the ratio between Gross Domestic Product and Raw Material Consumption. Compared to a 14% growth of material productivity in business as usual in the 2014-2030 period, the study assesses the implications for economic growth, employment and the environment of imposing more ambitious targets ranging between 15% and 50% in 2030 with respect to 2014. There is a generally positive effect on GDP (but in the most ambitious case of a 50% increase in resource productivity implying a reduction in GDP from 2029, and even worse if the option of revenue recycling is switched off) as well as on investments, while the main economic drawback is a significant reduction in exports. The effect on employment is also positive (up to 2 million additional jobs created by a 40% increase in resource productivity). In terms of environmental impact, it is generally negative: however, only information in CO_2 emissions (which increase due to higher economic growth) is provided, to the neglect of the environmental advantages from using fewer natural resources and producing less waste.

The present paper starts with the EU Commission's study, complementing it from different perspectives. More precisely, our main aim is to analyse the effects of the increased resource consumption on an aggregate measure of sustainable development. The analysis employs a macro-economic model extended and tailored to keep track of future trends of a set of sustainable development indicators as well as a composite indicator generated with a sophisticated survey-based technique that captures trade-offs and synergies among indicators and allows scenario comparison.

The paper is structured as follows: Section 2 describes the general approach used for the analysis. The third Section presents how the indicators evolve across the three releases (2009, 2011, 2013). Sections 4 and 5 provide a more in-depth methodological analysis. Section 6 introduces the policy context. Sections 7 and 8 discuss the results on sustainability in, respectively, the reference and policy scenarios. Finally, Section 9 draws the main conclusions.

[8] http://ec.europa.eu/environment/enveco/resource_efficiency/

1 The General Approach

The FEEM Sustainable Index (FEEM SI; Carraro *et al.*, 2013)[9] is an aggregate sustainability index, first released in 2009 and continually updated by including new indicators, extending the time-horizon of analysis and refining the aggregation methodology. The main original feature of FEEM SI is its nature: a model-based index conceived to provide future trends of sustainability indicators and sustainability performance at the country level.

The FEEM SI assessment comprises a complex five-phase procedure:

- literature review and selection of indicators;
- the modelling framework for indicator projections into the future;
- simulation of future reference and policy scenarios;
- normalisation of indicator values to a common scale;
- weighted aggregation of different indicators in a single index.

The multi-step procedure implies consistency as well as feasibility constraints: for example, the modelling framework reduces the employment of a broad set of indicators. Indeed, a Computable General Equilibrium model is used to reproduce the dynamics of indicators in the future, a technique that limits the number and characteristics of admissible indicators in our framework, favouring only those that can be satisfactorily linked to endogenous variables considered in the economic model. While for economic indicators such linkages are clear, for social and environmental variables some modelling efforts are required. Other limitations concern the country-level nature of our analysis and the data availability constrained by the global coverage of our index.

Our final aim is to have a compact, representative number of indicators consistent with the current literature on sustainability. The main source for the FEEM SI indicators is the scoping paper released by the GGKP in April 2013, which reports sets of indicators proposed by the Global Green Growth Institute, OECD and UNEP (GGKP, 2013).

[9] Carraro *et al.* (2013) report methodology and results for a previous version delivered in 2011. Full results of the 2013 release are available at *www.feemsi.org*.

2 FEEM SI indicators: history and current composition

FEEM SI indicators have gone through several updates in its different releases. Figure 1 shows the latest FEEM SI version and highlights the enhancements of the past two editions. Unmarked indicators represent the original core index.

FEEM SI 2009 described the **Economic pillar** using GDP per capita, GDP share devoted to Research & Development (R&D) and consumption share over GDP. FEEM SI 2011 featured an enhanced description of economic sustainability, introducing an Investment growth indicator (replacing the previous consumption indicator) to complement R&D as a growth driver, and two indicators for capturing economic system fragility (i.e., high dependence on imports [Relative Trade Balance] and magnitude of public debt over GDP [Public Debt]). The 2013 release keeps the same structure as in 2011.

The original set of **Social indicators** included: Population Growth (replaced by Population Density in 2011); the share of food expenditure over total expenditure (Food Relevance); energy consumption per capita (replaced in 2011 by Energy Access, which considers the country-specific share of population with access to electricity); the share of insurance and pension expenditure over GDP (removed in 2011); the public share on Education expenditure; the share of total and private health expenditure. While the indicator on Private Health expenditure is still in use, the "Life Expectancy" measurement has replaced the Total Health expenditure in 2013 release. An indicator on Imported Energy has been included in the social pillar since 2011 (before it was among the environmental indicators) to better capture countries' energy dependence. FEEM SI 2013 also introduces a technology access indicator (ICT Access) and a Corruption level indicator.

Environmental indicators in 2009 accounted for GHG per capita, CO_2 Intensity, Water use, Plant and Animal Biodiversity loss, Energy Intensity. FEEM SI 2011 included a more complete indicator on Renewable Energy production. The current 2013 release includes two additional elements: Waste generation per capita and Material Intensity (the same as Material Productivity in the European Union terminology). These indicators capture the pressure on non-energy resources to provide commodities and inputs for consumption and production processes, as well as their discharge in receptors that in the long-term can exceed the planet's absorption capacity.

The aim of the current analysis is to assess in detail the possible implications of a policy specifically designed to cope with this emerging issue, thereby paving the way for future sustainable consumption and production patterns.

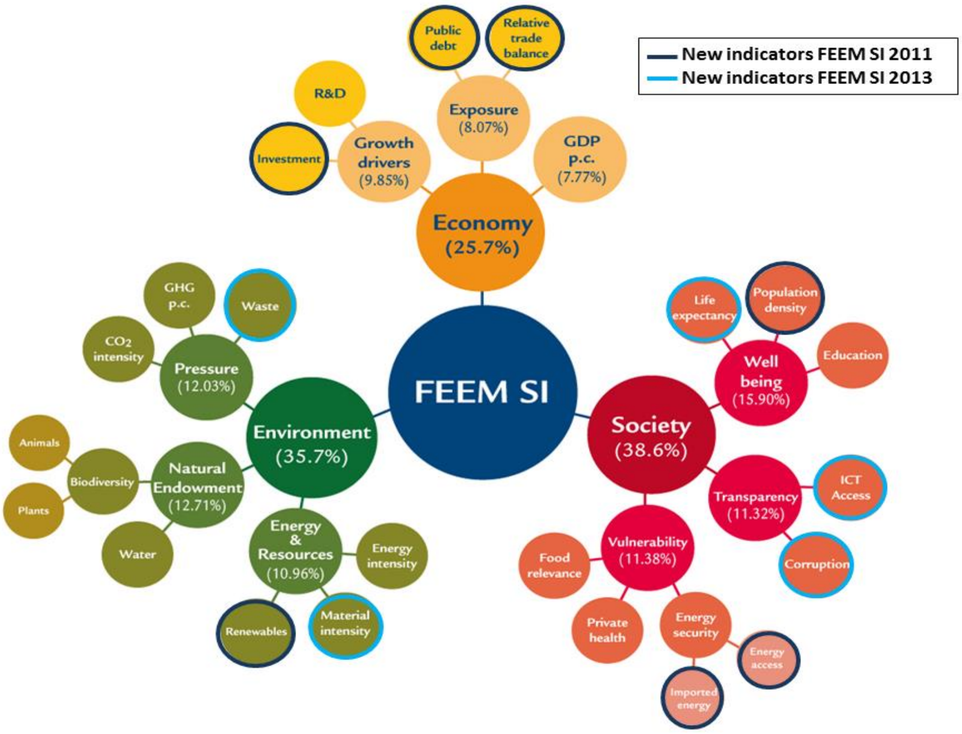

Figure 1 FEEM SI 2013 structure

3 The Modelling Framework for indicator projection

A macro-economic model makes it possible to move indicators over the future. In principle, using a model optimising economic behaviour can seem a limitation as it is partial in nature with respect to the broad meaning of sustainable development. Nevertheless, this modelling framework ensures: a) a consistent pattern of all variables into the future; b) the creation of trade-offs or synergies among indicators and sustainability dimensions following the alteration of a single variable pattern.

More specifically, the FEEM SI builds on the recursive dynamic computable general equilibrium (CGE) model ICES-SI, an extended version of the ICES model (Eboli *et al.*, 2010)[10]. The main scope of the ICES model is to assess the final welfare implication of climate change impacts and policies on world economies.

The initial economic benchmark relies upon the GTAP 8 database (Narayanan *et al.*, 2012), which collects economic information in Input-Output Matrix format covering the global economic system. The original detail accounts for 57 sectors and 129 countries/regions. The database provides details

[10] Also http://www.feem-web.it/ices/

at the country level if available; otherwise, several countries are grouped into a single macro-region. We aggregate the original 129 regions into 40, maintaining world coverage.

Economic agents are designed in the standard fashion of (both macro and micro) economic modelling. Sector-specific cost-minimizing representative firms in each country/macro-region are characterised by multi-nested production functions, in which primary factors and intermediate inputs are combined to produce the final output. The core structure follows the GTAP-E intra-energy substitution mechanism (Burniaux and Troung, 2002), enhanced by the explicit modelling of renewable energy sources. Representative households in each country/macro-region receive income by selling their endowments of primary factors (natural resources, land, labour and capital) and maximises its own utility by devoting disposable income either to the purchase of private and public commodities/services or to savings. Demand for production factors and inputs/commodities from both firms and households can be satisfied either by domestic or foreign producers who are not perfectly substitutable according to the "Armington" assumptions (Armington, 1969).

More interestingly for the present analysis, CGE models represent the actual economic inter-connections at the national (input-output relationships) and transnational (international trade) level, capturing the propagation of shocks originating in one sector and spreading to the rest of the global economy, thereby highlighting higher-order effects beyond the initial ones that can be neglected with other modelling tools. Moreover, such a framework makes possible a simultaneous consideration of the different aspects of sustainability seen as a multi-faceted concept, with pros and cons emerging from any proposed policy whose aim is to improve some indicators while possibly causing deterioration in others, thereby raising the issue of undesired effects.

Beyond the standard features of economic behaviour, here the peculiar extension of the model to incorporate sustainability indicators is the actual distinguishing feature.

Table 1 provides a concise but thorough description of indicators, along with data source to initialize value in the benchmark year, and model implementation to allow each indicator's future evolution.

Table 1 – FEEM SI Indicator description

NAME	*DESCRIPTION*	*DATA SOURCE*	*MODEL IMPLEMENTATION*
GDP p.c.	Typical indicator used to define average well-being in a country. Expressed in Purchasing Power Parity to allow comparison across countries and regions	GGGI – OECD – WDI – UN SDSN – UN MDG	GDP PPP / population
Investment	Main driver for economic growth. Weighted to the national capital stock.	WDI	Net Investment / Capital Stock (%)
R&D	Current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development (source: WDI).	UNEP – OECD - WDI	R&D Expenditure / GDP (%)
Public Debt	The entire stock of direct government fixed-term contractual obligations to others outstanding on a particular date. It includes domestic and foreign liabilities such as currency and money deposits, securities other than shares, and loans. It is the gross amount of government liabilities reduced by the amount of equity and financial derivatives held by the government (source WDI).	WDI	Government Debt / GDP (%)
Relative Trade Balance	Measure of the degree of a country's exposure in the international markets. It considers the country's net export value weighted by the market openness. The higher the exports, the stronger the degree of competitiveness.	OECD	(Net export) / (import + export)
Life Expectancy	Number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life (source WDI).	GGGI – OECD – WDI – UN SDSN – UN MDG	Expected number of years for the lifetime (using as a proxy: Health Expenditure / GDP (%))*
Population Density	Number of people living in a specific country or macro-region given the suitable surface to live in (excluding uninhabitable areas). It represents the available living space for each person. The lower population density, the better.	GGGI - OECD	Population / Country Surface
Education	Proxy of the country's investment in human capital. As a proxy of the often used "literacy rate", it is expected to improve future economic and social conditions, including gender equality.	UN SDSN - GGGI (literacy rate) – OECD (literacy rate) – UN MDG (literacy rate)	Education Expenditure / GDP (%)
ICT Access	Percentage of people with access to the worldwide network (source WDI). It measures the access to general knowledge and the speed of circulating information across and between countries	GGGI – WDI – UN MDG	Internet users / Total Population (%)
Corruption	Based on the Corruption Perception Index, measures the perceived levels of public sector corruption (source Transparency International).	Transparency International	Changes over time depend on changes in GDP p.c., share of oil exports over total country exports and share of public expenditure over GDP**
Food relevance	Proxy for the poverty level and malnutrition. According to Engel's well-known law, the higher the proportion of national income spent on food the lower the level of a country's welfare.	GGGI (malnutrition)	Food Consumption / Private Expenditure (%)
Private health	Percentage of private health expenditure over total health (public and private) expenditure. The higher the share of private expenditure, the lower the ability of poorer people to face health problems.	WDI	Private Health Expenditure / Total Health Expenditure (%)
Imported energy	Percentage of imported energy over total energy consumption. The higher the energy dependency from abroad, the higher the risks from energy price fluctuations and political instability in energy-rich countries.	WDI	Energy Imported / Energy Consumed (%)
Energy access	Percentage of population with access to electricity (source WDI). Main indicator to address the "Energy & Poverty" issue.	GGGI – WDI	Population with Access to Electricity / Total Population (%)
CO_2 intensity	Carbon Dioxide emissions linked to energy use. It measures the carbon intensity of the energy system in each country/region and the degree of available clean technologies.	GGGI – UNEP – OECD – UN SDSN	CO_2 Emissions / Total Primary Energy Consumption
GHG p.c.	The total amount of Greenhouse Gases weighted by population. The higher the ratio, the higher the burden in	GGGI – WDI – UN SDSN	GHGs Emissions / Population

	terms of climate change		
Waste	Amount of waste produced per capita. Reduction of waste production is at the top of the hierarchy of waste management options to reduce pressure on the environment.	GGGI – UNEP - OECD	Waste generation / Population
Biodiversity – Animal	Endangered animal species over total animal species.	IUCN	Endangered Species / Total Species (%)
Biodiversity – Plants	Endangered plant species over total plant species.	IUCN	Endangered Species / Total Species (%)
Water	Ratio between freshwater withdrawals and renewable internal freshwater resource flows referred to internal renewable resources (internal river flows and groundwater from rainfall) in the country (source WDI).	GGGI – UNEP – OECD - WDI	Water Use / Total Available Water (%)
Renewables	Clean energy share over total energy use. Clean energy is non-carbohydrate energy that does not produce carbon dioxide when generated. It includes hydropower and nuclear, geothermal, and solar power, among others (source WDI).	GGGI – UNEP – OECD - WDI	Renewable Energy Consumption / Total Primary Energy Consumption (%)
Material intensity	Measure of non-energy resources efficiency. It gives the idea of material productivity, that is how much raw material is required to produce a unit of economic value of industrial output	UNEP – OECD – WDI – UN SDSN	Raw Material (physical amount) / Industrial Output (economic value)
Energy intensity	Measure of energy resource efficiency. It gives the idea of energy productivity, that is how much energy source is required per unit of Gross Domestic Product	GGGI – UNEP – OECD - WDI	Total Primary Energy Supply / GDP PPP

* OECD (2011)
** Based on Treisman (2007)

4 From indicators to the composite sustainability index

Once the indicators are selected and initialised to the benchmark year, the model makes it possible to solve year-by-year equilibrium and gauge trends for all indicators in the time horizon under consideration (see next sections for assumptions in both business as usual and policy scenarios).

To get a measure of an overall sustainability trend in each country/macro-region and determine a world ranking, a two-step procedure is required: first normalization and then aggregation (OECD, 2008). The normalisation approach used to express all indicators through a common measurement scale[11] follows an indicator-specific stepwise benchmarking function whose intermediate values are established according to policy targets or observed trends. The upper and lower bounds of this function correspond to fully sustainable and unsustainable conditions, respectively.

Finally, the FEEM SI adopts a two-step aggregation process. First, an experts' elicitation process via an *ad hoc* questionnaire produces a set of weights for each indicator and their combinations in each node. A non-linear methodology (metric distance) computes a consensus measure combining

[11] The normalisation procedure converts indicator-specific unit measurements to a common one in the range [0,1] and then allows full comparability among indicators. This process is performed with respect to a benchmark to enable a uniform interpretation of changes in each indicator.

diverging responses into a 'representative' set of weights. The second step merges normalised indicator values and the weights created in the previous step through the Choquet integral. Following this approach, FEEM SI optimises the trade-off between simplicity and effectiveness in representing preferences by focusing specifically on the interrelations across indicators. Because of space limitations, we cannot provide a longer description of these steps. Details on both normalisation and aggregation methodology are in Cruciani *et al.* (2014).

The table below reports the weights used for each sustainability area, based on experts' opinions and computed through the Shapley index. This index makes it possible to measure the relative importance of components in FEEM SI's overall computation. "Society" results as the most relevant pillar (38.6%) followed by "Environment" (35.7%). "Economy" accounts for only 25.7%, showing lower relative importance. This outcome is quite different from previous issues released in 2011, where the three main pillars were almost equally balanced. This may reflect an inclination in the panel of sustainable development experts to pay more attention to social and environmental challenges than economic ones. The table also shows the relative importance of each topic by pillar (in terms of percentage weight relative to the overall FEEM SI), showing a more (but not totally) balanced situation especially in the environmental pillar.

Table 2 - Contribution by pillar and topic to the overall FEEM SI index

Pillar	Criteria	Shapley Value
FEEM SI	Society	38.60%
	Environment	35.70%
	Economy	25.70%
Society	Well-being	15.90%
	Vulnerability	11.38%
	Transparency	11.32%
Environment	Natural Endowment	12.71%
	Pollution	12.03%
	Energy & Resources	10.96%
Economy	Growth Drivers	9.85%
	Exposure	8.07%
	GDP p.c.	7.77%

5 FEEM SI as a policy tool: assessing the sustainability of EU target on resource efficiency

At the web-link *www.feemsi.org* a full set of scenarios is available, providing the world ranking and the decomposition by pillar for several policy experiments. Along with a business as usual scenario, there are three counterfactuals (social, environmental and transversal “sustainable development” policy) showing the improvement/deterioration of sustainability pillars as well as composite index as results of achievement/approaching towards a subset of so-called Sustainable Development Goals (SDGs) as provided by the United Nations Sustainable Development Solutions Network[12]. Namely, the social policy considers the implementation of a minimum target of both education and health expenditure for developing countries; the environmental policy refers to a greenhouse gas mitigation target at the world level, as well as a generalized improvement on water efficiency; the latter “sustainable development” policy combines both, as well as promoting more effort in R&D.

The Environmental Policy was focusing on climate/energy and water issues, historically felt as highly relevant. As described in Section 1, one main innovation of the 2013 FEEM SI release is the introduction of new environmental indicators pertaining to material use, specifically: material intensity and waste generation. In spite of general remarks on a more efficient use of resources globally, there are no clear targets to consider in guiding policy actions. Nevertheless, as described in the introduction, the European Union has started to cope with the topic by monitoring national performance as well as by defining targets for the future towards dematerialization and decoupling between economic growth and use of materials.

We use the FEEM SI methodology to perform a sustainability appraisal of the "Roadmap to a Resource Efficient Europe" (EC, 2011). As said, in the framework of the Europe 2020 Strategy, this roadmap has encouraged resource efficient and low carbon EU growth and, jointly with European Resource Efficiency Platform, has helped to set a clear target on resource productivity by 2030[13]:

"We call upon the EU to set a target for a substantially increased decoupling of growth from the use of natural resources, in order to improve competitiveness and growth as well as quality of life. The target should aim to secure at least a doubling of resource productivity as compared with the pre-crisis trend. This would be equivalent to an increase of well over 30% by 2030”

[12] www.unsdsn.org. Please note that the goals/targets used at the time of model simulations (http://unsdsn.org/resources/goals-and-targets/) are now gradually replaced/extended within the consultation process (http://unsdsn.org/resources/publications/indicators/).

[13] http://ec.europa.eu/environment/resource_efficiency/re_platform/index_en.htm

This section describes a practical application of our framework to this specific policy target. We focus on Material Productivity, which is directly referred to in the 2030 efficiency target. The Material Productivity indicator is measured according to the European Resource Efficiency Platform guidelines as the GDP produced over the material resources consumed. In our framework, the set of materials considered in the indicator computation includes only minerals and other extractive minerals (excluding fossil resources, to avoid double counting with other indicators). The main purpose of the analysis is to evaluate the effect of achieving resource productivity on EU Members States' overall sustainability as well as sustainability pillars.

The next sections will describe the trend of the Material Productivity indicator, the Sustainability index in our reference scenario, and the sustainability payoff of reaching the 2030 resource efficiency target.

FEEM SI normally performs a sustainability assessment for 40 countries/macro-regional aggregates. Here, we will restrict our analysis to the European Union (EU27), which is the direct recipient of the policy. The time span considered goes from 2007 (base year of the model) to 2030.

6 Material productivity and sustainability in the reference scenario

The construction of our reference scenario begins with replicating trends of past years in main macro-economic variables as well as carbon dioxide emissions for the period 2007-2012. From 2013 to 2030, we used projections in line with economic and demographic trends of Shared Socio-Economic Pathways (SSPs)[14] commonly used within the climate change community and CGE modelling for short and medium term climate policies. We reproduced the SSP2 ("Middle of the Road") scenario, whose main features are a moderate per capita income growth, the reduction of resource and energy intensity, and a decreasing dependency on fossil sources (O'Neill *et al.*, 2012). Figure 2 reports main features followed for the scenario construction. Particular attention was devoted to reproducing the historical trend of Material Productivity and to designing reference scenario assumptions. For this purpose, we used the historical pattern of price of Metals and Minerals (World Bank, 2014), which translates into some volatility of material use during the period 2007-2012.

[14] http://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/parallel_nat_scen.html; https://secure.iiasa.ac.at/web-apps/ene/SspDb/dsd?Action=htmlpage&page=about

SSP2 – Scenario building

Economy =>

- Exogenous [GDP per capita]
- Endogenous [investments, R&D investments, fossil fuels and mineral prices, commodity outputs, import-export, public debt]

Society =>

- Exogenous [population]
- Endogenous [sectoral shares (Edu, Food, Health, ICT), energy access]

Environment =>

- Exogenous [energy prices, fuel-switching parameters and yearly water availability constant]
- Endogenous [energy efficiency, RES share, water use, CO_2 and GHG emissions, waste generation, raw materials use]

Figure 2 - SSP2 and ICES SI variables

Analyzing the pattern of the Material Productivity indicator and its components in Europe since the beginning of the century (Figure 3), we observe that the Material use tracks GDP in the pre-crisis years, with an increase of Material Productivity (+2.71% in 2006 with respect to 2001). During the crisis (2007-2011), the demand for Metals and Minerals decouples from the GDP trend and follows the price signal; the result is a strong rise in Material efficiency (+20.88%). The future trend is determined by moderately decreasing prices of Minerals and Metals and the assumption of the future sectoral productivity pattern. The rate of growth of Material demand is assumed to be more than halved as compared to that of the pre-crisis period, and it is on average 0.79% per year between 2014 and 2030 (cumulatively 12.64%). This, coupled with the SSP2 assumptions about GDP growth, determines a persistent rise on Material productivity (16.67% in the period 2014-2030), supported also by other recent modelling exercises (EC, 2014a and 2014b).

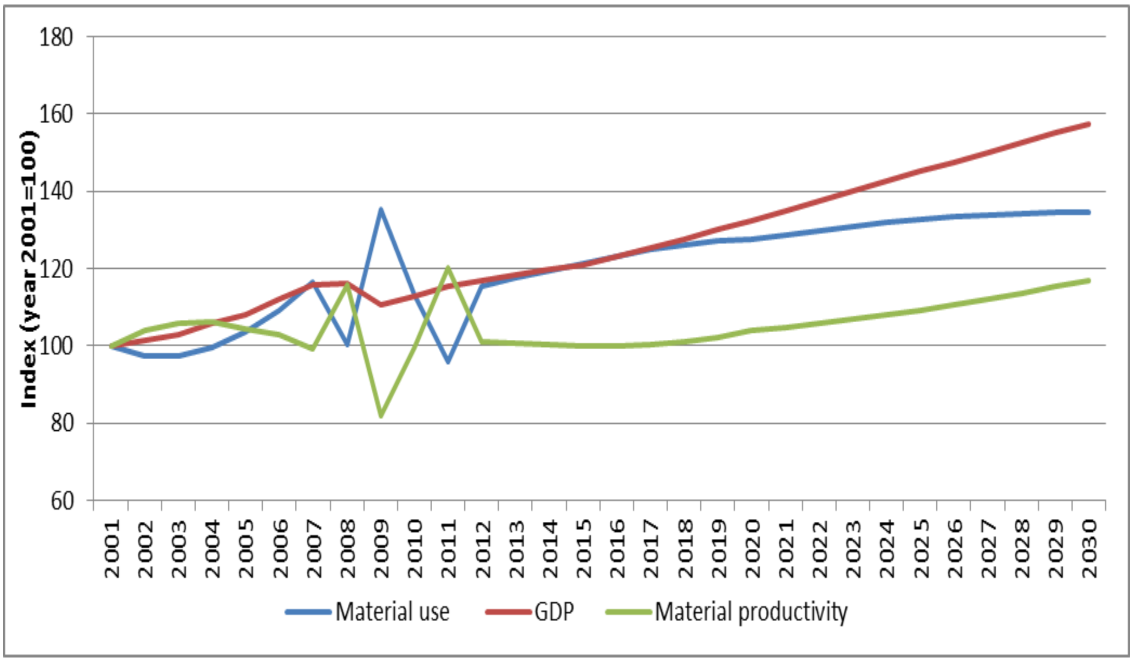

Figure 3 – Material Productivity and its components, European Union

In 2001, Material productivity was quite heterogeneous across EU27 countries, ranging from the highest ratio of Benelux (8.74 Million $\$_{2007}$/kt) to the lowest (1.42 Million $2007/kt) of Ireland (Table 3, first column). In the pre-crisis period, only few countries experienced a positive growth of material productivity: Benelux, France, Germany, Italy, UK, as well as the group of less developed EU economies (Rest of EU). These are the countries that were the top performers in 2001. In the period 2001-2006, all the other countries are characterized by a faster growth of mineral resource use than GDP (Table 3, second column). Regarding the post-crisis period, material productivity increases for nearly all EU27 countries as a combination of higher GDP growth than mineral resource use; material productivity decreases only in Ireland where the reduced speed of material consumption is still too feeble (Table 3, third column).

As already mentioned, the main scope of the analysis is broader than the material productivity outcome. Table 4 gives a snapshot of the 2013 Sustainability level for the European Union. Countries are ranked according to FEEM SI results, which summarize the performance in the Economic, Social and Environmental sectors. The first column shows the countries' position in the overall FEEM SI ranking (considering 40 countries/macro-regional aggregates). In general, EU27 countries occupy the first half of the FEEM SI ranking (excluding Spain, Poland and Greece). The top three countries in the ranking are Sweden, Austria and Finland, which show above average scores in the Economic and Social pillars and high values for the Environmental pillar, if compared with the other EU27 countries. In fact, Europe stands out for the Social sustainability, while the Environmental pillar is the worst compared to the other pillars, since the developing and least developed countries are less intensive in exploiting resources such as fossil fuels, water and materials. The EU27 score on Material Productivity indicator is below the average (at most 0.55 in UK).

Table 3 – Material productivity in 2001 (Million $\$_{2007}$/kt), pre-crisis trend (2001-2006) and post-crisis trend (2014-2030)

	2001	2001-2006	2014-30
Austria	3.23	-1.56	13.26
Benelux	8.74	21.80	37.85
Denmark	3.10	-14.99	17.41
Finland	1.53	-2.66	10.19
France	4.45	7.09	26.39
Germany	4.40	10.11	34.53
Greece	5.64	-9.37	26.97
Ireland	1.42	-6.46	-4.24
Italy	4.36	20.58	20.62
Poland	2.63	-7.22	11.15
Portugal	2.71	-10.03	25.77
Spain	3.23	-13.59	11.74
Sweden	2.00	-4.17	7.24
UK	5.95	24.50	31.82
RoEU	3.83	0.22	13.82
EU	4.06	2.71	16.76

Table 4 - FEEM SI ranking and values by pillar in 2013, European Union

Region	FEEM SI Ranking	FEEM SI Value	Economy	Society	Environment	Material productivity
Sweden	1	0.62	0.69	0.87	0.49	0.15
Austria	4	0.54	0.60	0.77	0.42	0.25
Finland	5	0.54	0.64	0.84	0.38	0.11
France	6	0.53	0.54	0.75	0.44	0.36
Benelux	9	0.48	0.58	0.72	0.35	0.54
Denmark	10	0.48	0.61	0.85	0.28	0.21
RoEU	11	0.47	0.47	0.55	0.45	0.24
UK	12	0.47	0.53	0.73	0.34	0.55
Germany	14	0.45	0.58	0.67	0.31	0.39
Ireland	16	0.45	0.54	0.74	0.30	0.09
Portugal	19	0.43	0.44	0.61	0.36	0.21
Italy	20	0.42	0.42	0.52	0.38	0.39
Spain	26	0.40	0.49	0.62	0.27	0.20
Poland	27	0.40	0.41	0.56	0.33	0.19
Greece	30	0.35	0.43	0.49	0.26	0.29

The added value of the sustainability framework rooted in a CGE model becomes manifest in comparing present and future sustainability levels. Figure 4 shows the percentage change of FEEM SI and pillar scores for EU in the period 2013-2030. EU27 countries are listed according to their ranking in 2030.

The reference scenario presents heterogeneous outcomes in terms of sustainability: half of the countries are better off in 2030 due to a consistent economic growth that more than compensates the decline of the Social pillar (explained by a lower share of money available for public services); the Environmental pillar is stable or increasing in these countries. The countries seeing a reduced sustainability level in 2030 are characterized by a deterioration of Environmental conditions due to a decline of Natural Endowments (loss of biodiversity and water overconsumption) and an increasing Pressure on the system (increasing GHG emissions and wastes). The Energy and Resource indicator that summarizes Material Productivity, Energy Intensity and Renewable resources is increasing for all EU27 countries due to positive performances of the three indicators also in the reference scenario[15].

The Material Productivity indicator also moves up, except for Ireland. In general, the variations are wider if compared with those of aggregate indicators such as Environmental sustainability or FEEM SI; this is because we are comparing an unweight indicator (Material Productivity, directly affected by declining prices) with some synthetic indices. We also notice that for several countries there is a divergent trend between the Environmental pillar and the Material Productivity indicator. This is particularly evident for Poland, Spain and Rest of EU, where negative performance of indicators on Natural Endowments and Pressure cannot be compensated by an improvement of Energy & Resource indicators.

The overall performance of the EU27 in the reference scenario is characterized by small loss of sustainability from 2013 to 2030 (-0.35 % compared to a score of 0.49 in 2013). This result is brought about by a drop of 4.92% in the Environmental pillar and 2.32% in the Social one (Economic pillar increases of 6.84%).

[15] This positive results in the reference scenario is certainly due to baseline assumptions on sectoral productivities, but it must also be noted that the reference scenario, reproducing the historical trend of main macroeconomic variables for the period 2007-2013, indirectly includes the impact of policies effective in that time span.

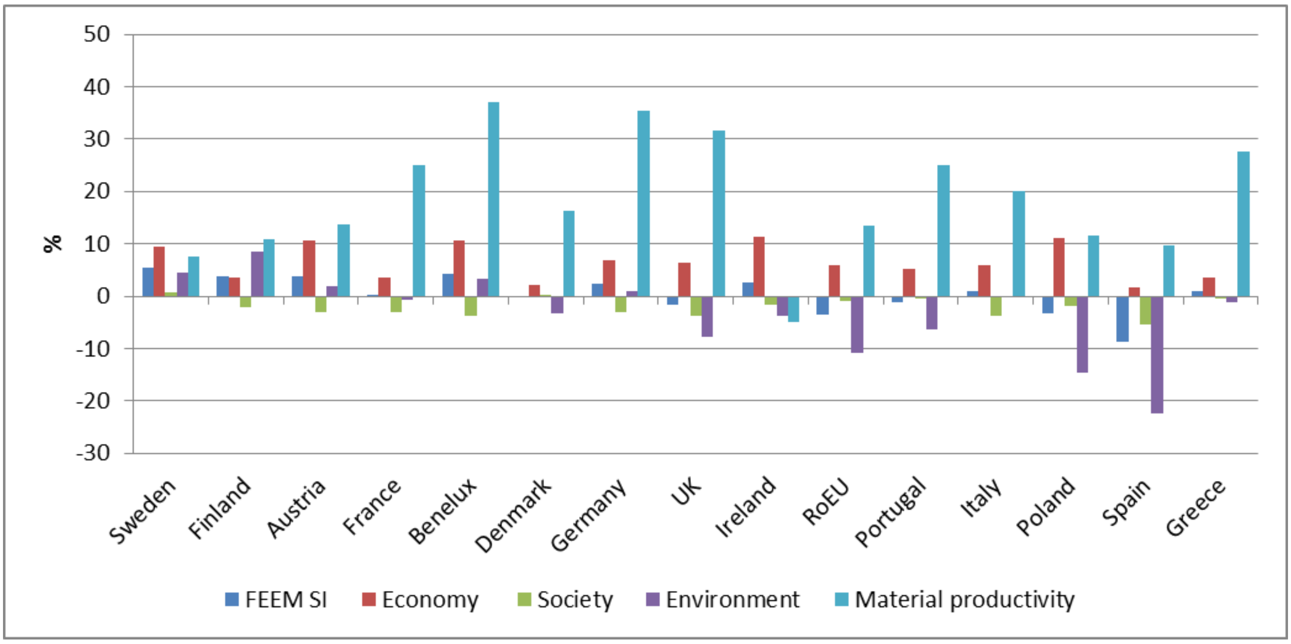

Figure 4 – Sustainability change in the reference scenario (2030 vs 2013), European Union

7 Implications of 2030 Resource Efficiency target on EU27 sustainability

The present section explores the implications of achieving the median Resource Efficiency target by 2030 for future EU27 sustainability. The policy starts in 2014 and mirrors the 2030 target: an increase of well over 30% by 2030 in EU27 Resource Productivity, which corresponds to nearly doubling the annual growth rate of the indicator observed in the pre-crisis period. This target can be achieved by increasing around 14% the ad valorem tax on Mining Resource use in the EU27. Figure 5 compares the divergent patterns of Material Productivity in the reference and policy scenarios. Table 5 highlights that the change of tax power required to reach the policy target is heterogeneous across EU countries: countries with high Resource Efficiency in the baseline experience the highest increase of tax in the policy scenario (Benelux, Germany and UK), forcing them to double their already high Material Productivity.

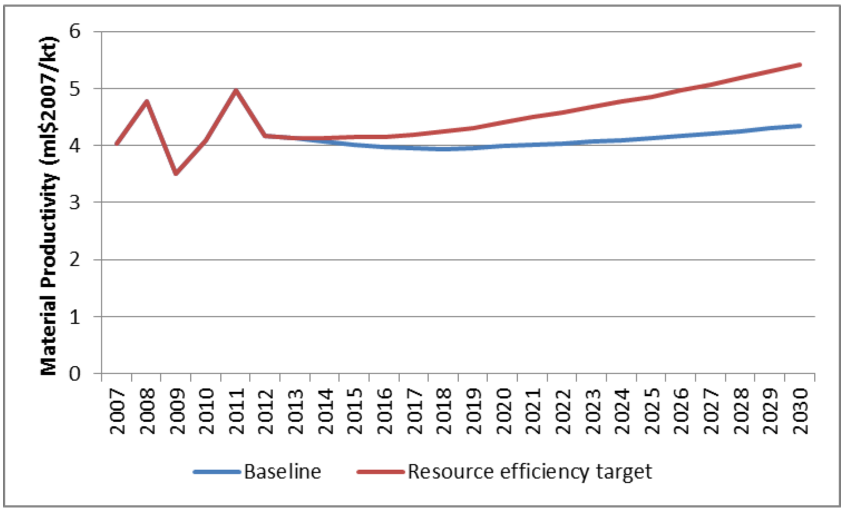

Figure 5 – Material productivity for EU27, baseline scenario vs Resource Efficiency target scenario

Table 5 - % change of power of tax on mining resources for EU27 countries, policy vs reference scenario

% change power of tax on mining resources	2030
Austria	11.45
Benelux	24.17
Denmark	13.88
Finland	9.03
France	19.03
Germany	23.41
Greece	18.27
Ireland	0.91
Italy	17.44
Poland	10.55
Portugal	17.90
Spain	9.12
Sweden	6.91
UK	22.00
RoEU	11.49

In the policy scenario, EU27 Material Productivity increases by 35.65% in 2030 as compared to 2014; the indicator passes from a score of 4.34 for 2030 in the reference scenario to 5.42 in the policy scenario (+ 24.82% with respect to the reference scenario).

As observed in the reference scenario, variations of one indicator value influence the performance of the corresponding pillar and, ultimately, overall sustainability. Furthermore, the modelling framework behind the FEEM SI computation makes it possible to capture higher-order effects within the economic system, i.e. the propagation of the shock across regions and countries through price signals and trade relations.

Figure 6 depicts the effects of achieving the 2030 Resource Efficiency target in the European Union. The policy scenario determines a rise of EU27 sustainability in the range from 0.02% (Ireland) to 2.01% (Benelux) compared to the reference scenario. The increased sustainability is led entirely by an improvement in the Environmental pillar ranging between 0.05% (Ireland) and 5.44% (Benelux). Looking more in detail to the determinants of the performance in the Environmental pillar, we see that Natural Endowment aggregate indicator is not affected by the policy, Pollution aggregate indicator shows a minor improvement (0.01%-0.07%), and Energy&Resources aggregate indicator has the strongest variation (0.13% - 14.39%). The Material Productivity change is certainly bigger and in the range of 1% to 28.47%.

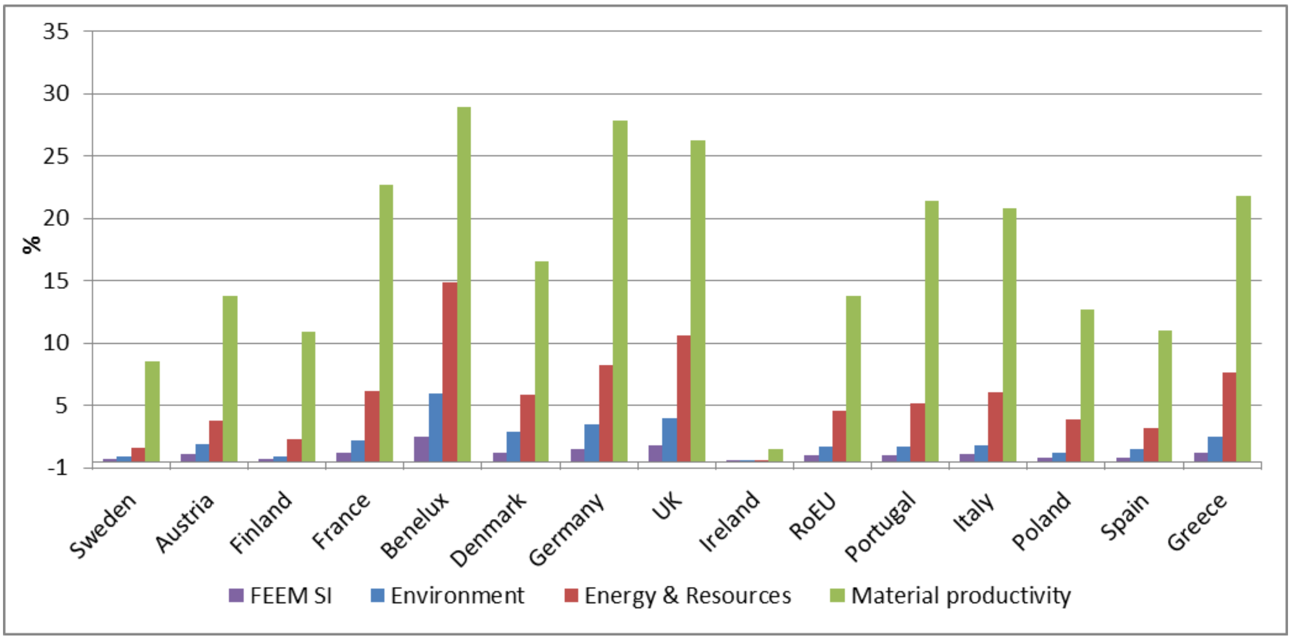

Figure 6 – Effect of Resource Efficiency target on FEEM SI, Environmental pillar, Energy & Resources index and Material Productivity indicator for EU27 countries in 2030, % change with respect to 2030 reference scenario

Despite the propagation effect that any policy determines on the rest of the economy, taxing the use of mining resources barely affects the Economic Pillar. The Social pillar is unaffected by this policy intervention, since it does not involve direct transfer of public resources within the economic system. Among European countries, Benelux, the UK and Germany benefit more than any of the others from increased efficiency in use of resources. This result is directly linked to policy design. In fact, the 30% increase of Material Productivity in the 2014-2030 period was achieved through taxing the use of mining inputs in such a way that each EU27 country doubles its Material Productivity. For this reason, the wider improvement in the indicator characterises countries that were performing best in terms of Material Productivity in the pre-crisis period.

Looking at the aggregate implications of the policy scenario for the EU27 (Figure 7), we see that a 24.82% increase of Material Productivity in 2030 with respect to the 2030 reference scenario determines a +1.02% rise of Sustainability (FEEM SI) in Europe. This effect is mediated by an improved performance of the Energy& Resources aggregate indicator (+5.36% with respect to the 2030 reference scenario) and the Environmental pillar (2.5% with respect to the 2030 reference scenario). In the EU27, the policy cost is negligible in terms of GDP loss (-0.01%); Economic sustainability slows slightly as compared to the reference scenario (-0.01%) due to the combined negative effect on GDP, Public Debt and Investment.

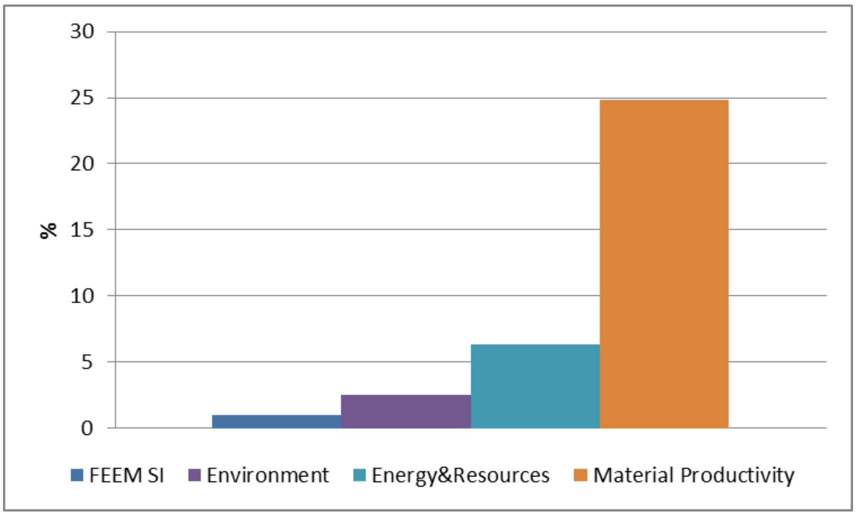

Figure 7 – Effect of Resource Efficiency target impact on Sustainability, Environmental pillar, Energy&Resource indicator and Material Productivity for the EU27 in 2030, % change with respect to 2030 reference scenario

8 Conclusions

The aim of this paper is to assess the impact of the Resource Efficient strategy for the EU by 2030 on the sustainability of the Member States. Complementary to the study developed by the EU (2014a), we evaluate the effects of the increase in resource productivity on an aggregate measure of sustainable development. The analysis uses a macro-economic model tailored to embody and project future trends of a set of twenty-three sustainable development indicators covering the three sustainability areas (economy, society, and environment). Then, a composite indicator is generated with a sophisticated survey-based technique, capturing trade-offs and synergies among indicators and allowing scenario comparison.

Our reference scenario up to 2030 depicts an improvement in Material Productivity (computed as GDP over Material Consumption) involving most of EU countries. Moreover, many factors other than Material Productivity determine heterogeneous change of sustainability across countries in the reference scenario: the post-crisis recovery paths, pressure on environmental resources and pollution, and exogenous social patterns.

Further improvement in Material Productivity, such as to accomplish the target proposed by the EU, sheds light on the positive marginal contribution of this indicator on the composite index. In fact, the methodology proposed can specifically address how a given policy can alter overall sustainability performance, since, while improving the policy-relevant indicator, it can cause the deterioration of other indicators. We find that, in spite of a medium tax level necessary for achieving the EU target, the benefits for the environmental pillar outweigh the negative economic effects (slightly lower GDP and Investment rate), thereby affording net positive results for sustainability in the EU.

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