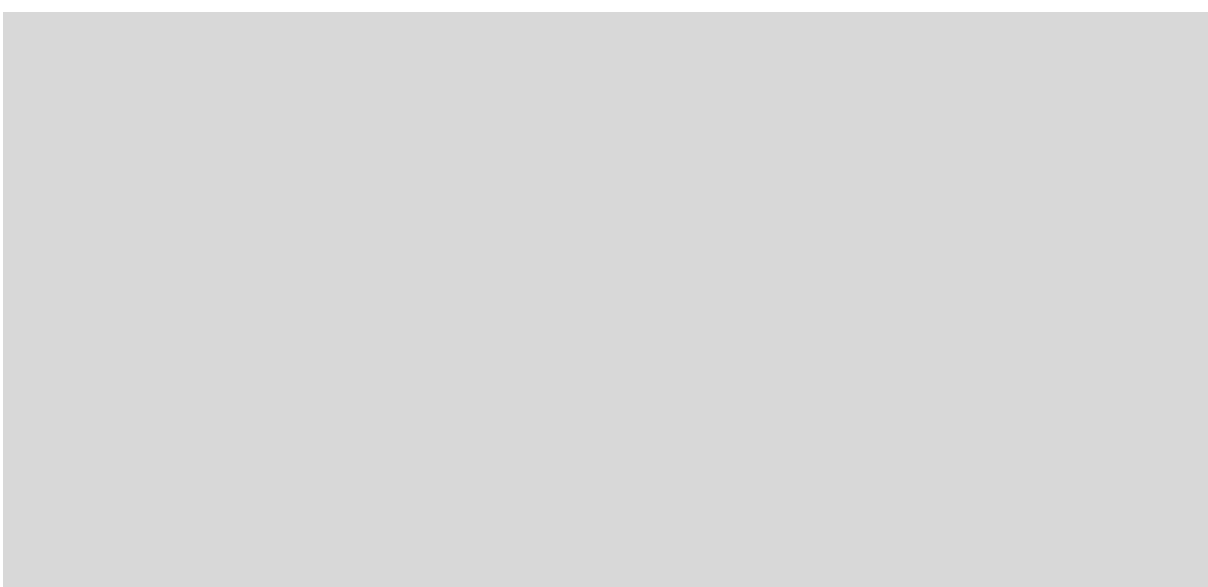




DYNAMIX

Decoupling growth from resource use
and environmental impacts

Report on Economic Quantitative Ex-Ante Assessment of DYNAMIX Policy Mixes



DYNAMIX Deliverable D6.2

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LIST OF ABBREVIATIONS

CGE	Computable General Equilibrium
DSGE	Dynamic Stochastic General Equilibrium
EU	European Union
GHG	Greenhouse Gases Emissions
GDP	Gross Domestic Product
p.p.	Percentage Points
TFP	Total Factor Productivity
WP	Work Package
BtN	Back to Nature
DwT	Divided we Trudge
EB	Economic Bonanza
SF	Safe Globe
CIT	Corporate Income Tax
VAT	Value Added Tax
PIT	Personal Income Tax
SCC	Social Security Contributions

1 Executive summary

The purpose of deliverable D6.2 is to support with a quantitative economic assessment the evaluation of a set of policies scrutinized within the DYNAMIX project, aiming to promote decoupling of resources use from GDP and material efficiency within the EU.

The analytical tools used for the investigation are three macro-economic models, ICES, MEMO and MEWA, all belonging to the category of Computable General Equilibrium modelling, but with complementary characteristics. More specifically: they all provide a sectoral representation of the EU economic system and endogenous price formation. In practice, they can assess direct and indirect policy effects on the whole economic system and the full macroeconomic feedbacks, beyond the sector initially subjected to the policy intervention. However, ICES representing the EU with a country detail, is better suited to capture intra and extra EU trade effects. MEWA and MEMO consider the EU as a single region, but differently from ICES, offer a more realistic representation of technological change, feature forward looking agents and have a richer representation of labour supply choices.

The policies examined by the different models and their slightly different implementation, due to the differences in the models' sectoral and functional details, are summarized in the table below.

Table 1 DYNAMIX Quantitative Economic Assessment Policy Matrix.

Policy fiche	Which model and What	Degree of Implementation	Timeline
Green fiscal reform: materials tax	<i>ICES: Sales tax of wood and mining to all other sectors (excluding fossil fuel extraction) + Sales tax of Oil Products to Chemicals.</i> <i>MEMO II and MEWA: Sales tax of wood, fuels, metal and other to all manufacturing sectors and construction + sales tax of chemical, metal and non-metallic mineral (excluding tax they pay for raw material purchase) to manufacturing and construction sector</i> + <i>MEMO II: recycling of 50% revenue to reduce labour taxation</i> <i>MEWA: different forms of revenue recycling: a) decrease in labour taxation, firms cannot pursue material efficiency improvements; b) decrease in labour taxation, firms can pursue material efficiency improvements; c) decrease in labour taxation and support to R&D in material efficiency.</i>	3 p.p./year (up to 30%) 8.5 p.p./year (up to 200%)	2021-2030 2031-2050
Green fiscal reform: internalisation of external environmental costs	<i>MEMO II and MEWA: Excise tax on all sectors but services with two alternative specification: a) common flat tax rate to all sectors; b) sector specific rate based on actual externalities</i> + recycling of 50% revenue to reduce labour taxation	linear increase up to 35%	2030-2050
Increased spending on research and development	<i>MEWA: increase in public investment in R&D for material efficiency</i>	Doubling with regard to current levels	2020 (kept constant up to 2050)
Strengthened pesticide reduction targets under the Pesticides	<i>ICES and MEWA: Tax on domestic and imported sales of chemicals to the agriculture sector</i>	8% linear increase up to 20%	2020-2050

Directive			
Targeted information campaign to influence food behaviour towards changing diets	<i>ICES: Gradual reduction in meat consumption such to reach the EU benchmark in dietary balance</i>	country-specific	2021-2050
VAT on meat	<i>ICES, MEMO II and MEWA: Fill the gap between current VAT on meat and the average country-specific VAT</i>	13 p.p. (EU average, in ICES country-specific)	2020 (kept constant up to 2050)
Circular economy tax trio	<i>ICES and MEMO II: Tax on domestic sales of mining (excluding fossil fuels) to non-metallic minerals and construction + Tax on exports of non-metallic minerals.</i> <i>MEWA: Tax on virgin materials, landfills and waste incineration</i>	38% linear increase up to 50%	2018-2050
Enabling shift from consumption to leisure	<i>MEWA: Change of the parameter reflecting the relative marginal utility from consumption and leisure</i>	arbitrary	2015 (kept constant up to 2050)

The first two policies examined - a material tax and a tax aimed at internalising environmental externalities - are based on different designs and implementation strategies. Nonetheless, their common trait is the breadth. They have direct and indirect effects on many sectors, and thus have impacts clearly detectable on the overall EU GDP.

The strongest message from the analysis is that the cost of the policy crucially depends upon (a) the sensitivity of the production system to the dynamic incentive to dematerialize induced by the policy signal, i.e. ultimately upon the reaction (or availability) of technological progress and (b) the use of tax revenues, i.e. on the implementation of an appropriate revenue-recycling scheme.

A combination of technological progress in response to the tax with a reduction in labour taxation can indeed, according to the modelled outcomes, end up stimulating economic growth (a maximum 8% GDP gain in 2050) and increasing material efficiency (in a range between 12 to more than 70% in 2050), reaping a material “double dividend”: more GDP and lower material use. Without these two factors, however, especially when taxes are rebated lump-sum to households, the policy can be particularly depressing for EU GDP (-5%), and, as a further drawback, might even worsen, rather than increase material efficiency in many material intensive sectors of the economy. This can happen when the reduction in economic activity outpaces the decline in material use at the sectoral level.

All in all, the tax shift fosters a huge transformation of the production system. Therefore, notwithstanding final net GDP gains, material intensive sectors would be highly penalized (a good example is the iron and steel sector which may experience a production decline up to 60% when exposed to a material tax). This calls for a careful designing and planning of the policies devising a set of accompanying measures to smooth the most adverse social effects.

Increasing public investment for R&D dedicated to material efficiency, whether financed through increases in labour, corporate or value added taxation, seems to have the highest potential to boost GDP among the three policies and is also the least burdensome for material intensive sectors. In fact, final material use can also increase, as an economic “rebound effect” materializes with the “production scale” effect being larger than the “material use decline” effect. This raises a caveat: although supporting material efficiency R&D might seem the “optimal” policy to foster absolute decoupling, it should be accompanied by further regulation or incentives limiting material use or promoting dematerialized services.

Despite the obvious differences, the tax to foster pesticide reduction, the increase in the VAT on meat and a targeted information campaign to influence food behaviour towards less meat

intensive diets, address a group of sectors with a “low weight” in term of EU value added. Thus, their relevance is prominently sectoral.

Raising the VAT on meat to the EU average VAT level can be successful in reducing meat consumption (between 2.5 and 14% in 2050). Meat industry exports are expected to increase in response to the decrease in world meat prices following the contraction of EU demand while effects on ‘Non-meat’ based food production in the EU is ambiguous but anyway moderate (0.7%, -0.24% in 2050 depending on the model). Potential declines in ‘Non-meat’ based food production might occur when the demand contraction induced by the tax on household budget meets higher input costs as some meat products are used as intermediates also by the non-meat food industry. Again, final GDP impacts are determined by the use of VAT revenues. If they are rebated in a lump sum to households, GDP in the EU could decline by 0.05%; if labour taxes are reduced, GDP could increase by 0.35%.

Comparable effects on meat industry production (a contraction by 6% in the ICES model) and slight GDP gains (by 0.04% in the EU in 2050) would be induced by the information campaign to shift food consumption habits. Notably, the effect on GDP is positive, rather than negative as in the VAT case, even without an accompanying reduction in labour taxes. This occurs as the recomposition of consumers’ preferences is not induced by any active tax policy which ultimately impacts household income, but just by the “persuasion” of consumers. In this sense, inducing “just” a substitution and not an income effect, the action of the campaign is less invasive. However, it has to be recognized that there is a huge uncertainty on the effectiveness of information campaigns and on the time they would need to accomplish the desired results. These issues are not considered in the current analysis though.

The pesticide tax, finally, can reduce the use of pesticides (up to 10% in the models) while exerting a limited effect on the EU agricultural activity (which in 2050 contracts of the 0.08% - 0.8%) and an even smaller one on overall EU GDP. When changes are so small, however, it is possible that indirect effects prevail over direct effects. For instance, in some simulations, an increase, albeit small, in EU chemical sector production is observed. This is explained by the increase in agricultural production outside the EU favored by the higher prices of EU agricultural commodities, which brings about an increased demand for fertilizers and pesticides, including those produced in the EU, which are exported more. The policy thus would not induce a decrease in the negative externality, but its de-location abroad. These unintended secondary effects should thus be dealt with specific corrections.

Like the material tax policy, the circular tax design aims to foster dematerialization, recycle and re-use, but with a much narrower scope as it focusses specifically on raw materials (excluding metals) extraction. In the light of the relatively limited economic relevance of the

mining sector in the EU, policy effects are mostly felt by raw-material-intensive branches of the production system, while systemic effects are small. Not surprisingly, mining of non-ferrous minerals (experiencing a production contraction in the range of 7-35%) and the non-metallic minerals transformation sector (contracting 7-10% by mid-century) are the more heavily affected. Once again, revenue recycling mechanisms play some role. Nonetheless, the small volume of revenues available to be recycled does not allow for significant GDP and employment expansion. Similarly, the absence of recycling does not cause huge GDP impacts, although they remain slightly negative (-0.32% in 2050). The overall dematerialization potential of the policy, especially in the long term, is limited if compared to that for instance of the material tax, producing at best a 3% material efficiency improvement with respect to the reference scenario.

The last policy examined, is the shift towards more “leisure consumption”. Its direct consequence is the decrease in the labour supply. Therefore, the price of labour (wages) will increase, leading to some substitution of labour with capital, energy and materials. In the short run, this will increase the capital-to-GDP ratio, energy-intensity and material intensity. However, in the long run, as the economy will produce less goods to be consumed, an absolute reduction in the use of energy and materials will occur along with the decline in GDP. Exports will also be penalized with potential negative consequences on the current account.

2 Introduction

The main objective of this report is to show the economic implications of a greener and more sustainable EU. It is complementary to the environmental assessment published by Ekvall et al. (2016).

Quantitative assessment is crucial to understand what can be the real world dimension of the transition to a less resource intensive EU. Future development pathways can themselves help reduce the use of materials in the EU system due to technological innovation and growing environmental awareness. Nevertheless, it seems reasonable for policy-driven scenarios to be envisaged to achieve substantial targets. Expectations from policy implementation bring concerns about the intrinsic trade-off between environmental advantages and economic net costs, at least in the short term that can move towards a win-win strategy in the long term if appropriately designed and facilitated.

The topic of decoupling economic growth from resource use covers the whole socio-economic system. This requires the use of methodologies which are capable of assessing the economic implications, focusing on the cross-sectoral perspective including the international trade sphere. In fact, the potential in terms of opportunity costs to move towards a greener and more sustainable EU strongly depends on the structure of the economic system, including the openness to other markets. Moreover, opportunities from technological development depend on the degree of flexibility and innovation of the economic system, as well as the attitude of final users to shift towards different consumption patterns. To this purpose, three macro-economic models have been selected and used for the economic assessment across different reference scenarios (cornerstones) and considering a number of policy-driven scenarios.

3 Scenarios and Methods

3.1 The Baseline Scenario and the Four Cornerstones Scenarios

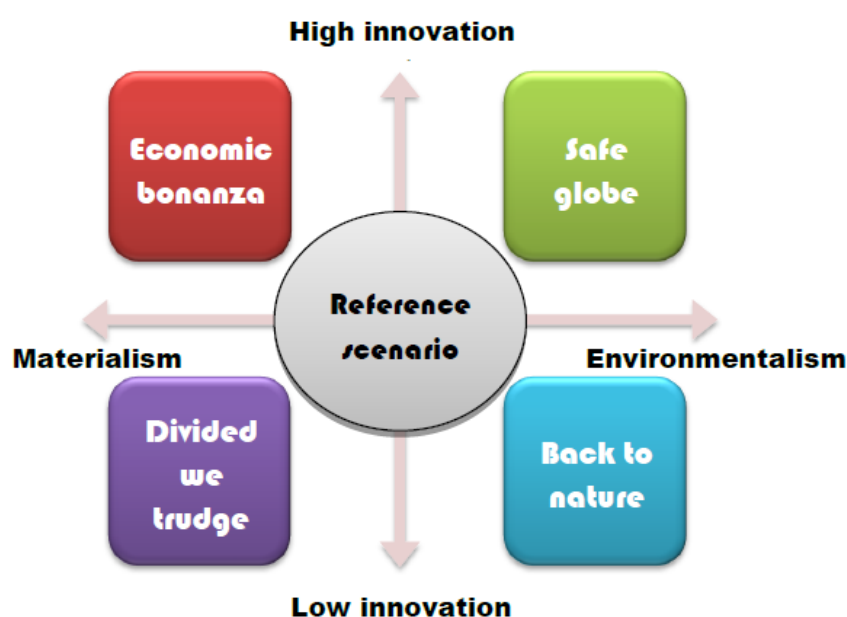
The evolution of population, technology, of GDP and its structural composition, of the price and trade systems, institutions and legislations, are determinants in defining the future pressure on resources, either natural or man-made, including energy. They are also key factors in determining the cost and effectiveness of specific policies addressing resource use.

The starting point of the present assessment is thus the definition of a set of reference scenarios common to the models described in section 3.2. They are extensively described in Gustavsson et al., 2013.

These are defined as ‘current policy scenarios’ as they embed the effect of scenarios based on policies already in force, and thus work as benchmarks for the assessment of proposed new policies.

They define quantitative assumptions on population, GDP, TFP¹, prices of fossil fuels and raw material. The scenarios conceive a central case and four “cornerstones” (Figure 1).

¹ Measure of the efficiency of all inputs to a production process. Increases in TFP result usually from technological innovations or improvements (www.businessdictionary.com).

Figure 1 DYNAMIX Reference and Cornerstone Scenarios.

Source: Gustavsson et al. (2013)

Table 2 summarizes the quantitative socio-economic assumptions used for the central reference scenario.

Table 2 Central Reference scenario quantitative assumptions.

EU Countries	GDP (% average annual growth rate 2010-2060)	TFP (% average annual growth rate 2010-2060)	POP (% growth rate 2010-2060)
Austria	1.4	1.0	6.0
Belgium	1.6	0.9	23.9
Bulgaria	1.3	1.4	-26.7
Czech Republic	1.5	1.2	0.0
Cyprus	1.8	0.8	37.5
Denmark	1.4	0.9	10.9
Estonia	1.5	1.2	-7.7
Finland	1.5	1.1	5.6
France	1.7	0.9	13.6
Germany	1.4	1.0	6.0
Greece	1.6	0.9	23.9
Hungary	1.3	1.4	-26.7
Ireland	1.5	1.2	0.0
Italy	1.8	0.8	37.5

EU Countries	GDP (% average annual growth rate 2010-2060)	TFP (% average annual growth rate 2010-2060)	POP (% growth rate 2010-2060)
Latvia	1.4	0.9	10.9
Lithuania	1.5	1.2	-7.7
Luxembourg	1.5	1.1	5.6
Malta	1.7	0.9	13.6
Netherlands	0.8	0.9	-19.0
Poland	1.0	0.8	0.0
Portugal	1.2	1.0	-12.0
Romania	2.1	1.0	46.7
Slovakia	1.2	0.8	7.3
Slovenia	1.1	1.2	-22.7
Spain	1.3	1.1	-18.2
Sweden	1.9	0.9	40.0
UK	1.4	1.1	0.0
EU27	1.3	1.0	3.0

Source: EC (2012)

The four cornerstone scenarios are: 'Economic Bonanza' (EB), 'Safe Globe' (SG), 'Divided we Trudge' (DwT), 'Back to Nature' (BtN). They are defined along two qualitative dimensions: the pressure on the environment reflecting a materialistic versus an environmental view of the world, and the degree of technological innovation, high versus low. EB and DwT are both characterized by a materialism-oriented development, but differ in the rate of innovation: high in the first and low in the second. SG and BtN share a more environmental-friendly view of the world, but coupled with a high and a low innovation rate respectively.

The quantitative description of the cornerstones is reported in Table 3. In EB and BtN population growth is higher than the reference (4% and 6% in the period 2010-2060 in the EU), lower in DwT (1%), the same in SG. A substantial increase in TFP compared with the central scenario is assumed in EB and SG. On the contrary, TFP declines the 50% and 25% respectively in the BtN and DwT scenarios.

Table 3 Quantitative Assumptions for the DYNAMIX Scenarios.

Variable	Reference Scenario	Economic Bonanza	Safe Globe	Divided we trudge	Back to Nature
TFP (% wrt baseline)	Consistent with GDP growth rate	+100	+50	-25	-50

Variable	Reference Scenario	Economic Bonanza	Safe Globe	Divided we trudge	Back to Nature
Population (2010-2060 % change)	+2.9	+4	+2.9	-1	+6

Each scenario is used to test the different policies described in section 4.1. However, not all the policies will be tested in all scenarios and by all models. The instruments from each policy mix that we are able to assess depend on capabilities and characteristics of the models.. These are described in the next section.

3.2 The Models

Three macro-economic models are employed to perform the quantitative assessment: one CGE and two DSGE models (Table 4). They all belong to the category of General Equilibrium models which denotes those models with explicit representation of the multisectoral dimension of the economic systems, of international trade and of endogenous price formation.

CGE models are particularly suited to assess economy-wide implications of policies. That is, they capture indirect effects spreading all over the economic system beyond the sector initially subjected to the policy intervention, and the macroeconomic feedbacks on the sectors. The explicit representation of international trade offers insights on competitiveness changes at the sectoral and country level. The high sectoral and country detail usually imposes simplified dynamics and an exogenous treatment of technological progress.

DSGE models are different from CGE models as they depict a more sophisticated process for the formation of expectations among economic actors. This includes knowledge of future trends of economic variables, while in CGE models decisions are taken on the basis of past and present information. Furthermore, such models often feature endogenous technical change. These richer dynamics usually imply a lower number of regions and sectors in DSGE than in standard CGE models.

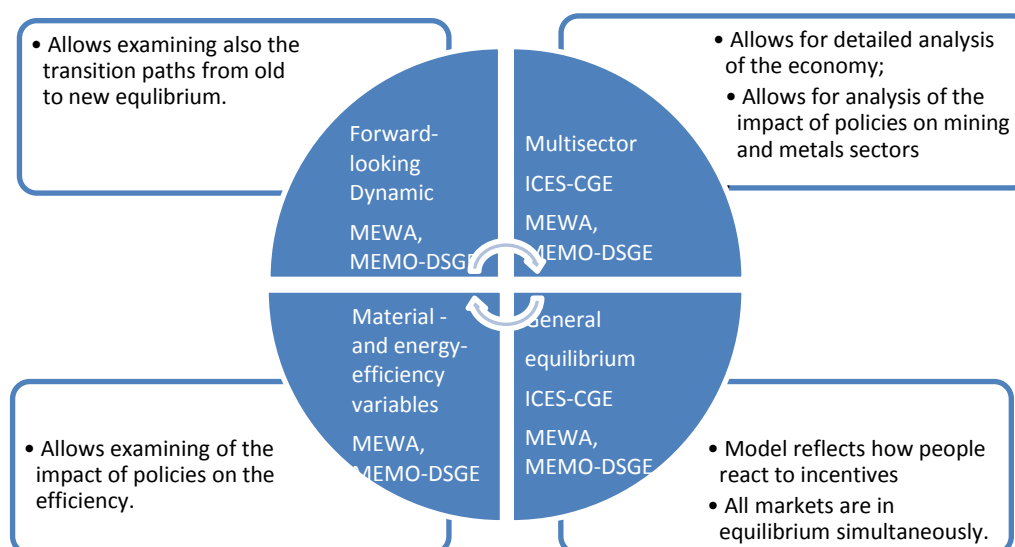
Figure 2 represents the main components characterizing CGE and DSGE models.

Table 4 DYNAMIX macro-economic models matrix.

MODEL	ICES	MEMO II	MEWA
Partner	FEEM	IBS	WISE
Model Type	CGE	DSGE	DSGE

MODEL	ICES	MEMO II	MEWA
Technical Change	Exogenous	Endogenous	Endogenous
Geographic detail	EU Member States	EU	EU
Cornerstones	YES	NO	NO

Figure 2 Characteristics of the economic models used in DYNAMIX.



3.2.1 ICES

Intertemporal Computable Equilibrium System (ICES) is a top-down recursive dynamic general equilibrium model based on the core structure of the GTAP-E model (Burniaux and Truong, 2002) and using the GTAP-8 database (Narayanan et al., 2012). It is solved recursively up to 2050.

For the purposes of the DYNAMIX project the global economy is divided in 19 geographic entities: 11 single EU countries, 3 EU groups (Benelux, Portugal&Spain, UK&Eire), 1 residual EU bundle and 4 more non-EU aggregates. Each country/region is then characterized by 20 representative industries. The model also features 4 primary factors of production (Table 5).

Table 5 ICES countries/regions, sectors and primary factors details.

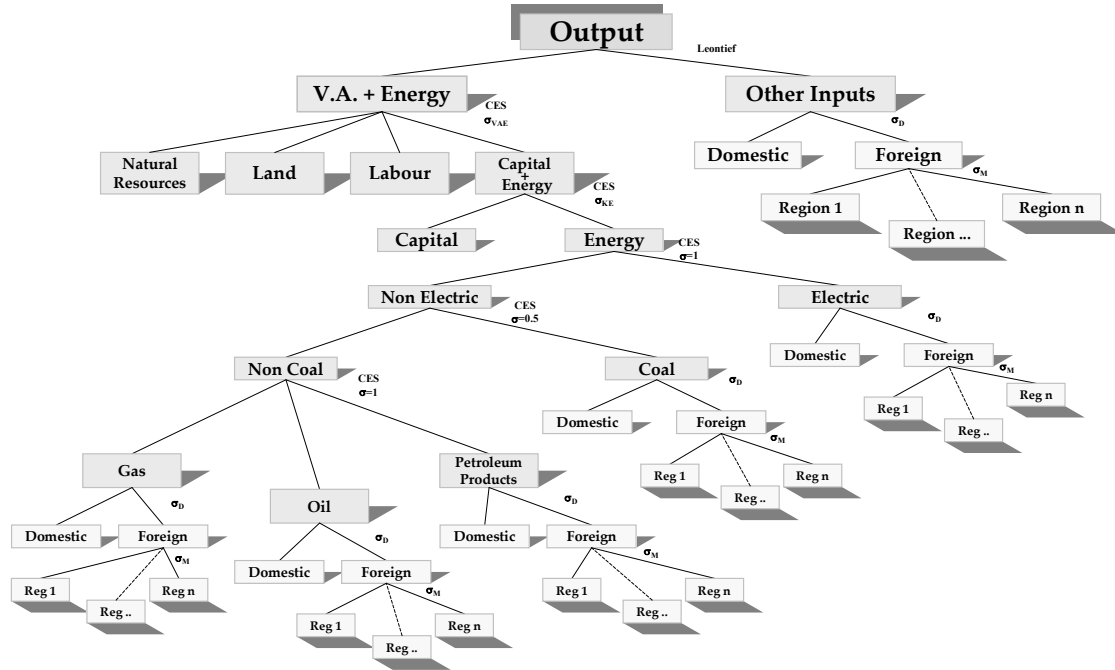
Countries/Regions	Sectors	Primary Factors
Austria	Agriculture	Land
BENELUX	Livestock	Labour
Czech Republic	Timber	Capital
Denmark	Fishing	Forest

Countries/Regions		Sectors		Primary Factors
Finland		Coal		Fish stock
France		Crude Oil		Energy Sources
Germany		Natural Gas		Mining/Metals
Greece		Oil Products		
Hungary		Electricity		
Italy		Mining		
Poland		Meat Industry		
Portugal&Spain		Food Industry		
Sweden		Chemical Industry		
UK&EIRE		Iron&Steel		
Rest of European Union		Non Ferrous Metals		
Rest of Europe		Non Metallic Minerals		
Rest of OECD		Construction Industry		
BRICS (Brazil, Russia, India, China, South Africa)		Light Industry		
Rest of the World		Market Services		
		Public Services		

Supply side²: Productive sectors are modelled in each country/region through a representative cost-minimizing firm, taking input prices as given. In turn, output prices are given by average production costs. Figure 3 illustrates the nested production function of each representative “firm” (an entity which here coincides with the concept of sector) within the model. Each node in the tree combines single or composite factors of production in a constant elasticity of substitution (CES) production function. All sectors use primary factors such as labour and capital-energy, and intermediate inputs. In some sectors (energy sources, extraction industries, timber and fishery) primary factors include natural resources (e.g. fossil fuels, raw metals, forest and fish), others (agriculture and livestock) use land. The nested production structure depicted in Figure 3 is the same across all sectors, and diversity in production processes as well as technologies are captured through sector-specific productivity and substitution elasticity parameters.

² In the mathematical description that follows, lower-case symbols in equations denote (linearized) variables expressed in percentage changes, while upper-case symbols represent variables in levels.

Figure 3 ICES nested production function.



At the top of Figure 3, production stems from the combination of intermediate inputs (QF) and a value added composite including all primary factors and energy (QVAEN). Perfect complementarity is assumed between value added and intermediates. This implies the adoption a Leontief production function. For sector i in region r final supply (output) results from the following constrained production cost minimization problem for the producer:

$$\min PVAEN_{i,r} QVAEN_{i,r} + PF_{i,r} QF_{i,r} \quad (1)$$

$$s. t. Y_{i,r} = \min[QVAEN_{i,r}, QF_{i,r}]$$

In (1) $PVAEN$ and PF are prices of the related production factors.

The second nested-level in Figure 3 represents, on the left hand side, the value added plus energy composite (QVAEN). This composite stems from a CES function that combines four primary factors: land (QLAND), natural resources (QFE), labour (QFE) and the capital-energy bundle (QKE) using σ_{VAE} as elasticity of substitution.³ Primary factor demand on its turn derives from the first order conditions of the following constrained cost minimization problem for the representative firm:

³ The values for all elasticities used in ICES are drawn from the GTAP8 database.

$$\min P_{i,r}^{Land} LAND_{i,r} + P_{i,r}^{NR} NR_{i,r} + P_{i,r}^L L_{i,r} + P_{i,r}^{KE} KE_{i,r} \quad (2)$$

$$s. t. QVAEN_{i,r,t} = \left(LAND_{i,r}^{\frac{\sigma_{VAE}-1}{\sigma_{VAE}}} + NR_{i,r}^{\frac{\sigma_{VAE}-1}{\sigma_{VAE}}} + L_{i,r}^{\frac{\sigma_{VAE}-1}{\sigma_{VAE}}} + KE_{i,r}^{\frac{\sigma_{VAE}-1}{\sigma_{VAE}}} \right)^{\frac{\sigma_{VAE}}{\sigma_{VAE}-1}}$$

On its turn, the KE bundle combines capital with a set of different energy inputs. This is peculiar to GTAP-E and ICES. In fact, energy inputs are not part of the intermediates, but are associated to capital in a specific composite. The energy bundle is modelled as an aggregate of electric and non-electric energy carriers. Non Electric commodities are produced in two levels, the first using Coal and Non Coal commodities and then at the basic level the Non Coal input is a composite commodity that contains Natural Gas, Crude Oil and Petroleum Products.

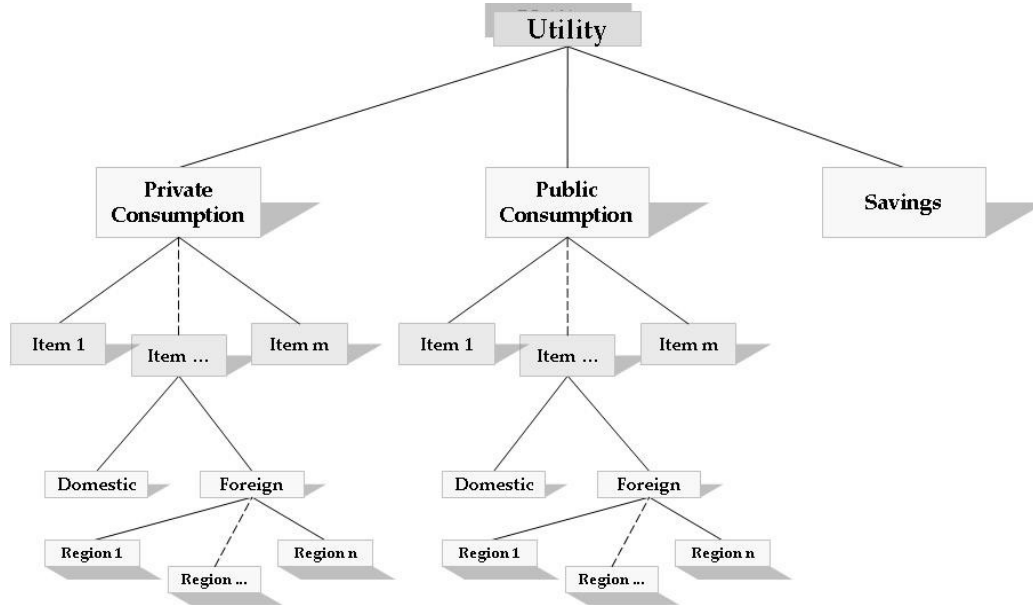
The demand of production factors (as well as of consumption goods) can be met by either domestic or foreign commodities which are however not perfectly substitutable and regulated according to the ‘Armington’ assumption. In general, inputs grouped together are more easily substitutable among themselves than with other elements outside the nest. For example, the substitutability across imported goods is higher than that between imported and domestic goods. Analogously, composite energy inputs are more substitutable with capital than with other factors.

In ICES, two industries are treated in a special way and are not related to any country: international transport and international investment production. International transport is a world industry, which produces the transportation services associated with the movement of goods between origin and destination regions, thereby determining the cost margin between *fob* (free on board) and *cif* (cost, insurance and freight) prices. Transport services are produced by means of factors submitted by all countries, in variable proportions. In a similar way, a hypothetical world bank collects savings from all regions and allocates investments so as to achieve equality in the absolute change of current rates of return.

Demand Side: In each country/region, a representative utility maximizing household receives income, originated by the service value of national primary factors (natural resources, land, labour, and capital) that she owns and sells to the firms. Capital and labour are perfectly mobile domestically but immobile internationally (note however that investment is mobile, see below). Land and natural resources, on the other hand, are industry-specific. The regional income is used to finance three classes of expenditure: private consumption, public

consumption and savings. These expenditure shares are generally fixed, which amounts to saying that the top-level utility function has a Cobb-Douglas specification. Also notice that savings generate utility and this can be interpreted as a reduced-form of intertemporal utility.

Figure 4 ICES nested tree structure for final demand.



Both private and public sector consumption are addressed to all commodities produced by each firm/sector. Public consumption is split into a series of alternative consumption commodities (item 1 to item m in Figure 4), again according to a Cobb-Douglas specification. However, almost all public expenditure is actually concentrated in the specific sector of Public Services, including education, defence and health.

Private consumption is analogously addressed towards alternative goods and services including energy commodities, that can be produced domestically or imported. However, the functional specification used at this level is the Constant Difference in Elasticities (CDE) form: a non-homothetic function, which is used to account for possible differences in income elasticities for the various consumption goods.

Thus, the upper level represented in Figure 4, mathematically translates into a Cobb-Douglas utility constrained maximization problem:

$$\begin{aligned} \max U &= C \prod_i U_i^{B_i} \\ \text{subject to } X &= \sum_i E_i(P_i, U_i) \end{aligned} \quad (3)$$

Where U_i are the per capita utility from private consumption, per capita utility from government consumption, and per capita real savings; C is a scaling factor and B_i are distribution parameters. X describes the budget constraint which must meet the sum of three types of expenditures E_i . P is the expenditure-share-weighted index of commodity group price indices.

At the second level, per capita utility from private consumption is derived from the aggregation of per capita private consumption of individual commodities. This is done using the Hanoch's constant difference elasticity (CDE) demand system (Hanoch, 1975).

$$1 = \sum_i B_i U^{Y_i R_i} \left(\frac{P_i}{X} \right)^{Y_i} \quad (4)$$

where U denotes utility, P_i the price of commodity i , X the expenditure, B_i are distribution parameters, Y_i substitution parameters, and R_i expansion parameters.

As can be noted by inspecting (4), the CDE in principle does not allow to define explicitly direct utility, expenditure or indirect utility functions. Accordingly, also explicit demand equations could not be defined. Fortunately, in a linearized equation system such as that used in GTAP, to do so it is sufficient to obtain the price and expenditure elasticities. Thus, taking (4) defining U implicitly as a function of X and P_i , first differentiate with respect to P_i . Then use Roy's identity⁴ to obtain implicit functions for Q_i and finally differentiate it again to obtain price and expenditure elasticities. This, in linearized terms and expressed in per capita terms, leads to the following demand equation:

$$q_{Pi} - n = \sum_k EP_{ik} p_{pi} + EX_i (x_p - n) \quad (5)$$

where EP_{ik} and EX_p are price and expenditure elasticities of demand, n population.

Dynamics: inside the ICES model, dynamics are driven either by endogenous or exogenous sources. The endogenous source involves two components.

The first and most important is the capital accumulation processes governed by endogenous investment decisions while the second regards foreign debt evolution. ICES is a recursive dynamic model. This means it presents a sequence of static equilibria which are

⁴ Roy's identity allows deriving the ordinary demands from the indirect utility function (Roy, 1947).

intertemporally connected by the process of capital accumulation. Capital growth is standard along exogenous growth theory models and follows:

$$Ke_r = I_r + (1 - \delta) Kb_r \quad (6)$$

where Ke_r is the ‘end of period’ capital stock, Kb_r is the ‘beginning of period’ capital stock, δ is capital depreciation and I_r is endogenous investment. Once the model is solved at a given step t , the value of Ke_r is stored in an external file and used as the “beginning of period” capital stock of the subsequent step $t+1$.

As with capital, at each simulation step the debt at the end of the period is stored in an external file and then recalled in the next simulation step as debt at the beginning of period.

Finally, debt is serviced at the world rate of return to capital, that is, regional income is increased or reduced by $R^w \cdot Db_r$. In terms of the Gempack code, this is shown as the variable ‘DEBS_r’.

The second source of dynamics is exogenous and is defined by a set of assumptions concerning changes in some supply-side parameters and variables like those described in Gustavsson et al., 2013, Appendix) and namely future trends for population (EC, 2012), TFP (EC, 2102), as well as fossil fuels (Eurelectric, 2010 and IEA, 2011) and metals/materials use (EC, 2014).

3.2.2 MEMO II

MEMO II (MacroEconomic Mitigations Options) is a multi-sector DSGE model. The equilibrium is an outcome of the optimization by agents in the economy: consumers, production firms in each sector of the economy, trading firms etc. All agents are forward looking, thus agents take into account not only the current, but also the future expected state of the economy. For example, if agents experience a decline in income, but expect a recovery in future periods, they will dissave (i.e. spend more than their current income) in order to smooth their consumption. The inter-temporal optimization of the agents and the high frequency of the time steps (simulations are done for each quarter) make the model particularly suitable to analyse the short and medium-run responses of the macroeconomic variables to the introduction of policies.

The production structure of the model is organized as follows. The economy is composed of ten sectors which produce a total of 16 products in accordance with NACE Rev. 2

classification of economic activities⁵. The particular choice and composition of sectors, which is shown in Table 5, was determined in order to satisfy the policies that were simulated with the model. In each sector, a firm invests in capital stock, which in turn is combined with labour, energy and material input using a mix of nested CES (constant elasticity of substitution) and Leontief production functions. The result of this process is an intermediate good, which is then used to produce aggregate final consumption, investment, public, material and export goods. The material input is composed of the intermediate goods from all sectors, both produced domestically and imported. Additionally, firms have the option to endogenously invest in the technological efficiency of material use, which is described in detail in the next paragraph. The production structure of the model is calibrated using the 2011 Eurostat symmetric input-output table. The elasticity of substitution between inputs are estimated from log-linear regressions using EUROSTAT data on prices and volumes.

The two features of the model, which additionally determine the dynamics of policy responses in the model are endogenous technology choices and friction on the labour market. Endogeneity of technology choices means that firms are allowed to change the characteristics of the technology parameters of their production function under market incentives. For instance, an increase in energy prices incentivizes firm to invest in the more costly, energy-saving technology. Actually, this gives a firm a possibility to substitute inputs with capital. Importantly, the substitution possibilities are limited in the short-run. Since the technology in the model is embodied in the capital goods, the firm cannot change the technology without replacing the old vintages of capital goods (purchased in firm's investment in the previous period) with the new, more recent vintages of capital goods. Only in the long run, when the share of old vintages in the total capital stock of the firm becomes negligible due to depreciation and new investments, can the firm fully adjust the characteristics of the technology to the shocks in prices of inputs.

The material efficiency variable EFF_t^s , where t denotes time and s denotes the sector is set by the following equation:

$$EFF_t^s = EFF_{t-1}^s \frac{(1 - \delta)K_{t-1}^s}{K_t^s} + Z_t^s \frac{I_t^s}{K_t^s}$$

where K_t^s is the capital stock, I_t^s is the level of investment, Z_t^s is the firm's choice of technology, and δ is the parameter describing depreciation rate of capital. The cost of technology and capital goods is given by:

$$IC_t^s = I_t^s(1 + (cZ_t^s)^\alpha),$$

⁵ <http://ec.europa.eu/eurostat/web/nace-rev2>

Where α is the parameter which sets the degree of rigidity of technology adaptation by firms. The frictions in the labour market are modeled in line with the Mortensen-Pissarides (1994) search and matching framework. The unemployment rate is determined endogenously and depends on the number of vacancies generated by firms and the number of unemployed job seekers. Remaining details of the model setup, equations as well as the simulation methodology can be found in Antosiewicz and Kowal (2016).

Table 6 MEMO II sectors detail.

	Sector	Products	Eurostat CPA sectors
1	Agriculture (AGR)	non-meat	CPA_A01; CPAC10-C12*
		meat	CPA_A01; CPAC10-C12*
		fish	CPA_A03
2	Raw Materials Production and Mining (MAT)	wood and timber	CPA_A02
		coal mining	CPA_B*
		fuels (natural gas, oil) extraction	CPA_B*
		metal (iron ores, non-ferrous ores)	CPA_B*
		other mining and quarrying	CPA_B*
3	Manufacturing of basic chemical materials (CHEM)		CPA_C20; CPA_C22
4	Manufacturing of basic non-metallic mineral materials (NMM)		CPA_C23
5	Manufacturing of basic metals materials (MET)		CPA_C24
6	Remaining Manufacturing (MAN)		Remaining CPA_CXX
7	Energy (ENERGY)		CPA_D35; CPA_E36-E39
8	Construction (CONSTR)		CPA_F
9	Market Services (SRV)		CPA_G45 - CPA_N80-N82
10	Public services		CPA_O84 - CPA_U

	Sector	Products	Eurostat CPA sectors
	(PBL)		

* For agriculture (A01) and food processing (C10-12) sectors the disaggregation into meat and non-meat products is done using EUROSTAT data on consumption of households. For mining sector (B) disaggregation into products is done using NACE Rev. 1 input-output table.

The methodology of running simulations using a DSGE model is such that results for variables are presented as deviations from the steady state of the model and separate simulations are independent of each other. In particular, the results of the simulations of the tax policies represented as percentage deviations do not depend on the simulation of the baseline scenario. Of course, since the various cornerstone scenarios differ in the paths of e.g. GDP, the result defined in absolute values, such as millions of euros, will be different, however in order to focus on the main findings we omit the discussion of cornerstone scenarios.

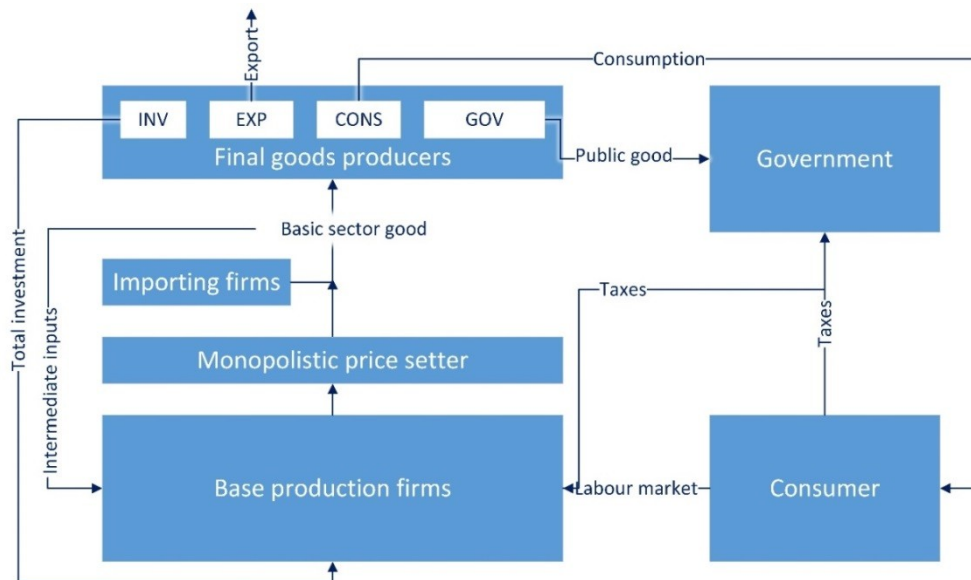
3.2.3 MEWA

MEWA (Material Energy Waste and Agriculture) is a large-scale DSGE model, which allows for a complex representation of an economy as a whole. In addition to common and competing DSGE models, MEWA has some unique features that makes it distinct from other similar tools. Firstly, the calibration method employed allows for quite extensive productive structure by considering 18 economic sectors, with detailed modelling of material flows in the economy. This approach allows a presentation of the impact of policies on energy and material efficiency for both metals and non-metals productive sectors, what is particularly relevant from the DYNAMIX point of view. Moreover, the model is detailed enough to allow us to apply changes to the taxation level in a form that exactly corresponds to the flows that are proposed in the policy mixes. At the same time, the rigidities introduced in the model (mainly price and labour market) allow for smooth transition between equilibria and reflect the complexity of the economy and the fact that reallocation of the production factors between sectors and firms is not immediate. Also an adaptation of capital-embodied technical progress, as in Bukowski (2014), allows the modelling of different scenarios in respect of the efficiency of R&D spending depending on factors such as the degree of trade liberalisation and other human attitudes.

Structure of the model: The basic structure of the MEWA model is similar to that used in the CGE modelling, where the main building block consists of production firms. They produce homogenous goods, engage in R&D activities and are taxed by the government. Goods are

thereafter differentiated by a monopolistic price setter and linked with imports using Armington aggregator into the final products. There are four kinds of composites – export good, investment goods (purchased by companies to build their capital, engage in R&D activities and by the government to improve public infrastructure), consumption goods which give utility to the consumers and public goods consumed by the government and financed by taxes. The government collects taxes, buys public good and undertakes infrastructure investments. Its decisions are discretionary⁶ – therefore the government does not optimize to increase social welfare. Consumers supply labour and receive wages and capital income (as they are owners of firms and capital). Their utility stems from consumption and labour (see the description below for more details). Labour is traded on the labour market modelled in line with the search and matching framework developed by Mortensen and Pissarides (1994). The most important feature of the MEWA model from the DYNAMIX point of view is an extensive production structure allowing for modelling of in-house R&D expenditures and of a consumer block that is described below.

Figure 5 MEWA model's basic scheme.



Commodity Details: The model is of annual frequency and consists of 18 sectors, presented in Table 7. For each sector there is a separate production firm, as well as a R&D firm and an Armington aggregator that defines the extent to which domestic and imported inputs can

⁶ In its basic version, the following taxes are implemented in the model: VAT (Value Added Tax) modelled as consumption tax, taxes on labour (both PIT - Personal Income Tax - and SSC - Social Security Contributions), CIT (Corporate Income Tax) and particular taxes on inputs in particular sectors and on the use of materials (circular economy tax).

substitute each other according to the country and sector-specific production function and specialisation.

Table 7 MEWA sectors detail.

Code	Description
CROPS	Crops
ANIM	Agriculture – animal production
FORE	Forestry
MEAT	Meat production
OTHFOOD	Other food production
IND_HEAVY	Heavy industry
IND_LIGHT	Light industry
MAT_IND	Raw materials intensive industry (Basic metals + other non-metallic mineral products)
MIN_F	Mining of fossil fuels
MIN_M	Mining of metal ores
MIN_O	Mining of other products
REC	Recycling (secondary raw materials)
CONSTR	Construction
FUELS	Fuels
CHEM	Chemical industry
ENERGY	Energy
SERV_PRV	Private services
SERV_PBL	Public services

Such a detailed sectoral structure of the MEWA model allows a very accurate modelling of the taxes on flows of materials between different sectors. Its particular strengths are the presence of three mining sectors, which allows for the imposition of different taxes on connected material flows, and the disaggregation of the agriculture and food sectors.

Production Structure: in the MEWA model, the production function is designed in such a way to reflect the substitution possibilities between different inputs as well as externalities produced by R&D activities. The firm maximizes the expected discounted sum of profits defined as:

$$\Pi_0^i = \sum_{t=0}^{+\infty} \Lambda_t \pi_t^i$$

Where $\Lambda_{t+1} = \beta \frac{\lambda_{t+1}^C}{\lambda_t^C} \Lambda_t$ is the stochastic discount factor, mirroring the preferences of households that own the firms, as λ_t^C is a Lagrange multiplier associated with households' budget constraint. Current cash flow is denoted by π_t^i and calculated in the following manner:⁷

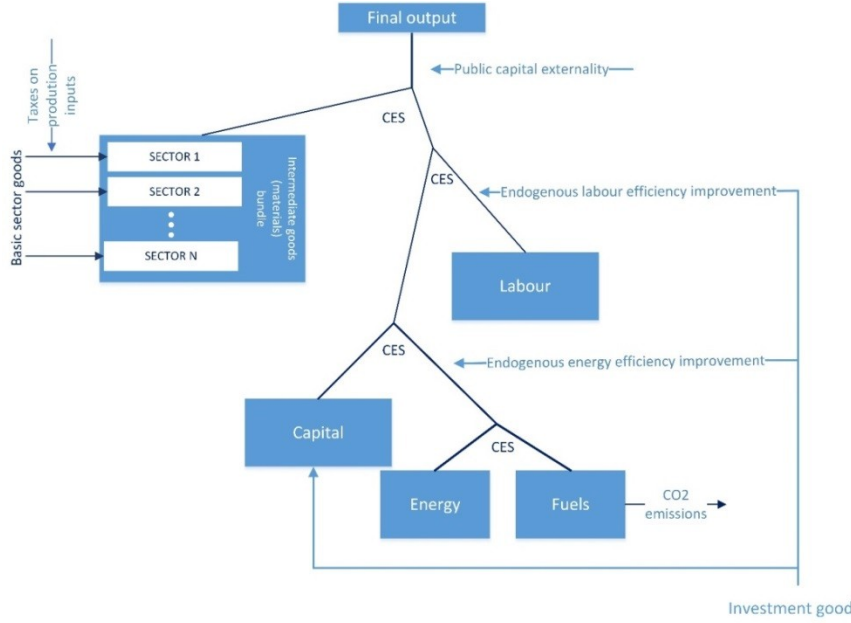
$$\pi_t^i = (1 - TX_{PROD_R}^i) * P_H^i * Y_H^i - W^i * L^i - I\_COST^i - COST_{MAT}^i - RND_{VAL}^i - CO2^i * \varphi^{CO2}$$

Where $(1 - TX_{PROD_R}^i) * P_H^i * Y_H^i$ is the value of production adjusted for taxes on production, $W^i * L^i$ is labour cost (wage multiplied by labour input), I_COST^i is investment cost, which is defined as:

$$I\_COST_t^i = P_{INV_t} * I_t^i + \frac{\varphi^{INV}}{2} * \left(\frac{I_t^i}{K_{t-1}^i} - \delta^{K,i} \right)^2,$$

Where $P_{INV_t} * I_t^i$ is the price of actual investment while the term $\frac{\varphi^{INV}}{2} * \left(\frac{I_t^i}{K_{t-1}^i} - \delta^{K,i} \right)^2$ reflects investment adjustment costs, that is standard in DSGE models. $COST_{MAT}^i$ is the cost of materials, which is equal to the sum paid for the intermediate inputs (including taxes on input), RND_{VAL}^i is the value of R&D expenditures and $CO2^i * \varphi^{CO2}$ is the cost of the emitted greenhouse gases. Production process is shown in Figure 6 and consists of a few steps. At the first stage from the bottom an energy bundle is created – fuels and energy are linked to reflect the possibility of replacing fossil fuels with electricity. This energy bundle is then linked with capital. A firm can increase the efficiency of energy use through in-house R&D activity (see below for details). At the next stage the capital-energy bundle is linked with labour. Again, the company can increase the productivity of labour through the in-house R&D effort. At the next stage, a material bundle is added to the production process. This bundle is a Leontief combination of products delivered by other sectors. At the last stage, final output is produced. At this stage, the level of public capital influences the extent to which infrastructure impacts on aggregate productivity.

⁷ In this and next equations we will skip time subscripts for clarity.

Figure 6 Production structure in the MEWA model.

Technological Process: Capital is accumulated according to the standard rule:

$$K_t^i = (1 - \delta^{K,i}) * K_{t-1}^i + I_t^i$$

The distinct feature of the MEWA model is the endogenous directed technological change, allowing for improving both energy and labour efficiency. The model incorporates technological progress through the endogenous, directed technological change that may improve energy or emission efficiency or increase the productivity of labour in the given sector. The idea of endogenous directed technological progress relies on the specific features of the capital that is employed in the particular sector. In other words, capital goods have additional, embedded attributes – energy efficiency, emission efficiency or labour efficiency ($X_t^{i,s}$, where i indicates sector and $s \in \{ENE, EM, LAB\}$ indicates the type of technological change). The evolution of this feature is governed by the following equation:

$$K_t^i X_t^{i,s} = (1 - \delta^s \eta^{-1}) K_{t-1}^i X_{t-1}^{i,s} + \left(\frac{I_t^i}{K_{t-1}^i} \right)^\eta K_{t-1}^i A_{t-1}^s Z_t^{i,s}$$

In this equation K_t^i denotes capital deployed in a sector i , $Z_t^{i,s}$ measures the adaptation activity s in sector j , while A_{t-1}^s denotes the technological frontier at the start of period t for the attribute s . Firms, at the expense of their current profits, can increase the level of $Z_t^{i,s}$ to make their investments more efficient. Increase in $Z_t^{i,s}$ requires an additional spending which is reflected in the following equation:

$$Z\_VAL_t^{i,s} = Z_t^{i,s \alpha_s} \phi^s.$$

Moreover, when firms invest in improving the efficiency of their capital, they also moves the economy-wide technological frontier for the attribute s – that is, the externality stemming from investing in the attribute $Z_t^{i,s}$. The movement of this frontier can be described as follows:

$$A_t^s = (1 - \delta_A^s)A_{t-1}^s + \delta_A^s * (\omega_s Z_t^{s\psi_s} + (1 - \omega_s)I\_PUB\_RND_t^{s\psi_s})^{1/\psi_s}$$

Where A_t^s is the current technology frontier for attribute s , $Z_t^s = \frac{\sum_{j \in S} I_t^s Z_t^{i,s}}{\sum_{j \in S} I_t^s}$ is weighted by investment sum of the attribute $Z_t^{i,s}$ over all sectors of the economy. A_t^s may be also increased by public R&D spending for the attribute s ($I\_PUB\_RND_t^s$). Therefore, an additional movement of the efficiency frontier results from the CES aggregate of public and private spending on the attribute in question. An increase in public R&D spending will thus result in a faster increase in the energy efficiency frontier and therefore an improvement of the $X_t^{i,s}$ trait of the capital, which translates into higher efficiency. That investment must be, however, somehow financed, so the efficiency improvement comes with some costs depending on the user choice.

4 Summary across all Policy Mixes

4.1 Overview of the Policies Evaluated by the Different Models

The DYNAMIX project identifies a set of policies grouped into policy mixes aiming at promoting decoupling and more efficiency in resource use (Ekvall et al., 2015). Two policy mixes tackle the metal and land-using sectors. A third one, ‘overarching’, has a wider breadth proposing policies affecting the overall economic system.

The previous chapter makes an overview of the main similarities and differences across models. Even though they belong to the same general category (macroeconomics or applied general equilibrium), the different models are tailored to assess specific policy questions.

Only for three measures (one per each mix) all models can provide results, such to allow comparison as far as is possible. Moreover, all models can capture at least one measure per policy mix. For several measures, only one model is involved in the quantitative assessment, namely MEWA for “Increasing Research and Development Spending” and “Enabling Shift from Consumption to Leisure” and ICES for “Targeted Information Campaign to Influence Food Behaviour towards Changing Diets”.

Table 8 shows which policy instruments have been analyzed by which model involved in the quantitative assessment.

Table 8 DYNAMIX Policy matrix.

Policy mix	Policy Instrument	ICES	MEMO II	MEWA
Metals and Other Materials (MOM)	1. Green fiscal reform: materials tax	X	X	X
	2. Green fiscal reform: internalisation of external environmental costs		X	X
	3. Increased spending on research and development			X
Land-Use (LU)	4. Strengthened pesticide reduction targets under the Pesticides Directive	X		X
	5. Targeted information campaign to influence food behaviour towards changing diets	X		
	6. VAT on meat	X	X	X
Overarching (O)	7. Circular economy tax trio	X	X	X
	8. Enabling shift from consumption			X

Policy mix	Policy Instrument	ICES	MEMO II	MEWA
	to leisure			

More specifically, three different policies to reduce the use of metals and other materials in the EU are tested: a tax on materials use levied when they enter the first node of the production process, the full internalization, again through taxation, of the external environmental costs associated to the use of materials, and a support to R&D to increase productivity in the use of metals.

In addition, analysis of costs and feasibility of policies aimed to reduce the environmental pressure connected to current land management systems included the analysis of: taxation on pesticides; domestic harmonization of meat taxation - which is equalized to the average VAT in each country; information campaigns aiming to facilitate the shift towards healthier and more sustainable diets.

The overarching policy envisages a closure of the production-consumption loop. This consists in a tax penalizing the purchases of extracted virgin materials by all sectors and in a policy aiming to create conditions to improve the utility from leisure allowing an easier shift away from work and the related income.

The table below summaries the assumptions adopted for implementation of the whole set of policies modelled, highlighting the differences when this is the case.

Table 9 Model implementation of the policy fiches.

Policy fiche	What	Degree of Implementation	Timeline
Green fiscal reform: materials tax	<i>ICES: Sales tax of wood and mining to all other sectors (excluding fossil fuel extraction) + Sales tax of Oil Products to Chemicals.</i> <i>MEMO II and MEWA: Sales tax of wood, fuels, metal and other to all manufacturing sectors and construction + sales tax of chemical, metal and non-metallic mineral (excluding tax they pay for raw material purchase) to manufacturing and construction sector</i> + <i>MEMO II: recycling of 50% revenue to reduce labour taxation</i> <i>MEWA: different forms of revenue recycling: a) decrease in labour taxation, firms cannot pursue material efficiency improvements; b) decrease in labour taxation, firms can pursue material efficiency improvements; c) decrease in labour taxation and support to R&D in material efficiency.</i>	3 p.p./year (up to 30%) 8.5 p.p./year (up to 200%)	2021-2030 2031-2050
Green fiscal reform: internalisation of external environmental costs	<i>Excise tax on all sectors but services with two alternative specification: a) common flat tax rate to all sectors; b) sector specific rate based on actual externalities</i> + recycling of 50% revenue to reduce labour taxation	linear increase up to 35%	2030-2050
Increased spending on research and development	<i>increase in the public investment in R&D for material efficiency</i>	Doubling of current levels	2020 (kept constant up to 2050)
Strengthened pesticide reduction targets under the Pesticides Directive	<i>Tax on domestic and imported sales of chemicals to the agriculture sector</i>	8% linear increase up to 20%	2020-2050

Targeted information campaign to influence food behaviour towards changing diets	<i>Gradual reduction in meat consumption such to reach the EU benchmark in dietary balance</i>	country-specific	2021-2050
VAT on meat	<i>Fill the gap between current VAT on meat and the average country-specific VAT</i>	13 p.p. (EU average, in ICES country-specific)	2020 (kept constant up to 2050)
Circular economy tax trio	<i>ICES and MEMO II: Tax on domestic sales of mining (excluding fossil fuels) to non-metallic minerals and construction + Tax on exports of non-metallic minerals.</i> <i>MEWA: Tax on virgin materials, landfills and waste incineration</i>	38% linear increase up to 50%	2018-2050
Enabling shift from consumption to leisure	<i>Change of the parameter reflecting the relative marginal utility from consumption and leisure</i>	arbitrary	2015 (kept constant up to 2050)

4.2 ICES

4.2.1 Green Fiscal Reform: Materials Tax

The tax on materials aims to foster a reduction in the overall use of resources with respect to the current and future reference trends. It is implemented as a tax on the sales of timber and of mined materials to all other sectors, excluding fossil fuels for energy generation purposes, but including fossil fuels used by the chemical industry (e.g. for plastic production). The tax is imposed also on imported commodities, but not on exports. In the simulation, tax revenues are by default rebated lump-sum to households.

The tax is so pervasive that it has huge and widespread negative consequences on production across all the sectors and EU countries (Table 10). Material-intensive heavy industries are particularly penalized, especially non-ferrous metals and iron and steel reaching a contraction of nearly 50% and 26% in 2050 at the EU level (Figure 7). However a cascading effect involves the energy sectors, especially gas and oil products, these last used by chemicals, and construction. The effect on prices is mixed: the tax increases the prices of the outputs from those sectors directly hit, i.e. material intensive productions, whereas in all the other sectors prices tend to decline (

Table 11). This is the aggregated demand effect at play. As shown by Figure 8, GDP losses are relevant: roughly 5% in the EU in 2050, with Finland (-22.07%), Czech Republic (-16.96%) and Poland (-12.88%) particularly worse off. The GDP contraction thus brings about a generalized demand contraction with declines in the prices of goods and services.

Albeit costly, the policy succeeds in decreasing material intensity of GDP of EU economies (Figure 9). On average this declines by 12% in 2050, with the best performances in Belgium, the Netherlands, Luxemburg and Sweden. For the Czech Republic and Poland the situation is different. Their economies are among the most resource-intensive in the EU. Therefore, the taxation policy forces a difficult substitution away from material uses that can be reached only with a heavy contraction in the economic activity and GDP. These ultimately turn out to be higher than the contraction in material use itself. As a consequence, the GDP material intensity of these two countries increases.

Figure 7 Materials Tax (ICES). EU sectoral production: % change with respect to 'no policy' in the reference scenario.

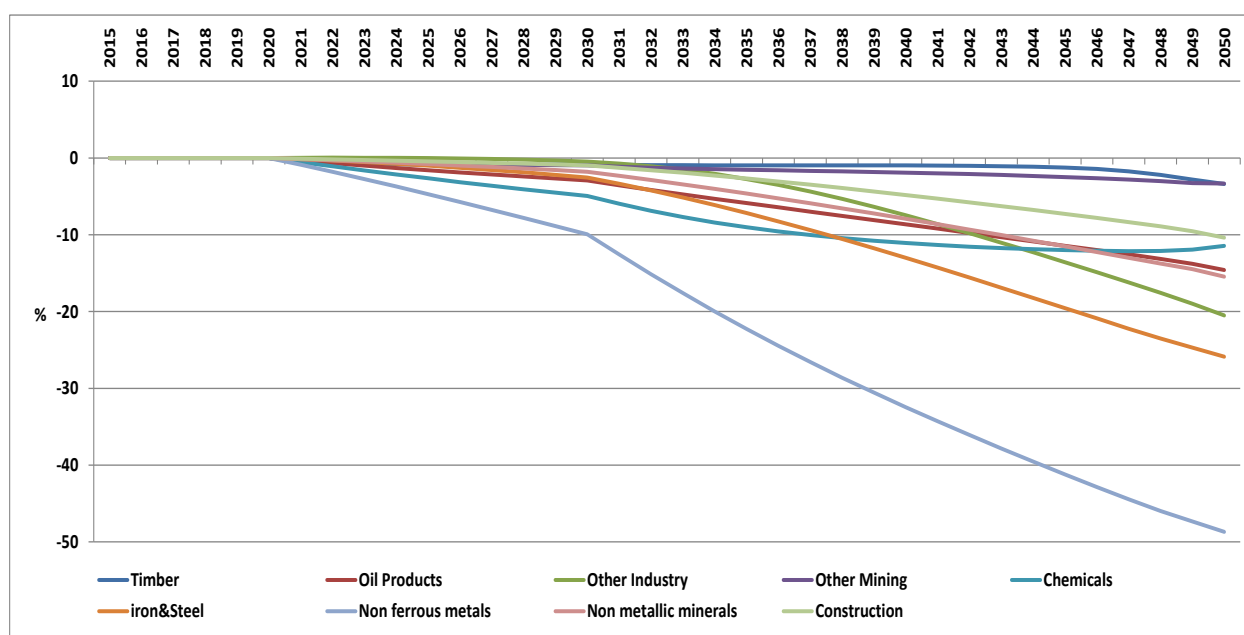


Figure 8 Materials Tax (ICES). GDP: % change with respect to 'no policy' in the reference scenario.

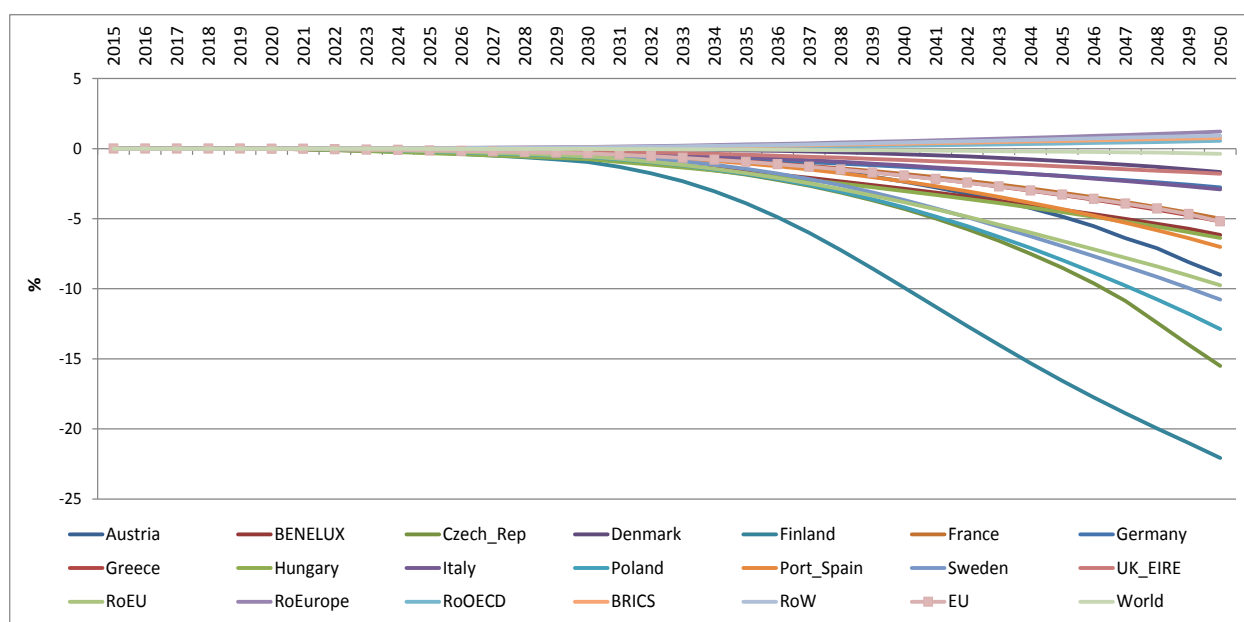


Table 10 Materials Tax (ICES). Sectoral output: % change with respect to ‘no policy’ in the reference scenario (2050).

	Austria	BENELUX	Czech_Rep	Denmark	Finland	France	Germany	Greece	Hungary	Italy	Poland	Port_Spain	Sweden	UK_EIRE	RoEU	RoEurope	RoOECD	BRICS	RoW
Agriculture	-0.06	-0.20	0.36	-1.24	2.96	-0.09	-0.65	-0.36	-0.75	-1.04	0.61	0.24	0.33	-1.11	-1.04	-2.19	-1.91	-3.02	-2.81
Livestock	-2.62	0.49	-1.83	-2.05	-7.01	-0.73	-4.13	-0.96	0.16	-3.10	-3.53	0.73	-0.28	-1.93	2.71	-2.74	-2.76	-3.25	-2.66
Timber	-9.29	-1.32	-7.47	-1.88	-1.82	-3.19	-2.49	-1.48	-2.25	-1.59	-3.22	-1.45	-1.54	-2.02	-2.00	-2.21	-1.94	-3.12	-2.59
Fishing	-1.26	-1.42	-1.14	-1.46	-1.29	-1.33	-1.34	-1.44	-1.31	-1.53	-1.46	-1.22	-1.28	-1.48	-1.71	-1.90	-2.01	-3.12	-2.66
Coal	1.91	4.30	4.39	4.35	5.24	-4.83	3.34	2.64	-0.07	0.76	2.06	2.41	5.12	-0.68	1.29	-0.70	-1.78	0.79	-1.71
Oil	5.23	7.23	0.93	7.65	5.01	5.39	6.94	0.53	4.17	0.59	5.00	6.00	2.68	4.66	5.97	4.11	2.23	1.16	0.36
Gas	-0.08	-1.53	-2.74	-6.16	-23.01	-3.18	-5.47	-9.40	-6.37	-9.66	-34.04	-11.06	-12.52	-6.57	-7.70	-2.99	-4.42	-2.02	-3.68
Oil_Pcts	-9.58	-8.59	-20.19	7.63	-17.72	-10.98	-8.36	-2.95	-13.64	-5.95	-21.55	-11.56	-12.50	-2.30	-10.97	1.36	1.54	1.15	-0.57
Ely	1.75	-6.82	4.01	-20.78	-35.79	-2.36	-3.17	-4.28	-5.58	-7.49	-10.17	-7.48	-10.10	-10.70	-8.81	-13.05	-8.82	-8.97	-7.57
Other_Min	-4.79	-2.92	-4.72	-7.38	-22.37	-6.10	-7.20	-1.54	-13.26	-7.13	-2.41	-4.30	-3.74	-3.94	-16.87	-3.04	-2.57	-4.26	-3.63
Meat_Ind	3.59	4.56	0.00	5.62	-2.32	3.52	-1.15	-1.49	3.68	-3.52	-4.92	3.24	5.80	2.48	6.55	-3.44	-3.52	-5.40	-3.19
Food_Ind	6.86	3.08	3.97	1.13	17.45	7.34	-0.34	-0.95	-4.29	-6.93	6.48	7.62	7.11	-2.79	-1.43	-2.57	-4.78	-4.48	-5.26
Chem_Ind	4.70	-42.94	-3.45	9.09	-29.23	-15.19	-14.90	-36.25	-33.22	-12.20	-16.12	-12.99	3.52	-14.58	-12.52	-4.32	-1.50	-1.93	-5.01
Iron_Steel	45.05	-42.09	-14.66	11.95	-71.29	-3.77	-19.73	-21.42	-9.21	-4.05	3.70	-46.87	-20.26	-32.68	-42.17	8.63	0.44	-4.28	-1.56
Non_Fer_Met	43.89	-73.09	-44.44	28.31	-89.22	-25.30	-54.93	-21.17	-27.44	-20.27	-3.01	-67.91	-59.61	-69.17	-77.99	22.58	8.72	-4.03	1.68
Non_Met_Min	-14.04	-40.59	2.60	-9.97	-19.65	-5.34	-14.70	-10.83	-7.98	-13.46	-1.70	-16.04	-32.25	-18.96	-16.91	2.40	-3.55	-4.52	-2.56
Cons_Ind	-15.12	-14.70	-20.67	-7.91	-29.12	-12.86	-8.62	-12.82	-14.59	-11.43	-19.48	-14.78	-18.14	-11.60	-19.25	-6.72	-6.47	-5.80	-4.33
Other_Ind	-45.64	-20.32	-39.27	-13.98	-66.25	-18.90	-6.77	-17.44	-10.14	-6.36	-39.52	-31.38	-50.61	-10.33	-43.23	-1.90	-4.04	-4.29	-3.25
MarketServ	-1.53	-3.26	-3.78	-3.04	-5.32	-5.74	-1.90	-2.60	-5.82	-6.09	-8.46	-2.63	-4.73	-4.29	-6.98	-6.20	-4.75	-7.23	-8.19
PublicServ	-0.27	-0.12	-2.14	-0.69	-0.86	-2.07	0.40	-2.26	-2.28	-3.21	0.84	0.39	-1.72	-2.49	0.25	-4.78	-3.86	-8.98	-8.50

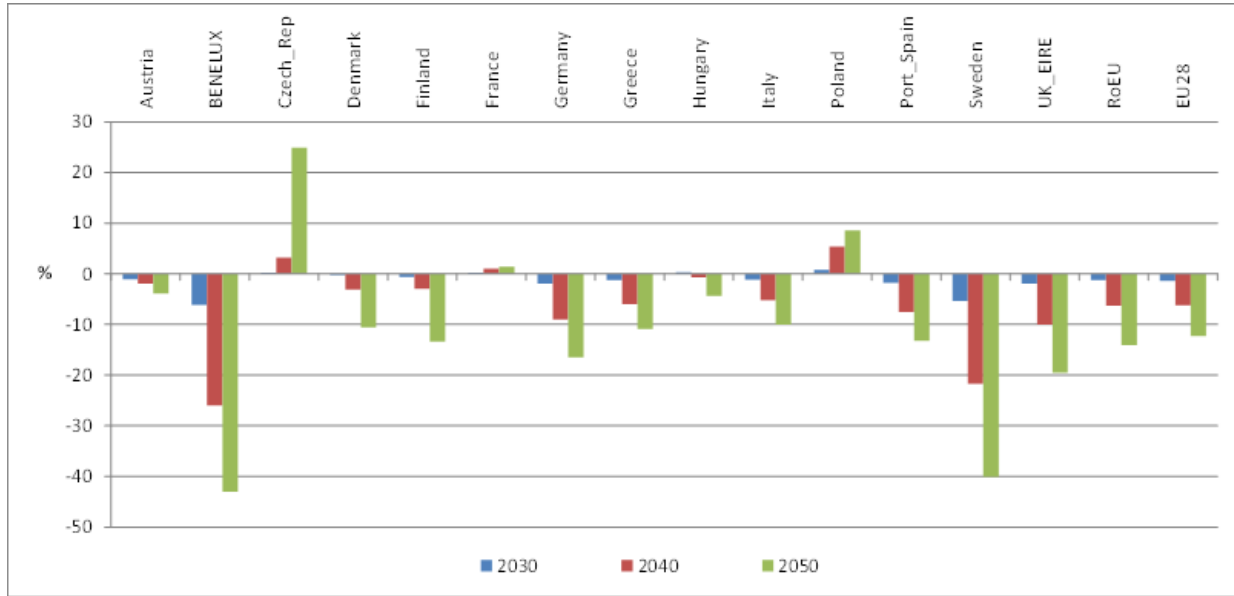
Note: In red the sectors primarily affected

Table 11 Materials Tax (ICES). Sectoral prices: % change with respect to ‘no policy’ in the reference scenario (2050).

	Austria	BENELUX	Czech_Rep	Denmark	Finland	France	Germany	Greece	Hungary	Italy	Poland	Port_Spain	Sweden	UK_EIRE	RoEU	RoEurope	RoOECD	BRICS	RoW
Agriculture	-6.51	-7.04	-7.18	-6.67	1.11	-7.14	-7.23	-7.67	-8.41	-9.51	-6.70	-7.09	-5.14	-8.92	-8.25	-6.79	-7.48	-4.44	-6.48
Livestock	-6.16	-6.11	-7.85	-5.42	-3.96	-6.98	-4.83	-7.48	-7.86	-9.66	-9.37	-6.55	-5.59	-8.71	-7.01	-6.08	-6.53	-4.61	-6.72
Timber	-22.67	-18.90	-26.44	-19.97	-22.69	-20.39	-18.32	-21.30	-24.29	-21.46	-25.14	-26.00	-25.06	-25.89	-23.30	-21.99	-18.14	-14.75	-17.56
Fishing	-13.44	-13.82	-14.04	-13.75	-12.02	-13.66	-13.73	-14.63	-14.58	-14.98	-13.60	-14.20	-13.93	-15.36	-14.35	-14.30	-14.73	-12.87	-13.13
Coal	-15.76	-10.25	-18.34	-12.17	-28.97	-5.62	-11.78	-15.48	-11.69	-8.10	-17.65	-10.97	-14.45	-7.94	-15.73	-8.34	-6.37	-4.21	-5.00
Oil	-12.06	-12.21	-13.09	-10.63	-15.01	-12.13	-12.25	-6.70	-11.30	-8.06	-16.11	-12.90	-12.72	-10.71	-13.18	-9.17	-6.72	-6.18	-6.19
Gas	-4.94	-10.55	-11.05	-3.32	5.63	-4.23	-1.71	-2.02	-1.06	6.28	24.56	-2.27	-4.35	-2.24	-10.14	-3.81	1.75	2.67	0.53
Oil_Pcts	-6.18	-5.54	-6.86	-9.51	-5.12	-6.25	-5.68	-5.30	-5.24	-5.39	-1.30	-5.57	-6.73	-8.32	-5.98	-5.39	-4.39	-1.81	-2.86
Ely	-3.67	-3.11	-5.86	12.11	7.20	-3.02	-0.85	-5.05	0.25	1.59	-4.24	-1.94	2.36	6.05	-4.04	9.27	5.80	13.17	6.71
Other_Min	-8.34	2.03	-14.22	-3.39	-11.98	-10.81	-5.70	-4.76	-2.09	-3.50	-11.80	-20.86	-9.06	-3.97	1.15	-1.84	3.91	6.76	6.18
Meat_Ind	-5.25	-4.67	-5.12	-4.83	-4.85	-5.61	-4.08	-4.94	-5.91	-3.20	-7.44	-5.84	-5.91	-6.01	-4.17	-2.75	-2.19	-0.47	-3.03
Food_Ind	-3.99	-3.86	-4.62	-4.31	-5.82	-4.59	-3.19	-4.20	-2.78	-2.03	-4.62	-5.01	-4.39	-2.44	-3.15	-3.54	-1.01	-1.67	-2.08
Chem_Ind	5.75	16.61	6.50	5.46	11.97	9.86	9.36	19.36	15.63	9.95	9.19	8.96	6.43	10.17	8.44	8.15	5.91	6.70	8.65
Iron_Steel	1.83	20.25	8.42	6.11	33.46	8.67	13.84	13.91	9.28	9.33	3.12	26.43	12.72	23.16	19.81	7.19	6.48	10.42	11.06
Non_Fer_Met	7.85	33.12	22.07	8.36	49.75	17.89	25.19	14.78	19.45	17.24	11.69	39.47	25.42	34.41	51.38	9.38	6.78	11.47	9.93
Non_Met_Min	13.37	40.27	5.97	13.51	10.54	7.14	16.04	8.32	9.06	15.98	5.05	15.18	23.29	21.13	10.88	6.71	7.56	14.36	10.76
Cons_Ind	4.77	6.91	0.91	5.52	0.23	0.08	5.36	9.08	4.67	9.31	1.65	3.41	3.15	13.54	4.94	7.76	6.86	13.58	10.47
Other_Ind	17.34	9.56	13.92	8.84	35.50	9.81	6.47	9.72	7.26	6.49	16.04	14.27	22.77	7.49	17.07	5.84	5.56	6.57	6.44
MarketServ	-1.37	-0.25	-4.63	3.16	-8.32	-2.56	1.56	0.76	0.84	4.39	-3.46	-3.07	-3.77	3.36	-1.26	8.25	8.12	13.20	13.11
PublicServ	-8.16	-6.79	-10.99	-0.54	-23.47	-7.57	-2.74	-3.71	-5.74	2.05	-14.07	-9.38	-10.49	-0.06	-12.82	5.81	5.90	15.24	11.76

Note: In red the sectors primarily affected

Figure 9 Materials Tax (ICES). Material efficiency*: % change with respect to ‘no policy’ in the reference scenario.



Note: * Measured as material input/GDP

4.2.2 Strengthened Pesticide Reduction Targets under the Pesticides Directive

The policy on pesticides is assumed to be implemented through a tax increasing the cost of using chemicals in agriculture (in effect, a simplification of the policy approach described in Ekvall et al. 2015). In the ICES model indeed it is not possible to disentangle pesticides from fertilizers. We can only single out the sales from the chemical to the agricultural sectors.

As shown by Figure 10, as expected, the demand of chemical inputs and agricultural production⁸ in the EU declines as pesticides and fertilizers are charged with the tax and overall production costs in agriculture increase. Agricultural production contraction ranges from the 0.35% in Austria and Sweden to the 0.05% in Italy as soon as the tax is implemented (2020). Then, as the sector adjusts, the contraction shrinks. A similar effect, albeit milder, spreads to the food industry which is one of the main recipients of agricultural products.

Price effects are also limited. In 2020, there is an increase in agriculture production up to 0.39% in Sweden, 0.33% in Austria and 0.32% in France. Moving towards 2050, this impact reduces with respect the ‘no policy’ case in the reference scenario and prices are at most 0.9% (in Sweden, Denmark, France and Hungary) higher.

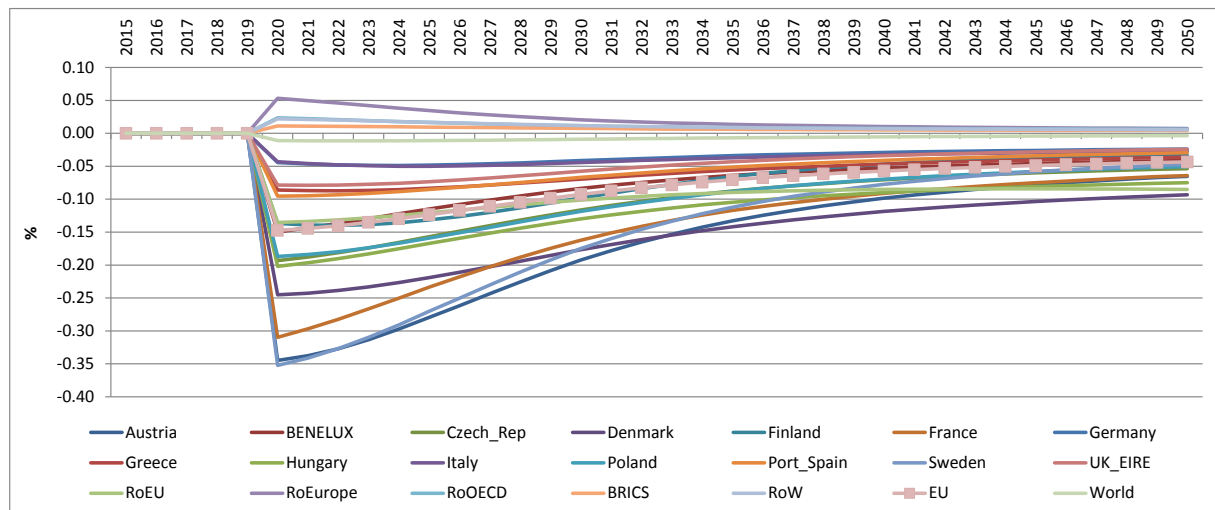
⁸ In the ICES model, given that intermediates are perfect complements with primary production factors, the two things coincide.

The overall GDP effect on the countries adopting the policy is determined by the relevance of chemical products as intermediate inputs to agricultural production (i.e. on the technology in agriculture) and by the contribution of agriculture to the production of national value added. Considering that, on average, in the EU this contribution is roughly the 2%, small effects can be expected. Indeed, as shown in Figure 11, tiny effects on GDP are generated by the tax. They go in an opposite direction of what might be expected though, as GDP in the EU slightly increases (on average by the 0.006% in 2050).

The positive effects on GDP are thus generated by an interesting “rebound” second-order effect. The contraction in EU agricultural production is compensated by an increase in non EU agricultural activity. Non EU agricultural sectors thus increase their input demand, including chemical products. This spurs chemical production for agricultural uses also in the EU which is now directed to the foreign rather than the domestic markets. Indeed EU chemical sectors, notwithstanding the tax and the reduced EU demand, increase their production (Table 12).

Summarizing, the policy is moderately successful in reducing chemical products use in the EU agricultural sector. The direct effect on agricultural production is small and the final impact on EU countries’ GDP is almost null. The tax thus has some relevance just for the sectors directly impacted without substantive cascade impacts on the overall economic system. The policy however is not successful in decreasing EU production of chemicals for agricultural purposes. As exports are not taxed, EU chemical industry simply redirects its production to non-EU markets. Moreover, given that non-EU agricultural production increases to compensate the contraction in the EU, EU chemicals industries could even experience a net increase in demand and expand their activity.

Figure 10 Pesticide Tax (ICES). Output: % change with respect to ‘no policy’ in the reference scenario (Agriculture: top; Food Industry: bottom).



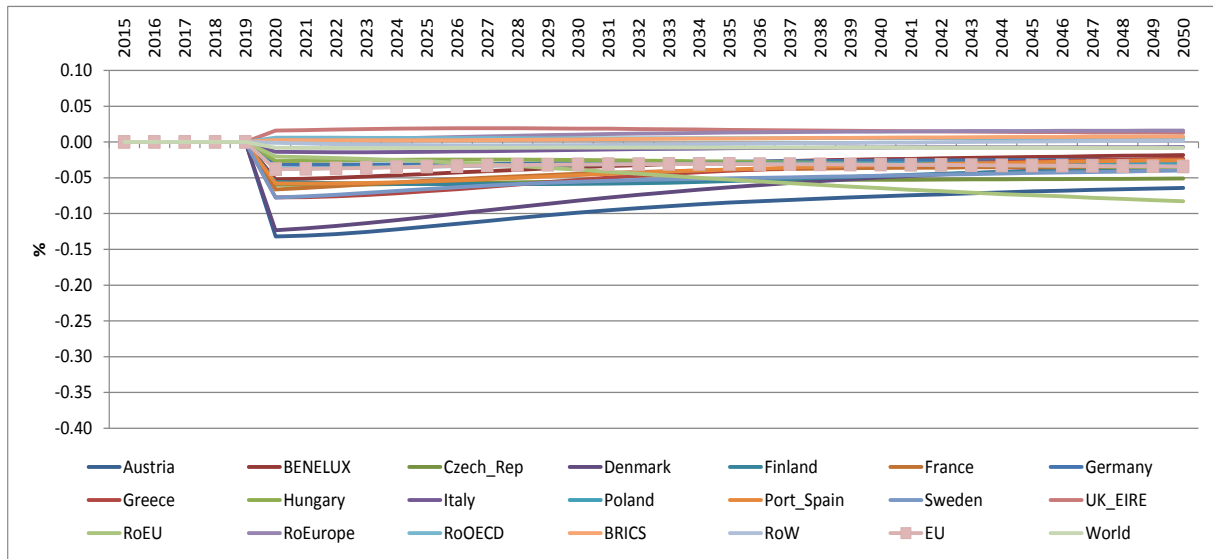


Figure 11 Pesticide Tax (ICES). GDP: % change with respect to 'no policy' in the reference scenario.

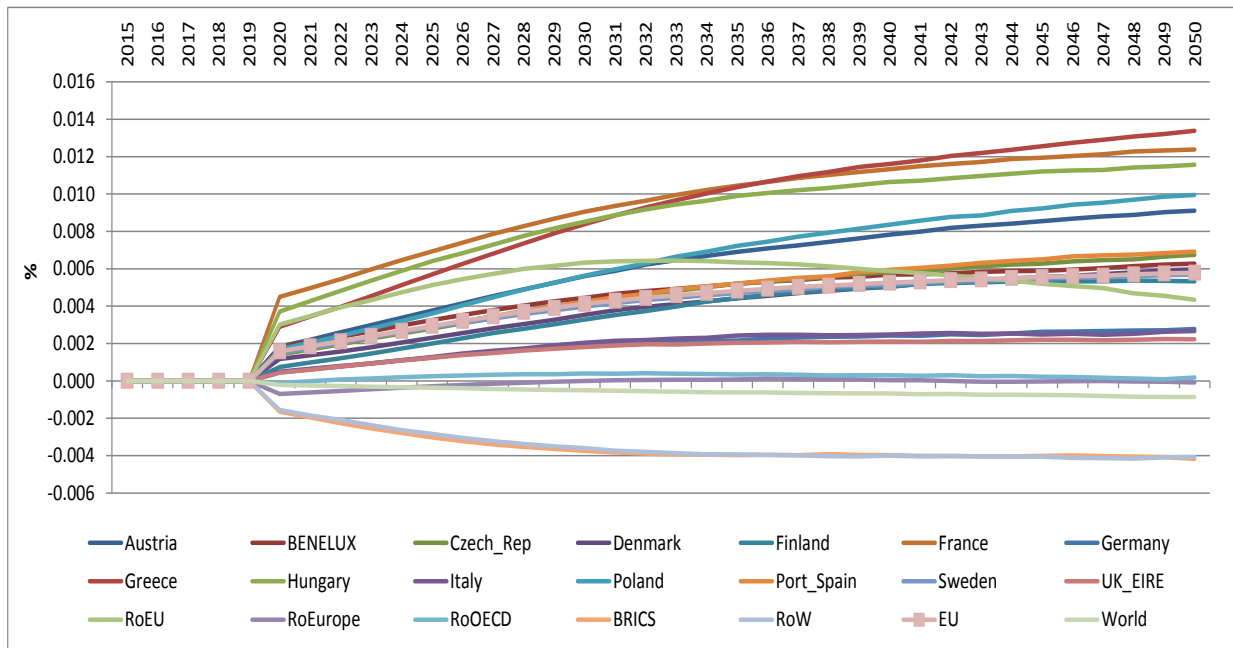


Table 12 Pesticide Tax (ICES). Sectoral output: % change with respect to ‘no policy’ in the reference scenario (2050).

	Austria	BENELUX	Czech_Rep	Denmark	Finland	France	Germany	Greece	Hungary	Italy	Poland	Port_Spain	Sweden	UK_EIRE	RoEU	RoEurope	RoOECD	BRICS	RoW
Agriculture	-0.072	-0.044	-0.057	-0.099	-0.036	-0.070	-0.025	-0.039	-0.078	-0.029	-0.055	-0.032	-0.053	-0.026	-0.085	0.008	0.006	0.005	0.006
Livestock	0.152	0.094	0.175	0.169	0.087	0.145	0.048	0.034	0.191	0.030	0.089	0.048	0.176	0.030	0.144	-0.059	-0.032	-0.008	-0.016
Timber	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fishing	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Coal	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gas	0.007	0.001	0.001	0.001	-0.016	0.004	0.001	0.012	0.006	0.003	0.002	-0.001	-0.012	0.000	0.007	0.000	0.000	-0.001	-0.001
Oil Pcts	-0.002	0.001	-0.003	-0.001	-0.003	-0.005	0.001	0.005	-0.001	-0.002	-0.013	0.001	0.001	0.002	-0.003	0.000	0.002	-0.001	-0.001
Ely	0.009	0.001	0.006	0.002	0.004	0.011	0.002	0.007	0.006	0.001	0.007	0.005	0.004	0.001	0.006	-0.002	0.001	-0.002	-0.002
Other_Min	0.004	0.000	0.003	0.002	0.003	0.007	0.001	0.005	0.006	0.001	0.003	0.001	0.000	0.000	0.004	0.000	-0.001	0.000	0.000
Meat_Ind	0.282	0.133	0.161	0.214	0.061	0.213	0.086	0.047	0.177	0.058	0.063	0.076	0.274	0.032	0.171	-0.067	-0.038	-0.033	-0.038
Food_Ind	-0.067	-0.020	-0.052	-0.037	-0.039	-0.035	-0.025	-0.026	-0.034	-0.008	-0.029	-0.027	-0.042	0.013	-0.078	0.016	0.005	0.007	0.001
Chem_Ind	0.022	0.011	0.018	0.001	0.017	0.024	0.005	0.029	0.011	0.005	0.015	0.013	0.013	-0.002	0.015	0.002	-0.001	-0.001	-0.004
Iron_Steel	0.024	0.010	0.016	0.010	0.016	0.030	0.004	0.029	0.013	0.004	0.024	0.011	0.008	-0.004	0.017	-0.002	-0.002	0.000	-0.004
Non_Fer_Met	0.022	0.009	0.013	0.009	0.011	0.029	0.002	0.031	0.012	0.003	0.026	0.009	0.006	-0.006	0.015	-0.005	-0.004	0.000	-0.001
Non_Met_Min	0.014	0.007	0.010	0.007	0.009	0.015	0.002	0.019	0.010	0.003	0.012	0.007	0.005	0.001	0.010	-0.001	0.000	-0.002	-0.001
Cons_Ind	0.008	0.006	0.006	0.005	0.005	0.009	0.003	0.011	0.011	0.002	0.007	0.006	0.005	0.003	0.006	0.001	0.001	-0.002	-0.002
Other_Ind	0.024	0.012	0.015	0.013	0.020	0.028	0.006	0.024	0.016	0.003	0.022	0.011	0.013	-0.001	0.018	0.001	0.000	-0.002	-0.001
MarketServ	0.008	0.005	0.005	0.005	0.004	0.010	0.003	0.011	0.009	0.002	0.006	0.006	0.005	0.002	0.002	0.000	0.001	-0.003	-0.002
PublicServ	0.005	0.004	0.004	0.003	0.002	0.009	0.002	0.018	0.008	0.004	0.006	0.007	0.002	0.002	0.007	0.000	0.001	-0.001	0.000

Note: In red the sectors primarily affected

4.2.3 Targeted information campaign to influence food behaviour towards changing diets.

This exercise tests the economic and environmental effects of an idealized information campaign able to shift the EU consumers' behaviour toward a less meat intensive diet.

This exercise is highly stylized. Namely:

- It does not consider issues related to the quality of what is consumed; that is, meat and non-meat are undifferentiated aggregates.
- It does not quantify nor evaluate economically the potentially positive health effects induced by the dietary shift.
- It quantifies environmental effects only in terms of changes in GHG emissions and associated social gains.
- It abstracts from any consideration about the design, implementation strategies and costs of the information campaign.

With these qualifications in mind, it is assumed that, following the campaign, all the EU countries, while keeping the total per capita caloric intake of the reference scenario unchanged, redistribute it across meat and non-meat-based food, mimicking the least meat-intensive European country. This is Bulgaria whose average citizen gets today 21% of her/his calories from meat and 79% from other (non-meat) food⁹. It is assumed that the campaign starts in 2020 and slowly reaches its objectives in 2050.

Table 13 reports the reallocation between meat and non-meat food categories required in each country. The largest change in habits would affect Finland that is expected to reduce meat consumption by 39% and increase that of non-meat by 21%. The mildest change awaits Greece with a meat consumption reduction of the 21% and an increase in consumption of non-meat food products of the 3.5%.

Consequently, in 2050 processed meat production in the EU declines by 8%, with a peak of roughly 17% in Hungary, Finland and Sweden. On average, the production contraction is thus somewhat smaller than the demand contraction. This is due to the possibility for EU meat producers to export outside the EU area. On the contrary, non-meat food products experience an increase in production of around 3% at the EU level. This is again on average quite lower than the EU demand increase as the bulk of the latter is fulfilled by non-EU imports. This stresses the particular import dependence of non-meat food products in the EU which increases by 1.9%.

⁹ Our computation based upon FAO Food Balance Sheets - <http://faostat3.fao.org/download/FB/FBS/E>

Apparently, the recomposition of the sectoral activity toward non-meat production induces small (+0.04% at the EU level in 2050), but generally positive effects on EU countries' GDP with Hungary as the best performer (+0.4%) (Figure 13).

The improvement of GDP is mostly driven by a slight improvement of terms of trade consequent on the recomposition of household consumption bundle.

GHG emissions, that the model is able to quantify worldwide, thus tracking all the indirect effects triggered on non EU food (meat and non-meat) industry as well as on all the other economic sectors, decline (Figure 14). Over the whole 2020-2050 period the Mtons of CO₂ equivalent saved are 508.36. This amounts just to the 0.27% of the EU emissions of the period, however the social advantages should not be easily dismissed. For instance, according to the survey by Tol (2008) the social cost of one ton of carbon emitted ranges between 24 and 317 \$. The campaign would thus be able to produce a social benefit of roughly 12 to 160 Bln \$.

Table 13 Information Campaign (ICES). Dietary change envisaged (%)

	Meat consumption	Non-meat food consumption
Austria	-27.24	11.16
BENELUX	-32.70	14.98
Czech_Rep	-20.45	7.41
Denmark	-34.88	16.77
Finland	-39.51	21.24
France	-34.55	16.50
Germany	-28.42	11.92
Greece	-11.20	3.50
Hungary	-29.57	12.69
Italy	-13.25	4.27
Poland	-17.44	6.01
Port_Spain	-18.42	6.45
Sweden	-31.44	14.02
UK_EIRE	-25.93	10.36
RoEU	-16.47	5.58

Figure 12 Information Campaign (ICES). Production: % change with respect to 'no campaign' in the reference scenario (meat processed food: top; non-meat processed food: middle; fisheries: bottom).

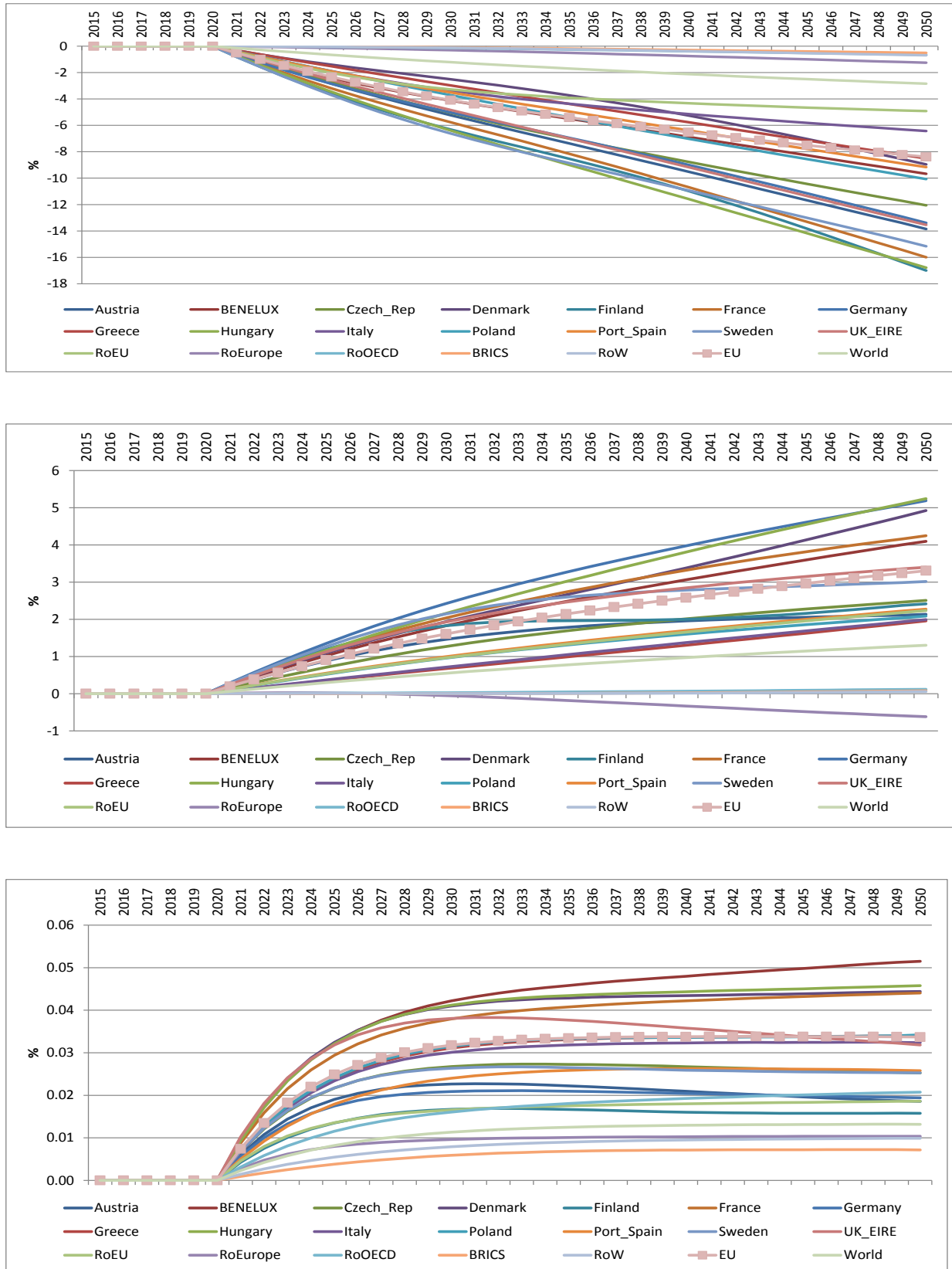


Figure 13 Information Campaign (ICES). GDP: % change with respect to 'no campaign' in the reference scenario.

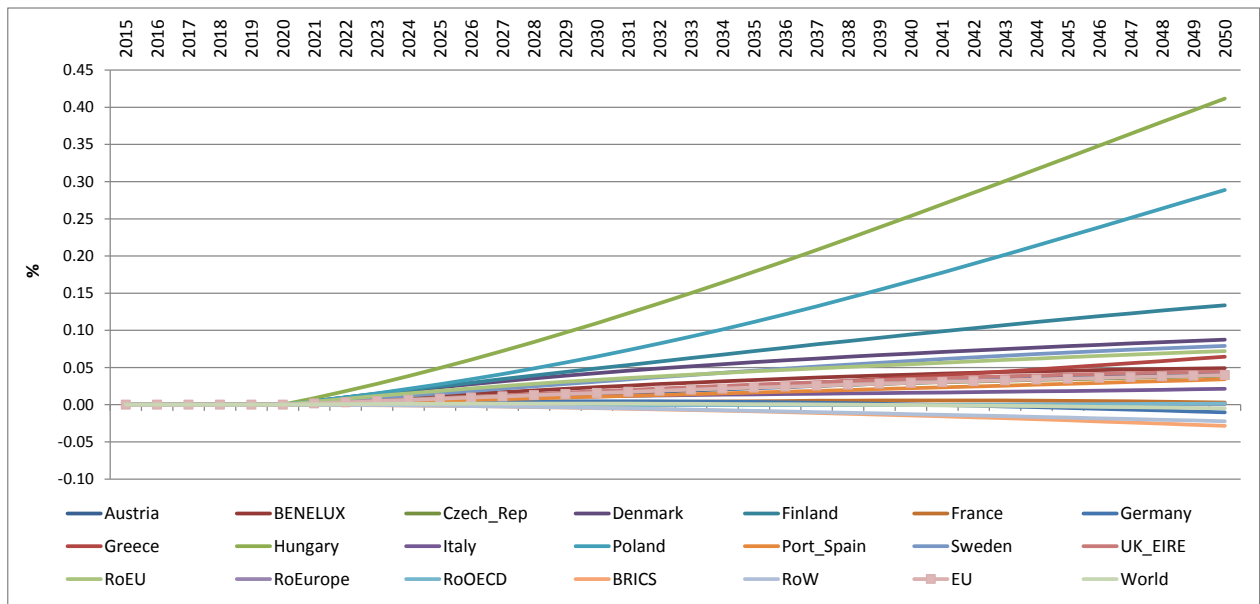
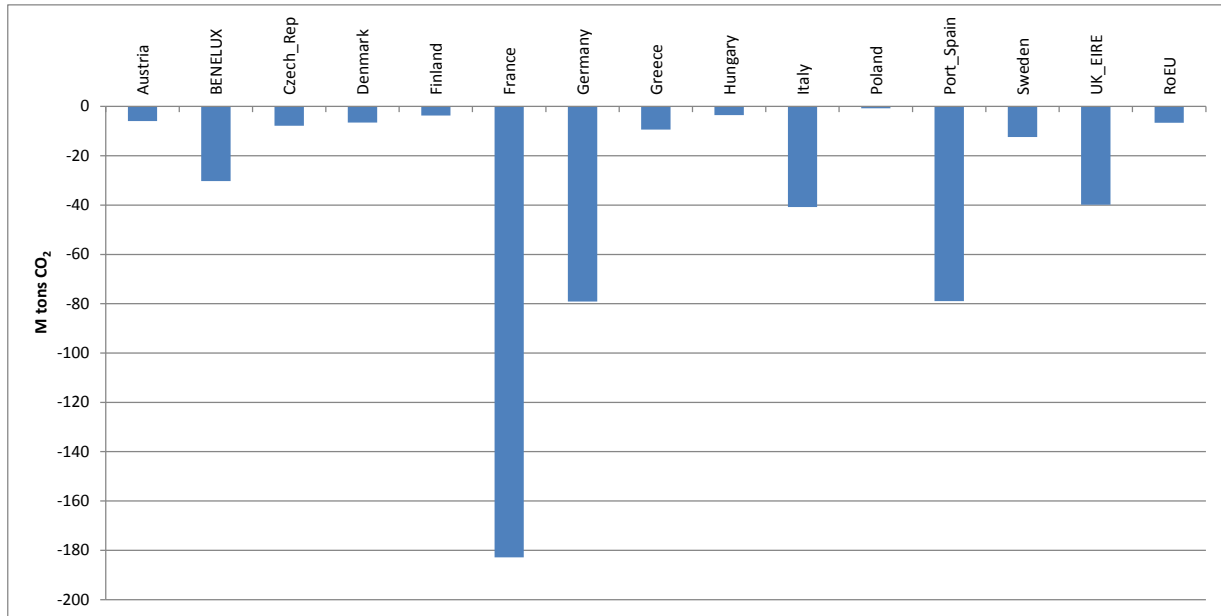


Table 14 Information Campaign (ICES). Sectoral output: % change with respect to ‘no campaign’ in the reference scenario (2050).

	Austria	BENELUX	Czech_Rep	Denmark	Finland	France	Germany	Greece	Hungary	Italy	Poland	Port_Spain	Sweden	UK_EIRE	RoEU	RoEurope	RoOECD	BRICS	RoW
Agriculture	0.54	0.64	0.71	0.82	0.63	0.54	0.67	0.27	1.29	0.84	1.18	0.48	0.61	1.15	1.17	0.12	0.10	0.07	0.09
Livestock	-4.33	-4.32	-6.14	-2.63	-4.14	-6.72	-4.26	-5.49	-6.74	-4.10	-6.34	-5.04	-6.25	-3.51	-3.38	-1.41	-0.56	-0.12	-0.27
Timber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fishing	0.02	0.05	0.03	0.04	0.02	0.04	0.02	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.02	0.01	0.02	0.01	0.01
Coal	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	-0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas	-0.10	0.02	-0.57	0.03	-0.33	-0.47	-0.09	0.09	0.52	0.15	0.44	0.07	0.07	-0.03	0.18	-0.02	-0.01	-0.01	-0.01
Oil_Pcts	-0.06	-0.17	-0.12	-0.13	-0.14	-0.13	-0.30	0.10	0.36	0.10	0.48	0.03	-0.10	-0.11	0.29	0.05	0.04	-0.02	-0.01
Ely	-0.04	0.04	0.02	-0.07	0.01	-0.13	0.02	0.01	0.29	0.04	0.07	-0.02	-0.03	0.03	0.26	-0.02	-0.01	-0.03	-0.01
Other_Min	0.01	0.01	0.03	0.04	0.05	0.01	0.04	-0.03	0.17	0.00	-0.07	-0.01	0.02	0.01	0.02	0.00	0.00	0.00	0.00
Meat_Ind	-13.86	-9.67	-12.06	-8.96	-16.99	-15.99	-13.39	-8.51	-16.78	-6.42	-10.07	-9.16	-15.16	-13.54	-4.92	-1.25	-0.65	-0.50	-0.69
Food_Ind	2.14	4.10	2.51	4.92	2.42	4.25	5.19	1.96	5.25	1.99	2.09	2.27	3.02	3.40	2.24	-0.62	0.12	0.08	0.06
Chem_Ind	-0.10	0.30	0.19	0.32	0.26	-0.06	0.21	-0.18	0.29	0.01	-0.44	-0.14	0.17	0.07	0.20	0.00	-0.03	0.03	-0.05
Iron_Steel	-0.05	0.25	0.08	0.51	0.27	-0.07	0.23	-0.27	0.11	-0.07	-0.78	-0.15	0.15	0.00	0.07	-0.03	-0.05	0.00	0.01
Non_Fer_Met	0.00	0.28	0.08	0.64	0.24	-0.06	0.29	-0.26	0.03	-0.05	-1.06	-0.16	0.16	0.04	0.09	-0.01	-0.07	0.01	0.00
Non_Met_Min	-0.02	0.10	0.09	0.19	0.17	0.00	0.05	0.01	0.36	0.02	-0.17	0.02	0.11	0.12	0.20	-0.01	0.00	-0.01	0.00
Cons_Ind	0.04	0.01	0.02	0.04	0.06	-0.01	-0.05	0.10	0.49	0.01	0.39	0.05	0.06	0.02	0.10	0.02	0.02	-0.04	-0.01
Other_Ind	-0.01	0.17	0.05	0.34	0.26	-0.12	0.08	-0.31	0.03	-0.09	-0.40	-0.10	0.13	-0.05	0.18	-0.06	-0.04	0.01	0.00
MarketServ	-0.12	-0.19	-0.13	-0.14	-0.19	-0.17	-0.26	0.03	0.44	0.06	0.32	-0.03	-0.09	-0.17	0.39	0.02	0.01	-0.08	-0.02
PublicServ	-0.05	-0.16	-0.11	-0.11	-0.11	-0.13	-0.23	0.16	0.44	0.07	0.21	0.05	-0.10	-0.11	0.18	0.04	0.02	0.01	0.01

Note: In red the sectors primarily affected

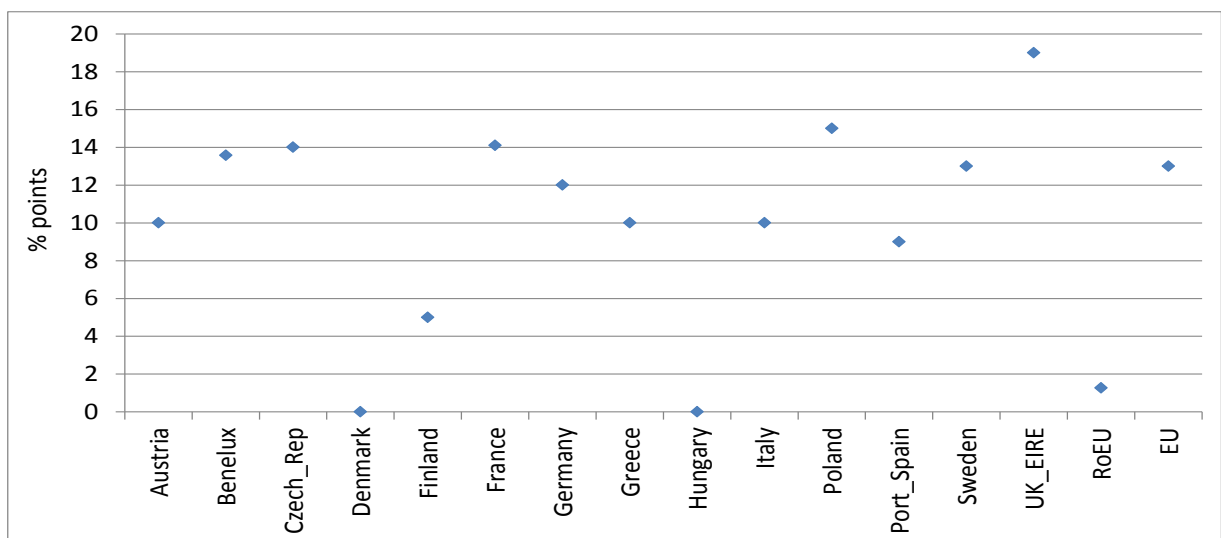
Figure 14 Information Campaign (ICES). Change of GHG emissions (CO₂, N₂O and CH₄) with respect to 'no campaign' in Million tons of CO₂ equivalent (over the period 2020-2050).



4.2.4 VAT on Meat

This policy addresses meat consumption and consists in harmonizing national VAT on meat products to the country average. Figure 15 summarizes the consequent change in meat VAT needed in each country.

Figure 15 VAT on Meat (ICES). Gap between current level of VAT on Meat and current average VAT rate in EU countries (percentage points).



Effects on the sectors directly targeted by the policy are not negligible (Figure 16). The contraction in livestock and meat industry production in 2020 is 3% and 6% respectively at the

EU level. It is also generalized across all EU countries, including Hungary and Denmark that in principle do not need to raise their VAT on meat products as it is already equalized to the national average. The effects on the non-meat food industry are mixed. It expands, as expected, in the majority of EU countries with a maximum of 0.7% in Denmark, but it contracts in countries like UK and Ireland, France and Poland. Indeed, also non-meat food industry uses some intermediates from the meat industry and these, in becoming more costly, increase the production costs of food. In the long term, the shift towards non-meat products benefits agricultural activity.

A glance at the overall sectoral production (Table 15) shows that the remaining sectors of the economy are negatively affected by the higher VAT, albeit with tiny impacts.

As in the case of chemicals for agricultural use, the policy is addressing sectors whose share of total value added is limited (livestock and meat industry together account for 0.75% of value added in the EU). Accordingly, the final impact on overall economic activity summarized by GDP variation is small: a loss of 0.05% at the EU level in 2050 (

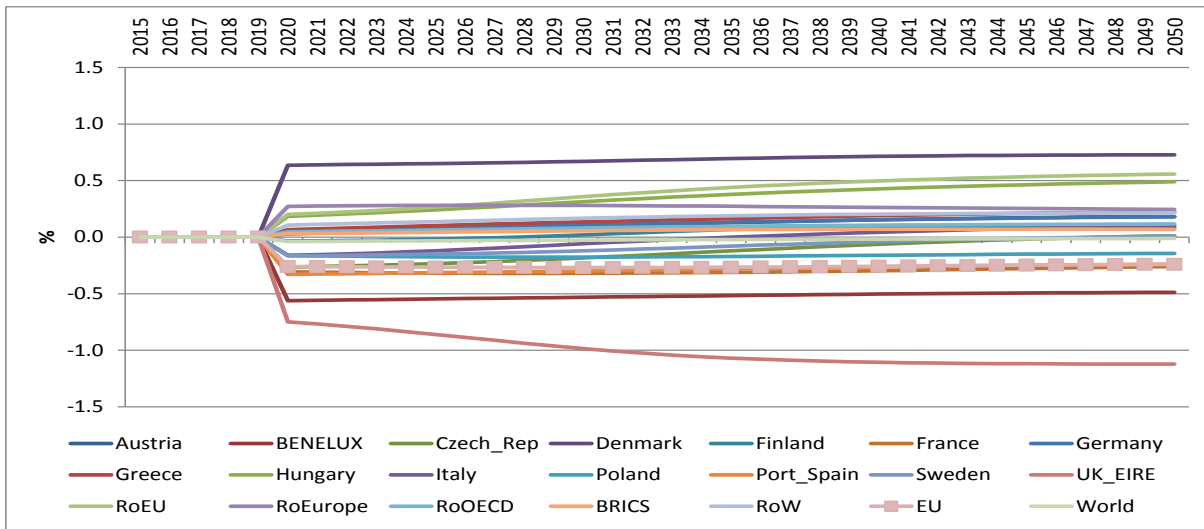


Figure 17). Significant differences can be highlighted at the country level. Poland is the worst-off country with a GDP loss of roughly 0.2% in 2050. This is due to the higher economic relevance in the national economy of the impacted sectors, and to their higher orientation to export compared to other EU countries. On the contrary, Denmark and Hungary, are slightly benefited by the policy. The latter indeed increases their international competitiveness as, in contrast to other EU countries, their production systems are not burdened by an increase in taxation consequent on implementation of the policy.

Figure 16 VAT on Meat (ICES). Output: % change with respect to ‘no policy’ in the reference scenario (Livestock: top; Meat Industry: middle; Agriculture: bottom).

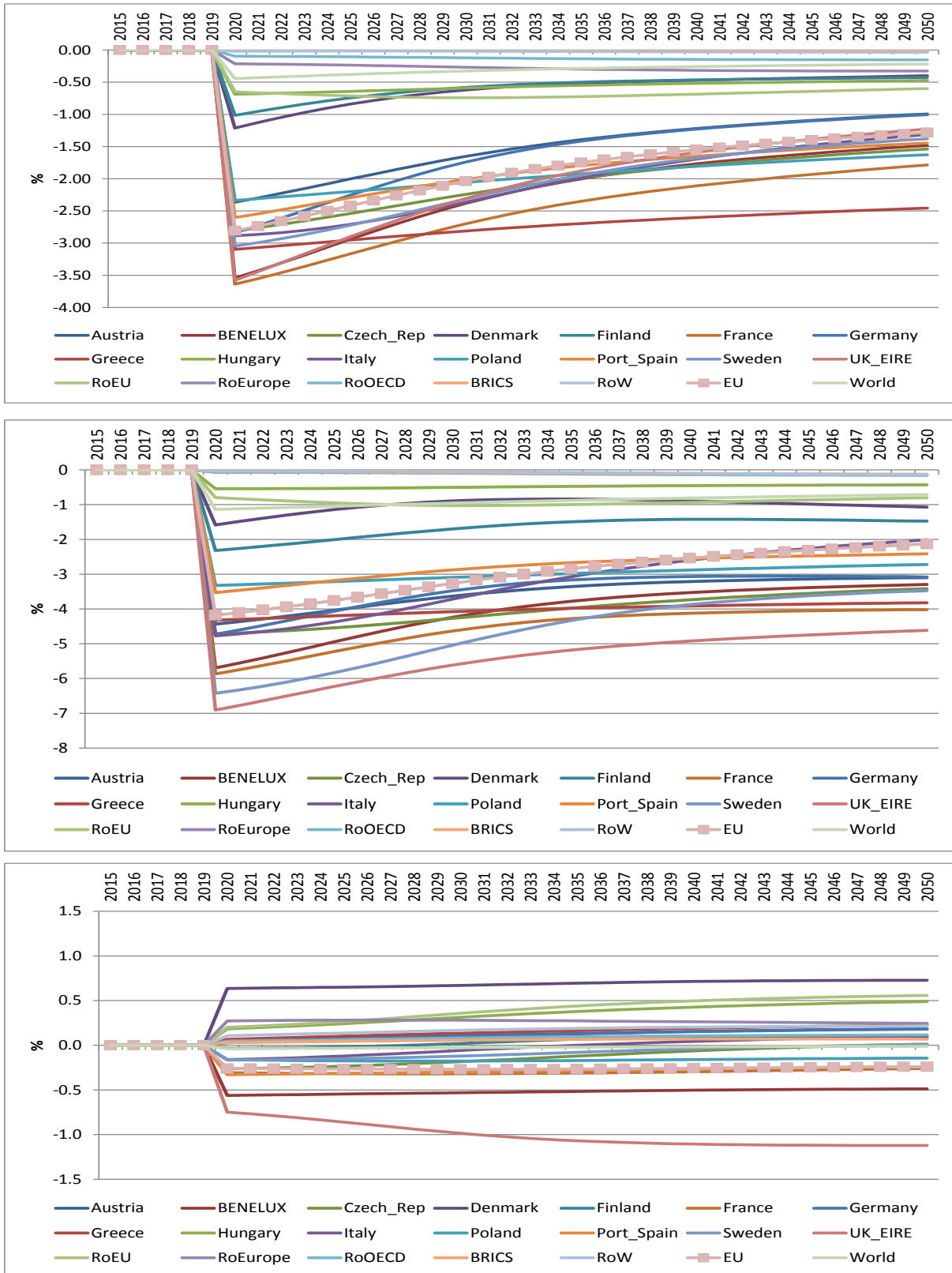


Figure 17 VAT on Meat (ICES). GDP: % change with respect to the ‘no policy’ case in the reference scenario

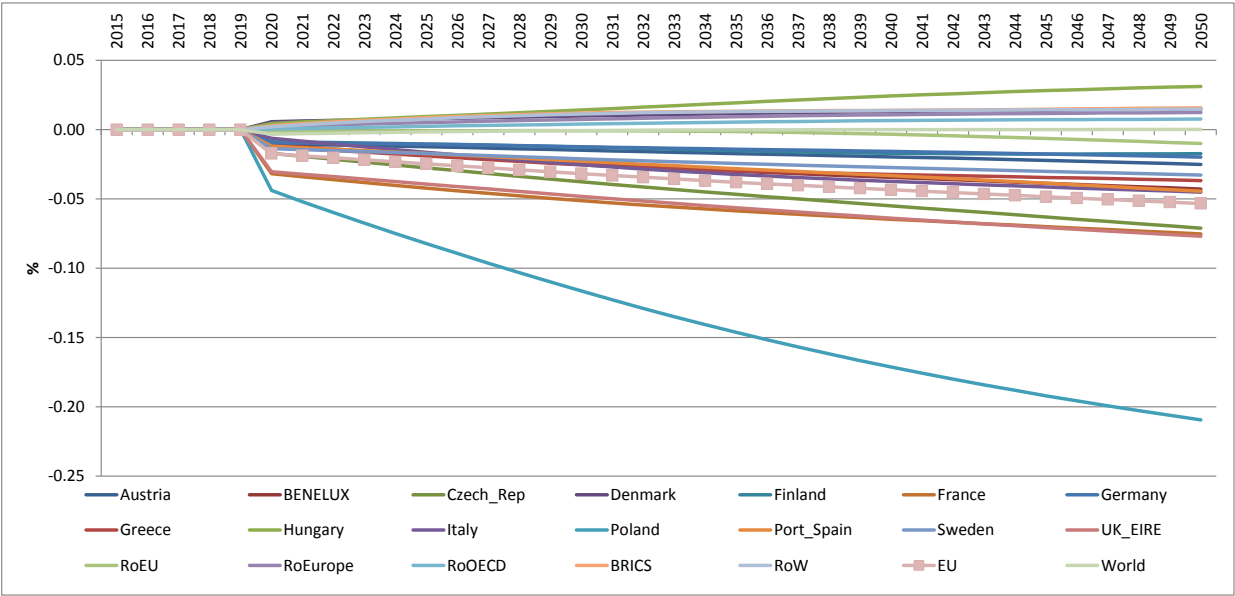


Table 15 VAT on Meat (ICES). Sectoral output: % change with respect to the ‘no policy’ in 2050 in the reference scenario.

	Austria	BENELUX	Czech_Rep	Denmark	Finland	France	Germany	Greece	Hungary	Italy	Poland	Port_Spain	Sweden	UK_EIRE	RoEU	RoEurope	RoOECD	BRICS	RoW
Agriculture	0.044	0.134	0.122	0.063	0.011	0.046	0.067	0.020	0.058	0.162	0.249	0.054	0.060	0.219	0.171	-0.008	0.006	-0.003	-0.005
Livestock	-1.029	-1.530	-1.581	-0.412	-0.434	-1.841	-1.041	-2.482	-0.481	-1.374	-1.658	-1.480	-1.425	-1.286	-0.616	-0.327	-0.153	-0.012	-0.035
Timber	0.002	0.003	0.002	0.002	0.002	0.003	0.002	0.003	0.003	0.002	0.001	0.002	0.003	0.003	0.005	0.003	0.002	0.002	0.001
Fishing	-0.001	-0.004	-0.002	-0.003	0.000	-0.004	-0.002	-0.004	-0.002	-0.002	-0.006	-0.002	-0.002	-0.007	0.002	0.000	0.002	0.001	0.002
Coal	-0.001	0.001	-0.001	0.000	-0.001	-0.001	-0.001	0.000	0.000	-0.001	-0.003	0.002	0.000	0.001	0.003	0.000	0.000	0.000	0.000
Oil	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	-0.004	0.001	0.000	0.001	0.003	0.000	0.000	0.000	0.000
Gas	-0.004	0.004	0.071	0.006	0.016	0.094	-0.005	0.039	-0.029	0.053	-0.015	-0.005	0.010	0.007	0.024	0.001	0.007	0.004	0.005
Oil Pcts	0.012	-0.020	-0.007	-0.001	-0.003	-0.032	0.012	0.028	0.002	0.018	-0.069	-0.025	-0.001	-0.005	-0.022	0.006	-0.003	0.000	0.008
Ely	-0.009	-0.022	-0.021	0.000	-0.045	-0.011	-0.008	0.004	0.013	-0.023	-0.136	-0.006	-0.011	-0.012	0.038	0.019	0.012	0.012	0.014
Other_Min	0.004	0.005	-0.008	0.022	-0.001	-0.006	0.006	-0.001	0.040	-0.002	-0.039	0.010	0.007	0.009	0.045	0.006	0.008	0.002	0.004
Meat_Ind	-3.111	-3.329	-3.465	-1.035	-1.459	-4.028	-3.066	-3.835	-0.434	-2.102	-2.747	-2.438	-3.522	-4.664	-0.826	-0.145	-0.153	-0.125	-0.133
Food_Ind	0.180	-0.490	0.002	0.727	0.084	-0.266	0.176	0.219	0.480	0.093	-0.146	-0.243	0.003	-1.122	0.550	0.248	0.115	0.070	0.214
Chem_Ind	-0.028	0.067	-0.028	0.081	-0.066	-0.012	-0.059	-0.066	0.040	-0.044	-0.226	0.041	-0.050	0.129	0.131	0.009	0.007	-0.009	0.018
Iron_Steel	-0.011	0.069	-0.017	0.065	-0.073	0.008	-0.025	-0.074	0.042	-0.034	-0.257	0.039	-0.007	0.112	0.128	0.021	0.021	0.000	0.025
Non_Fer_Met	0.059	0.081	0.022	0.140	-0.025	0.054	0.029	-0.033	0.081	-0.023	-0.244	0.082	0.044	0.158	0.140	0.086	0.025	-0.001	0.002
Non_Met_Min	-0.014	-0.017	-0.019	0.038	-0.026	-0.048	-0.012	-0.015	0.048	-0.034	-0.227	-0.014	-0.019	-0.045	0.074	0.021	0.019	0.010	0.006
Cons_Ind	-0.008	-0.037	-0.047	0.027	-0.009	-0.051	0.003	-0.008	0.046	-0.018	-0.196	-0.027	-0.019	-0.056	-0.009	0.021	0.015	0.019	0.016
Other_Ind	-0.084	0.063	-0.068	0.057	-0.157	-0.022	-0.020	-0.026	0.034	-0.010	-0.332	0.018	-0.095	0.084	0.081	0.006	0.011	0.012	-0.007
MarketServ	0.001	-0.018	-0.012	0.012	-0.001	-0.016	0.012	0.018	0.021	0.019	-0.183	0.003	0.001	0.008	0.017	0.011	0.005	0.021	0.022
PublicServ	0.057	0.050	0.137	-0.025	0.046	0.089	0.034	0.157	-0.020	0.106	0.370	0.077	0.068	0.097	-0.007	0.000	-0.002	0.005	0.005

Note: In red the sectors primarily affected

4.2.5 Circular Economy Tax Trio

As it is modelled in ICES, the policy penalizes primarily the purchases of virgin materials ('other mining' in the ICES model) by the non-metallic minerals transformation sectors. Furthermore, non-metallic minerals exports outside the EU are also taxed. The rationale of the policy is thus to foster de-materialization curbing overall material uses by the EU transformation industry. Figure 18 reports impacts on the production of the sectors more directly affected. Non-metallic mineral output contraction in the EU is acute: a roughly constant -10% since 2018, the year of the implementation of the policy. In 2050 it ranges between the -33% in the Czech Republic and -3% in UK-Eire. The policy hits more indirectly, but still detectably, "other mining" that sources its output to the non-metallic mineral transformation industry (-2.5% at the EU level in 2018) and the building and construction sector which is sourced by it (-0.5% at the EU level in 2018). These two sectors have anyway an important "safety valve" compared to the non-metallic mineral transformation sector. They are indeed free to compensate with exports to, or imports from, non-EU markets the EU lack of demand for their output or supply of their inputs. The international trade mechanisms at play are also highlighted by the increased activity in non-EU, mining, non-metallic mineral, and building and construction sectors which fill the EU production gap. Note that the expansion of the second allows the EU construction sector to substitute non-EU, non-taxed input for the EU taxed input; that of the third enables the EU mining sector to increase that part of its production sourced outside the EU.

The overall effects on GDP of the tax on extracted materials are negative and increasing, but remain moderate: they peak for the EU as a whole to -0.32% in 2050 with a minimum loss of 0.15% in UK-Eire and a maximum loss of 1.47% in the Czech Republic (Figure 19).

Table 16 reports the complete sectoral picture in 2050. The most notable outcome is the small, but detectable decrease in the use of energy products which is directly linked to the decrease in energy-intensive mining, non-metallic transformation, and building and construction activity.

Figure 18 Circular Economy Tax Trio (ICES). Output: % change with respect to ‘no policy’ in the reference scenario (Non-metallic mineral transformation sector: top; Mining sector: middle; building and construction industry: bottom).

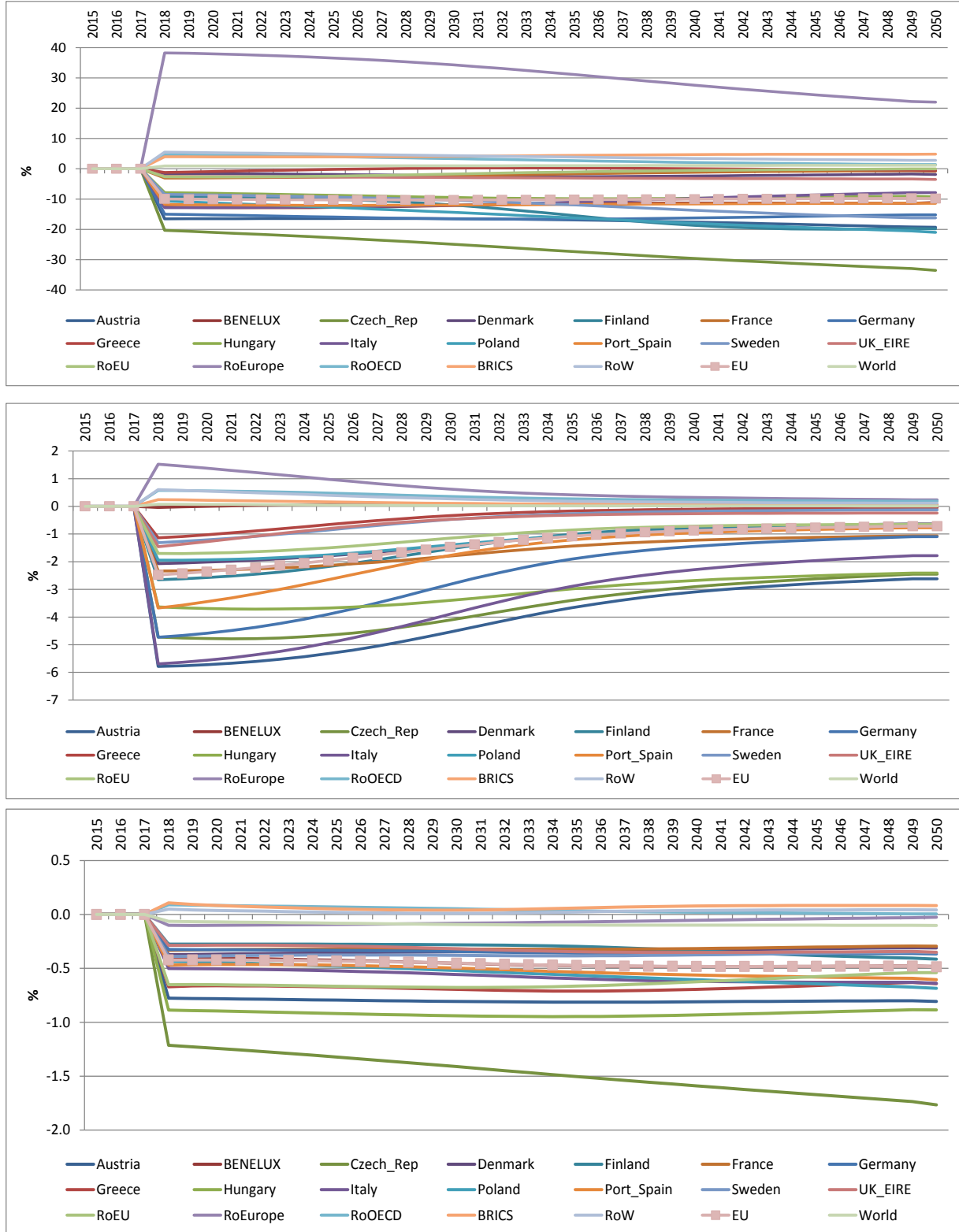


Figure 19. Circular Economy Tax Trio (ICES). GDP: % change with respect to 'no policy' in the reference scenario.

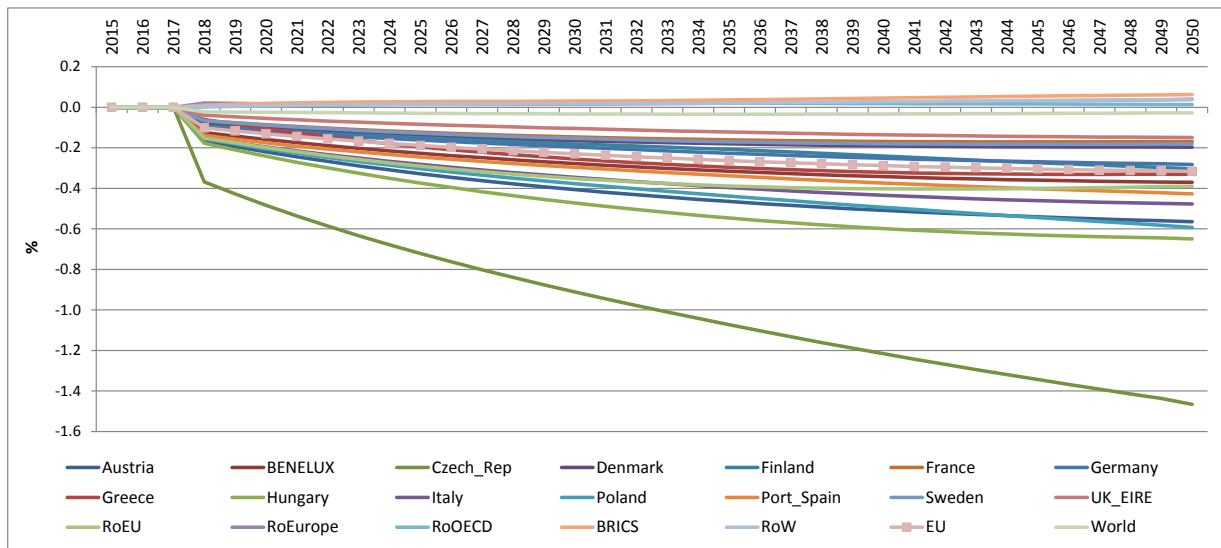


Table 16 Circular Economy Tax Trio (ICES). Sectoral output: % change with respect to ‘no policy’ in 2050 in the reference scenario.

	Austria	BENELUX	Czech_Rep	Denmark	Finland	France	Germany	Greece	Hungary	Italy	Poland	Port_Spain	Sweden	UK_EIRE	RoEU	RoEurope	RoOECD	BRICS	RoW
Agriculture	0.09	0.03	0.15	0.00	0.10	0.00	0.03	0.00	0.03	0.04	0.12	0.06	0.01	0.01	0.01	-0.02	-0.01	-0.01	-0.01
Livestock	-0.04	0.01	-0.13	0.02	-0.14	-0.04	0.01	-0.09	-0.01	0.01	-0.18	0.02	-0.01	-0.03	-0.03	-0.08	-0.01	0.00	0.01
Timber	0.00	0.00	0.02	0.00	0.00	-0.01	0.00	-0.01	0.00	0.00	0.01	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	0.00
Fishing	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coal	-0.02	0.00	0.00	0.01	0.01	0.02	-0.01	0.00	-0.02	0.00	0.01	0.02	-0.01	0.01	0.00	0.00	0.01	0.01	0.01
Oil	0.01	0.00	0.02	0.00	0.01	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas	-0.24	-0.09	-0.38	-0.09	-0.26	-0.19	-0.31	-0.31	-0.40	-0.93	-1.30	-1.79	-1.18	-0.16	-0.32	-0.13	0.01	-0.02	-0.02
Oil_Pcts	-0.73	-0.25	-1.54	-0.11	-0.49	-0.20	-0.41	-0.24	-0.64	-0.67	-0.63	-0.86	-0.27	-0.15	-0.36	0.19	0.03	0.07	0.04
Ely	-0.40	-0.29	-0.23	-0.20	-0.20	-0.24	-0.35	-0.25	-0.58	-0.66	-0.25	-0.75	-0.30	-0.24	-0.46	0.04	0.02	0.14	0.05
Other_Min	-2.34	0.04	-2.18	-0.57	-0.62	-0.95	-0.93	-0.04	-2.18	-1.60	-0.64	-0.69	-0.11	-0.23	-0.57	0.21	0.17	0.04	0.10
Meat_Ind	0.20	0.03	0.29	0.02	0.00	-0.01	0.10	-0.07	0.13	0.06	-0.24	0.06	0.09	0.04	-0.02	-0.22	-0.02	-0.03	-0.01
Food_Ind	0.55	0.06	0.81	-0.04	0.49	-0.11	0.17	-0.19	-0.05	0.03	0.69	0.30	-0.05	-0.05	-0.32	-0.37	-0.04	-0.03	-0.06
Chem_Ind	1.08	0.16	1.86	-0.06	0.95	-0.09	0.48	-0.51	-0.10	0.02	0.90	0.83	0.01	0.00	-0.50	-1.07	-0.07	0.02	-0.13
Iron_Steel	1.86	0.62	4.23	0.80	1.66	0.80	1.56	-0.10	0.50	1.14	2.08	2.57	1.11	0.62	0.08	-0.39	0.15	-0.43	0.33
Non_Fer_Met	5.02	2.36	8.78	2.67	5.26	3.48	4.87	1.63	3.19	3.62	5.72	7.18	3.74	3.30	1.38	1.93	0.15	-0.69	-0.67
Non_Met_Min	-19.32	-11.10	-33.57	-1.90	-19.81	-0.77	-15.22	-0.57	-9.28	-7.86	-20.98	-11.42	-16.22	-3.50	-0.04	21.99	1.39	4.85	2.80
Cons_Ind	-0.81	-0.48	-1.77	-0.31	-0.41	-0.29	-0.37	-0.64	-0.89	-0.64	-0.69	-0.60	-0.35	-0.35	-0.54	-0.02	0.00	0.08	0.04
Other_Ind	0.69	0.00	1.40	-0.20	0.61	-0.10	0.38	-0.68	-0.11	0.07	0.84	0.46	0.18	-0.09	-0.34	-0.76	-0.09	-0.12	0.00
MarketServ	-0.20	-0.15	-0.52	-0.10	-0.04	-0.15	-0.11	-0.31	-0.46	-0.32	-0.24	-0.16	-0.12	-0.12	-0.34	-0.08	0.01	0.01	-0.01
PublicServ	-0.06	-0.05	-0.38	-0.03	-0.01	-0.06	-0.08	-0.03	-0.26	-0.17	0.00	0.00	-0.03	-0.04	-0.13	-0.07	0.01	-0.04	-0.01

Note: In red the sectors primarily affected

4.2.6 Cornerstones Analysis

To provide a more complete understanding of the resource efficiency policies conceived within the DYNAMIX project, the ICES model performed a multi-scenario assessment. The objective of the exercise was to analyze to which extent socio-economic drivers can alter effectiveness and cost of the policies already evaluated in the reference scenario.

To this purpose, we built the four additional cornerstones scenarios described in Section 3.1 using the assumptions reported in Table 3.

More specifically, changes in TFP are assumed to be uniform across all EU countries / macro-regions, considered in the ICES model; population trends are country specific as in the reference they are already diversified.

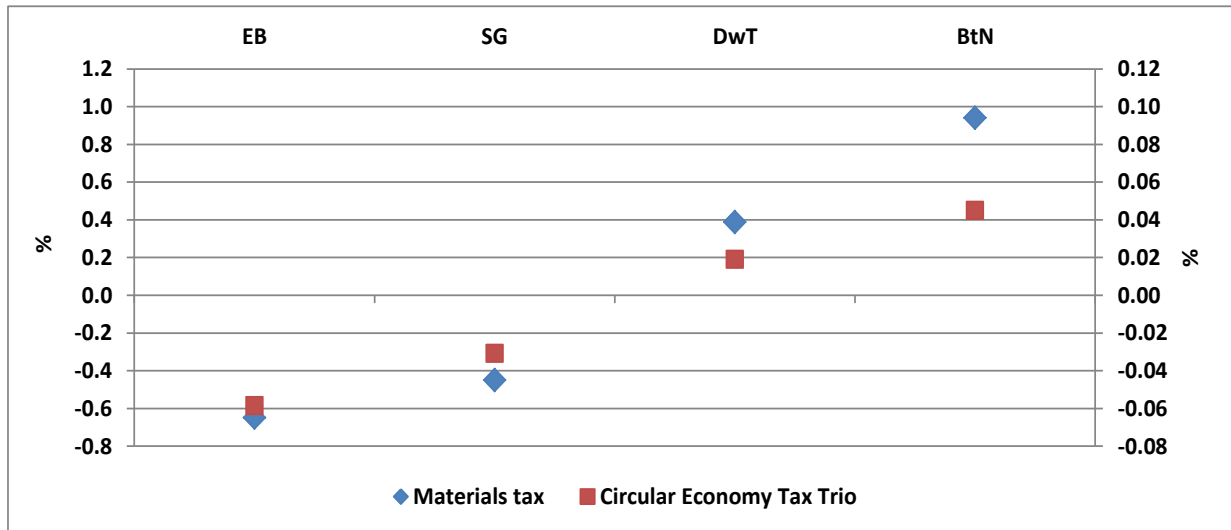
The two drivers have different implications on the endogenous growth mechanism in ICES:

- TFP influences the supply side since it implies faster / slower technological progress.
- Population influences both the demand and the supply side. The former, since it implies higher / lower demand for commodities and services. The latter, as it also determines changes in labor supply.

The scenario analysis is then conducted over a subset of all the policies: the Materials Tax, the Circular Economy Tax Trio and the Vat on Meat.

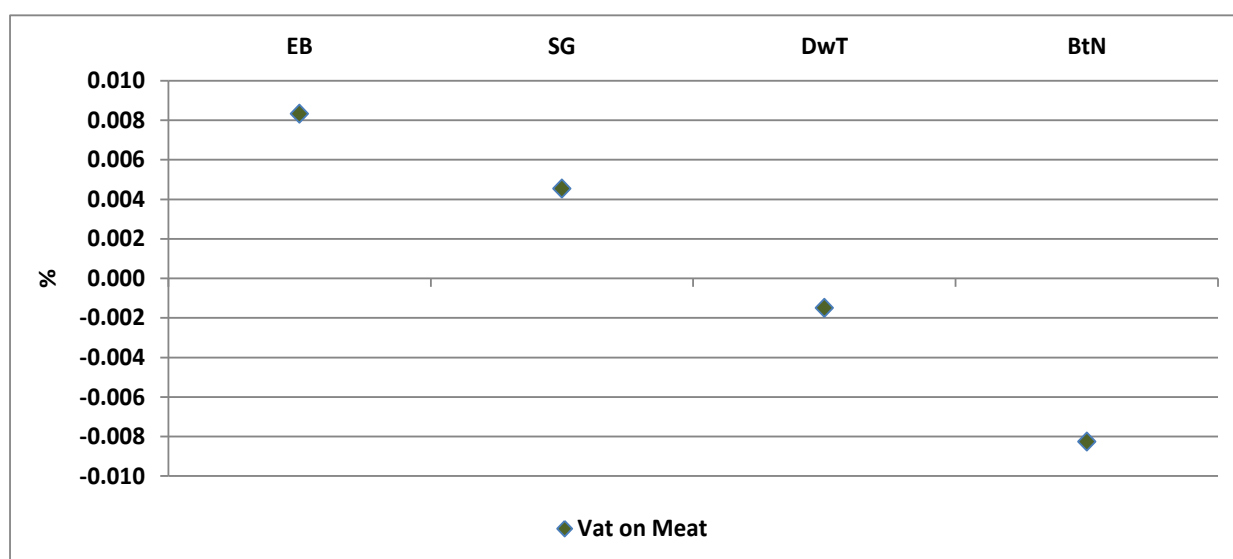
Figure 20 reports the GDP performance of the two policies addressing the industrial sector (Materials Tax and Circular Economy Tax Trio) in % deviation from the corresponding reference scenario. It can be immediately grasped that scenarios characterized by higher technological progress (EB and BtN) also feature higher GDP policy costs. This is the direct consequence of two facts: firstly, when technological progress is higher the model tends to expand the size of the industrial sectors. Accordingly, compared to the reference case, the tax policies are hitting a relatively more important section of the economy with a stronger depressing effect. Secondly, in the ICES model technological progress is exogenous. Therefore, even when it is higher, it does not react to the policy. In other words, the model cannot capture the fact that a better technology may also imply an easier shift toward dematerialization. It is worth noting however that dematerialization is higher if compared with the reference. The opposite occurs in the lower technological development scenarios (DwT and BtN).

Figure 20 Cornerstones Analysis for Materials Tax and Circular Economy Tax Trio (ICES). GDP % deviation with respect to the central scenario.



The same mechanism, but with opposite outcomes, applies to the Vat on Meat policy that affects the EU agricultural sector. In this case, the GDP loss is lower for the most technology-advanced scenarios, as in this case, the value added share of agriculture shrinks. Vice versa, GDP reduction is larger in DwT and BtN as the low rate of development increases the relevance of agriculture in the EU system (agriculture also benefits by the increase in TFP but to a lower extent than the industrial and service sectors). Overall, the magnitude of deviations is much smaller than in previous policies since it affects a much more limited part of the economic system.

Figure 21 Cornerstones Analysis for VAT on Meat (ICES). GDP % deviation with respect to the central scenario.



4.3 MEMO II

4.3.1 Green Fiscal Reform: Materials Tax

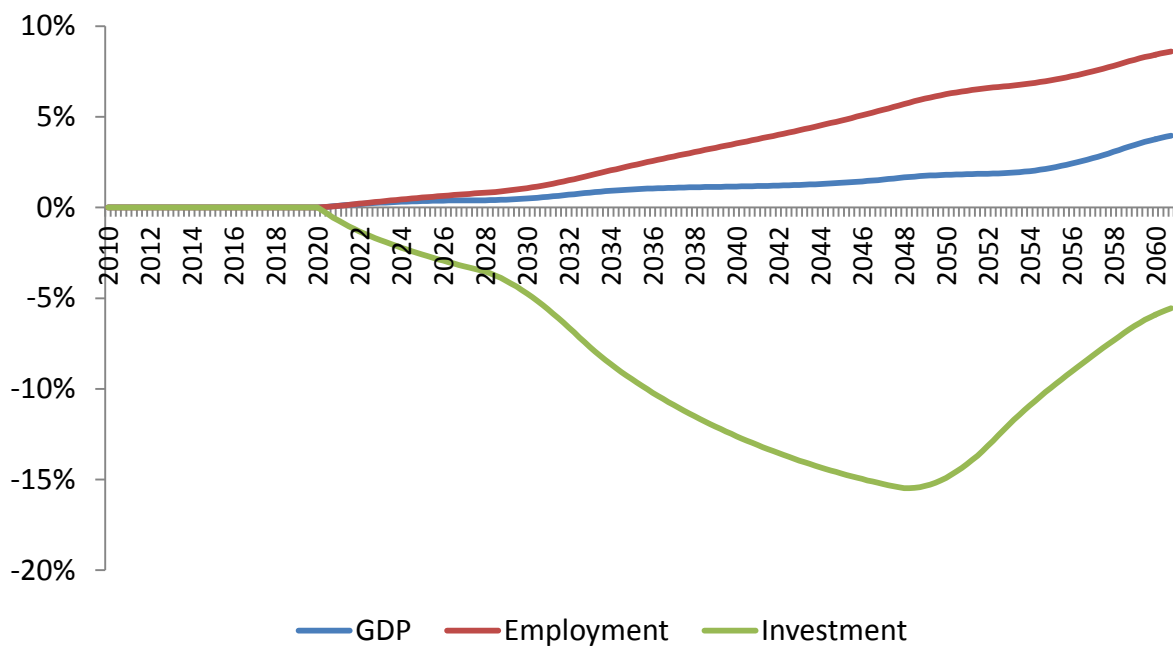
The materials tax policy is modelled as a tax on the purchase of Raw Materials in the production process of Manufacturing and Construction sectors. This production chain can be split into two parts. In the first the following flows are taxed: the purchase of wood, fuels, metal and other by all manufacturing sectors and construction. In the second the purchase of materials manufacturing (chemical, metal and non-metallic mineral) by manufacturing and construction sector, less the tax paid by the materials manufacturing sectors when purchasing their raw materials. The tax is introduced in 2020 and rises linearly from 0% to 30% in 2030, after which the tax increases at linearly at a faster rate to reach 200% in 2050. In order to be consistent with the simulation of environmental taxes and fees, we also assume that 50% of the revenue is used to reduce labour taxation.

Figure 22 shows the impact of the materials tax policy on main macroeconomic indicators. When the tax reaches its final level in 2050, GDP is expected to be approximately 1.9% above the baseline scenario. The implementation of the tax will cause a drop in investment, which will peak at around -15% in 2050, however once the tax level is constant investment can be expected to slowly rebound. The increase in employment of approximately 6.2% in 2050 is mainly brought about by the reduction of labour taxes – simulation experiments show

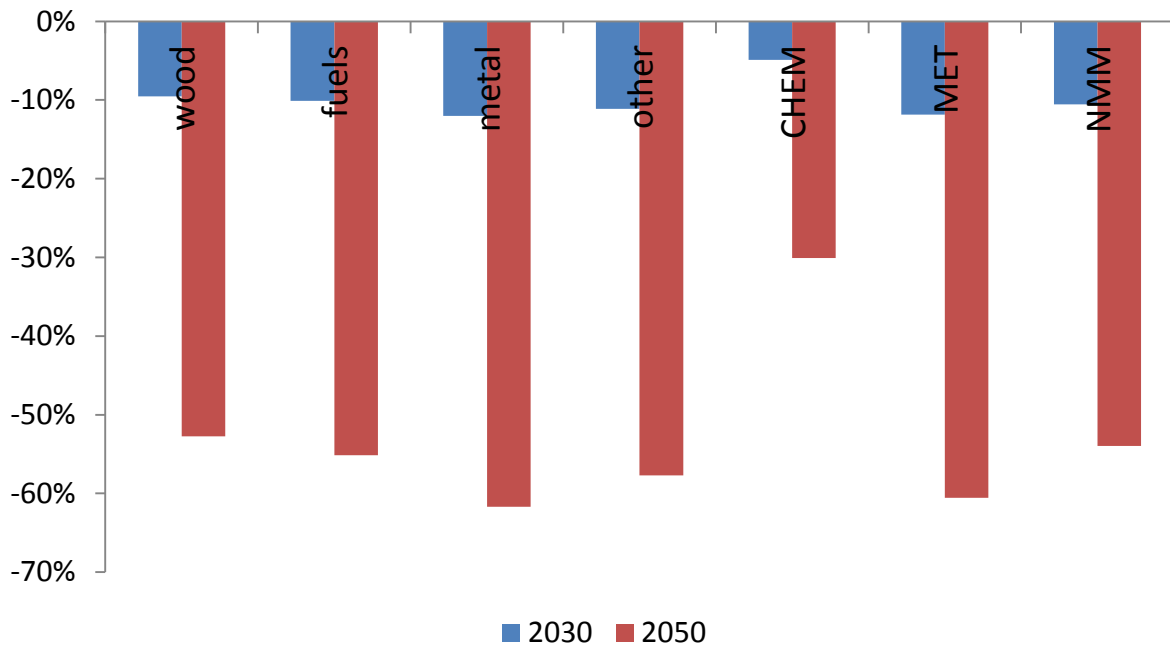
that, under the assumption of standard lump sum closure¹⁰, employment is expected to decrease. The maximum revenue from the tax, calculated as the tax base multiplied by the target tax rate is approximately 10.7% of GDP, which is slightly more than in the case of environmental taxes and fees policy.

Figure 23 shows the impact that the materials tax is expected to have on material use in the economy. The figure shows the results for the variables representing the physical volume of output of the material-intensive sectors. The initial introduction and small increase of the tax until 2030 will not have a huge impact on the reduction of material use – it is expected to drop between 5% for the manufacturing of chemical materials, up to 12% for the mining of metals. However, the full implementation of this policy has the potential to reduce material use by a large margin, going a long way in reaching the assumed target of an 80% reduction in resource use. The reductions in raw materials output is between 53% and 63%, whereas for the manufacturing of basic materials is 30%, 54% and 61% for chemical, non-metallic mineral and metal products respectively.

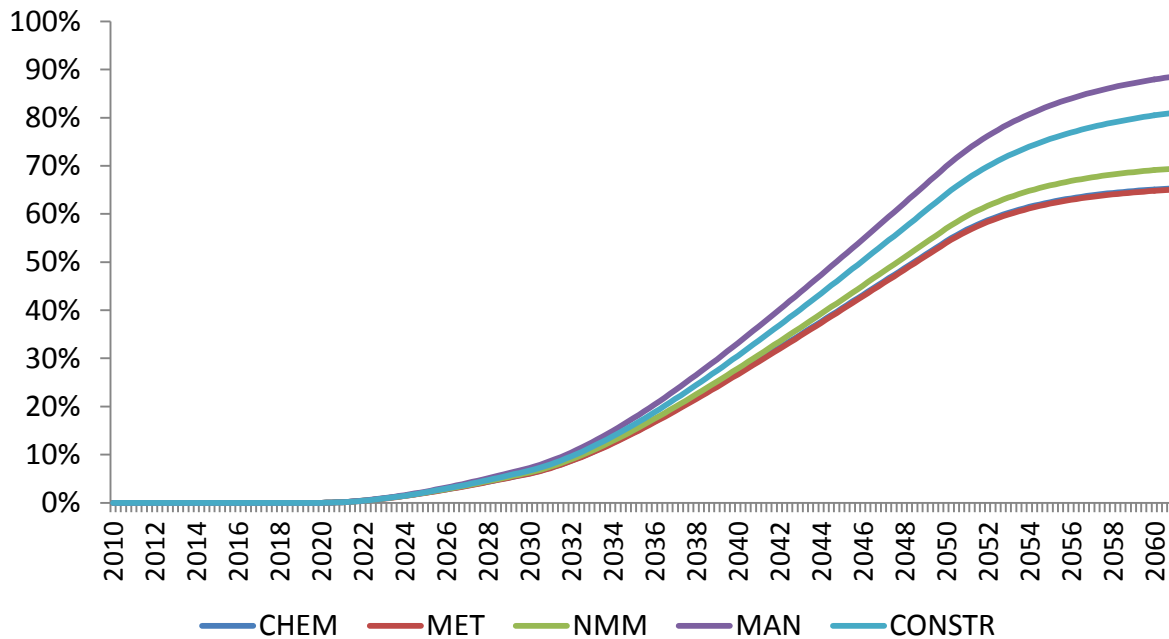
Figure 22 Materials Tax (MEMO II). Change in main macroeconomic variables.



¹⁰ This means that tax revenues are given to households, increasing their disposable income.

Figure 23 Materials Tax (MEMO II). Effect on use of materials by material type.

In order to understand the differences between the results of the materials tax and the environmental taxes and fees it is necessary to analyze the impact on the material efficiency of the respective sectors, which is shown in Figure 24. It turns out that the materials tax induces additional investment in more resource efficient technologies, which coupled with the reduction of labour taxes, results in more optimistic paths for macroeconomic indicators. The investments in material efficiency also allow for a greater reduction in resource use, without bringing about a reduction in GDP. The material efficiency shown in this figure is the endogenous technology variable EFF_t^s , and not to the overall economy-wide material efficiency defined as the ratio of GDP to volume of material use. The latter is a more general indicator, as it also takes into account overall sector shifts in the economy and substitution between various factors of production.

Figure 24 Materials Tax (MEMO II). Effect on material efficiency.

4.3.2 Green Fiscal Reform: Internalization of External Environmental Costs

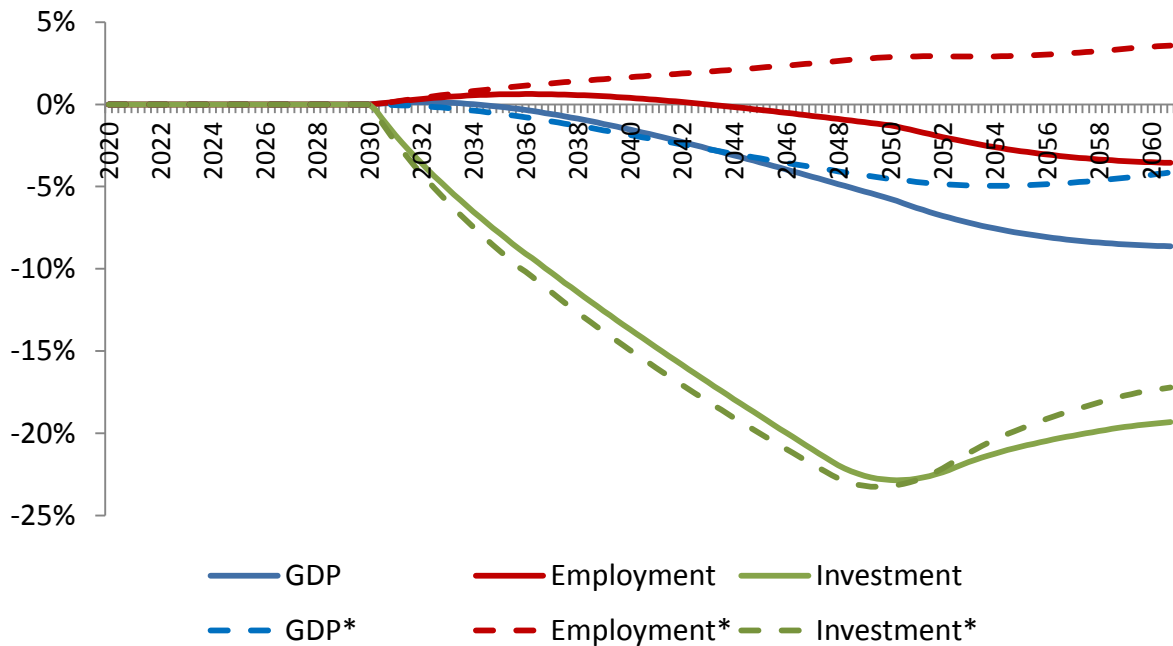
This policy is modelled as an excise tax proportional to the value added of the following sectors: Agriculture, Mining, all the Industry sectors, Energy and Construction. We conduct two simulations: one in which we assume a maximum flat tax rate of 35% on all the sectors and another in which the tax rate is differentiated across sectors with respect to sector-specific externalities (the tax rates are the same as in WISE specification). Moreover, we assume that 50% of the revenues from the tax are spent on decreasing taxes on labour. For the remainder of the tax proceeds, we assume the standard budget closure through lump sum transfers to the household. In both cases the taxes are introduced in 2030 increasing linearly to reach target rate in 2050.

As can be seen from Figure 25, both versions of the environmental tax have a negative impact on GDP, reaching approximately -5.8% and -4.5% in 2050 for the flat rate and differentiated cases respectively. In both simulations the maximum revenue from the tax, calculated as the tax base multiplied by the target tax rate is approximately 8.5% of GDP. The decrease in investment is even more pronounced and reaches approximately 22% in 2050 for both cases and reverses afterwards. It has to be stressed that the general macroeconomic slowdown would be much more severe without the assumption on the recycling of the revenue to decrease labour taxation. This decrease mitigates the reduction of employment which would take place if the standard lump sum fiscal closure was assumed, and in case of

the differentiated tax rate even increases overall employment. The difference in the responses of employment between the two simulations mainly result from the fact of using a smaller differentiated tax rate for the labour-intensive construction and manufacturing sectors.

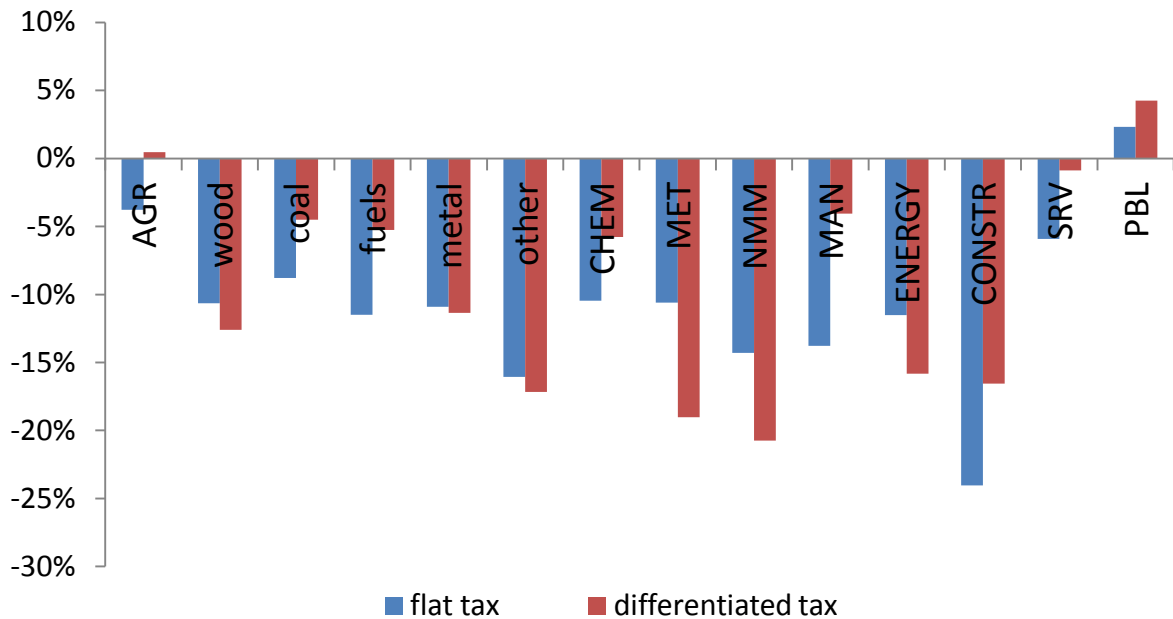
Figure 26 shows the final (in 2050) effect of both versions of the environmental tax on sector output, from which at least three main conclusions can be drawn. First, this policy does not result in a significant reduction of materials use. The second important result is the difference between the two simulations: the differentiated tax has a significantly smaller effect in manufacturing and construction sectors and significantly larger effect in metallic and manufacturing of metallic sector. Finally, one can observe that the policy will induce a switch to an economy that is more service-based.

Figure 25 Internalization of Environmental Costs (MEMO II). Effect of environmental taxes and fees on macroeconomic variables.



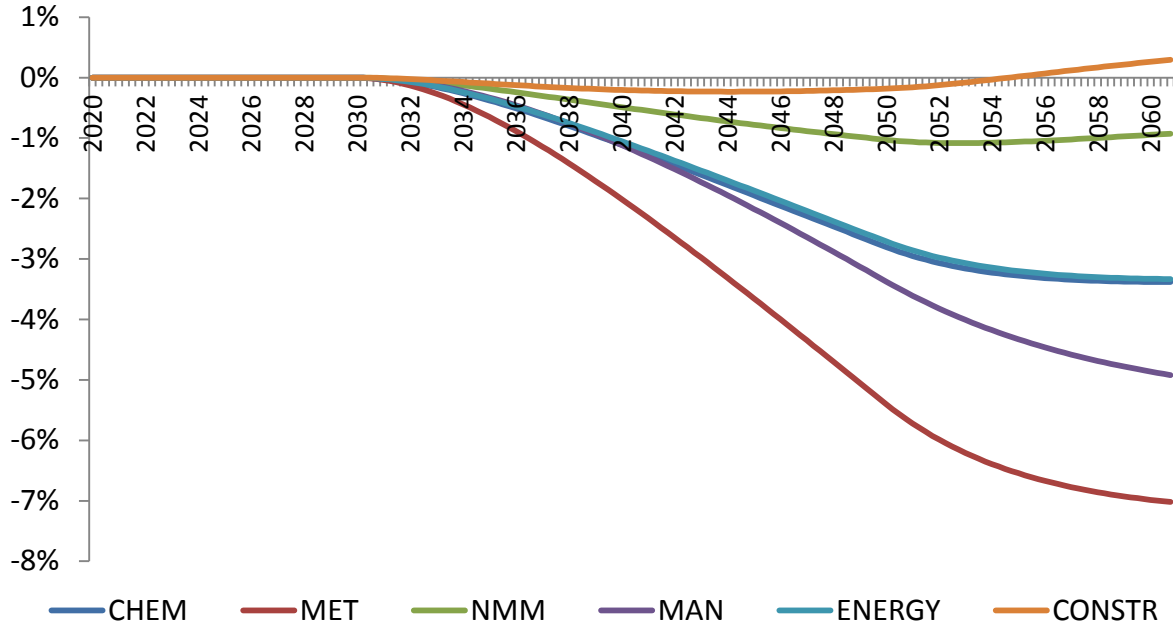
* asterisk denotes simulation with differentiated tax rates

Figure 26 Internalization of Environmental Costs (MEMO II). Effect of environmental taxes and fees in 2050 on output (physical volume).



One of the main reasons behind the relatively small drop in material production is the fact that the environmental tax which is levied on the output of selected sectors does not provide an incentive for firms to invest in cleaner and more resource-efficient technologies. Figure 27 shows that at the end of the simulation horizon material efficiency could even be 7% lower than in the baseline scenario. Similar to the material tax simulation, this result applies to the endogenous technology variable EFF_t^S . Furthermore, it has to be stressed that modelling this policy as a tax on value generated by the sectors is only an approximation of the way the policy is designed and that implementing a tax which is directly linked to negative externalities could provide altogether different results. The main conclusion from this simulation exercise is that special care should be taken when designing policies as some policies may lead to drop in efficiency in material use.

Figure 27 Internalization of Environmental Costs (MEMO II). Effect of environmental taxes and fees on material efficiency of Energy, Construction and Manufacturing sectors.



4.3.3 VAT on Meat

We simulate the effect of 13 p.p. increase (from 8%) in the value added tax rate on meat products from 2020. The revenue from the VAT tax goes as a lump-sum transfer to the households consumers. The outcomes are presented in Table 17 and Figure 28. The results suggest also that the tax increase has the expected effect on non-meat expenditure, although this effect is modest: a 13 p.p. increase in VAT on meat products leads to a 1.6% increase in non-meat expenditure. Almost exactly the same picture can be observed for 2050.

Table 17 and Figure 28.

As expected the increase in VAT has a clear effect on meat consumption expenditure: in 2030, the expenditure increases by 4.3% relative to the baseline. This effect remains unaltered in the long-run: in 2050 the expenditure is 4.4% higher compared to the baseline. This increase is clearly driven by the growth of after-tax prices of meat. In turn, the volumes purchased by households drop by 7.8% relative to the baseline scenario in 2030 and 7.6% in 2050. Interestingly, the percentage drop in total output of the agriculture sector is significantly smaller than the drop in the volume of household consumption: e.g. in 2030 the reduction of output was 3.3%, that is 4.5 p.p. less than the reduction in household consumption. This is due to the fact that the VAT had little impact on purchases of meat in other sectors of the

economy. For example, a closer inspection of the simulation results reveals that export of meat has marginally increased, due to a small drop in pre-tax prices.

The results suggest also that the tax increase has the expected effect on non-meat expenditure, although this effect is modest: a 13 p.p. increase in VAT on meat products leads to a 1.6% increase in non-meat expenditure. Almost exactly the same picture can be observed for 2050.

Table 17 VAT on Meat (MEMO II). Effect of VAT on meat products on meat and non-meat products

Variable	2030	2050
Consumption Expenditure (Change)		
Non-meat products	1.7%	1.8%
Meat products	4.3%	4.4%
Volume purchased by household (change)		
Non-meat products	1.7%	1.8%
Meat products	-7.8%	-7.6%
Output of Agriculture sector (change)		
Non-meat products	0.7%	0.8%
Meat products	-3.3%	-3.4%

The total effect of the VAT increase on GDP and employment is illustrated in Figure 28. In the first ten years the increase has a reverse effect on both, while in the latter period it leads to an increase in the two variables. The after-tax price of consumption goods relative to investment goods increases, stimulating investment, larger capital accumulation and higher production in the future periods. However, the simulation suggests that both effects are small.

Figure 28 VAT on Meat (MEMO II). Change in main macroeconomic indicators.

4.3.4 Circular Economy Tax Trio

Due to the nature of the sectoral decomposition in the MEMO II model, within this policy we are only simulating the effect of the tax on the extraction of selected virgin materials and disregard the tax on landfilled waste and waste incineration. This policy is modelled as an excise volume-based tax on the other mining and quarrying sector coupled with a tax on the exports of the non-metallic minerals sector. A crucial difference between the simulation setup of the MEMO model and the ICES model stems from the regional coverage of the models. Whereas ICES accounts for the tax on intra-EU trade of the non-metallic mineral sector, MEMO model does not, as it does not disaggregate the EU27 area. We assume that the tax is introduced in 2018 with the rate of 38% of the price of the good and increases linearly to 50% in 2050 and then remains constant afterward. In this simulation we assume the standard budget closure of lump sum transfers.

As can be seen from Figure 29, the effect on macroeconomic variables of this tax is rather small, with a peak drop in GDP of approximately 0.5% from baseline expected around 2030. The resulting drop in employment of similar magnitude is also expected. Note, however, that the revenue of the circular economy tax trio is also fairly small, amounting to just a little over 0.2% of GDP. The introduction of the tax induces investment in more resource-friendly technologies, especially in the non-metallic minerals sector (which is the main buyer of other mining and minerals products), which results in the negative effect of the tax being reversed in the long run.

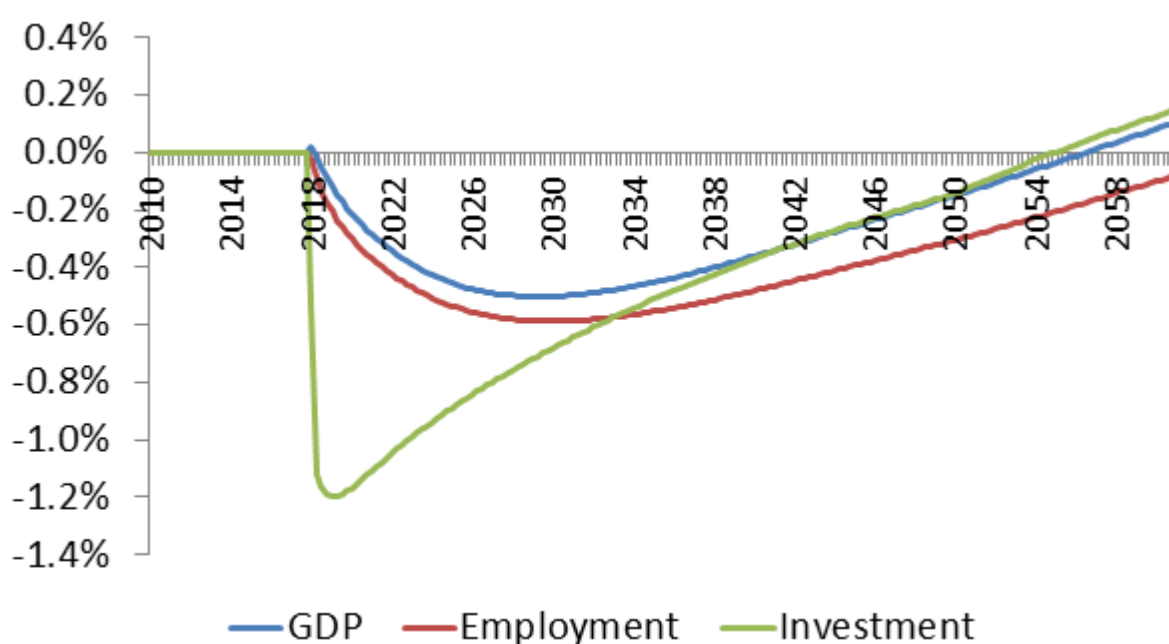
The introduction of the tax has a significant effect on the production of materials compared to the relatively small general macro effect. The output of the other mining and quarrying sector

drops by 30% in 2030 and by 36% in 2050, whereas non-metallic minerals experiences a moderate decrease (7% and 8% respectively). The difference in the reaction between these sectors is mainly due to the fact that in case of the latter, only exports are taxed. The overall output reduction of these two sectors is mainly driven by the drop in the volume of exports, which amounts to approximately 60% in 2030 and 70% in 2050. However, when the increase in the price of the goods due to the tax is taken into account, it turns out that the decrease of the exports value is much smaller.

Table 18 Circular Economy Tax Trio (MEMO II). Effect on material output and export.

Variable	2030	2050
Output (volume)		
Other mining	-30%	-36%
Non-metallic mineral products	-7%	-8%
Export (volume)		
Other mining	-60%	-71%
Non-metallic mineral products	-62%	-72%
Export (value)		
Other mining	-17%	-20%
Non-metallic mineral products	-17%	-20%

Figure 29 Circular Economy Tax Trio (MEMO II). Impact on macro indicators.



4.4 MEWA

4.4.1 Green Fiscal Reform: Materials Tax

MEWA model incorporates this policy in the production sector block. The flows between each two sectors can be taxed – in this case, the price of certain inputs is higher for particular sectors. These should lead to the substitution by other production inputs: energy, capital or labour. Therefore, we have the following equation, defining the price of the material bundle for the given industry:

$$P\_MAT^i = \sum_{j \in S} \vartheta^{i,j} P^j * (1 + TX^{i,j})$$

where P_MAT^i denotes the price of material bundle in sector i , $\vartheta^{i,j}$ is the share of materials produced by sector j in material bundle for sector i , P^j is the price of the output of sector j and $TX^{i,j}$ is the tax imposed on the flow from sector i to j .

Materials that are used by a particular industry form the Leontief bundle (that assumes that they cannot substitute each other due to technological constraints in the production function), so the material use as such is becoming more expensive. Therefore, in addition to the fall of production in sector i , the substitution of materials by energy, capital and labour should be expected (as these possibilities are reflected in production structure described in section 3.2.3).

According to the assumptions of Ekvall et al. (2015) we assume that the taxation on materials increases gradually between 2020 and 2030, and again afterwards up to 2050 with a steeper annual rate. This leads to the steady increase in the price of materials and other production factors including labour and capital relative to consumption good (its price is treated as a numeraire in the model). Implications for the demand for materials depend on assumptions on technological improvement potential and policy implementation. In order to capture this differentiation, we consider three scenarios:

- Base case: material tax is introduced, tax revenues are used to decrease labour taxation, companies are not able to pursue material efficiency improvements (e.g. because of physical limits or lock-in effects);
- Alternative 1: similar to base case, but companies are unable to pursue material efficiency improvements through R&D (e.g. because of physical limits or lock-in effects);

- Alternative 2: similar to base case, but tax revenues are redistributed to households in a form of transfers (e.g. through a universal basic income scheme).

The base case reflects green tax reform as proposed by Ekvall et al. (2015), while alternative scenarios show two major factors (technological barriers and policy choices) which may hinder its effectiveness in terms of stimulating both decoupling and employment in the EU.

Modelling results indicate that successful introduction of green fiscal reform results in significant macroeconomic benefits by 2050, both in terms of GDP (+5.8%) and employment (+7.2%). This, however, requires both significant material efficiency adjustments in the private sector and deep fiscal restructuring. If firms are not able to invest in material efficiency upgrades, the positive impact of the decrease in labour taxes will not fully offset the negative impact of the material taxation on GDP. However, the net negative impact relative to no policy scenario (-1.8%) is rather limited, especially considering that it occurs gradually over several decades. Furthermore, employment impacts are still positive (+0.1%) in 2050 in this scenario. If, however, European governments decide to increase transfers instead of decreasing labour taxation, the macroeconomic impacts will be negative: both GDP (-6.5%) and employment (-1.1%) will be lower in 2050 as a result of the policy.

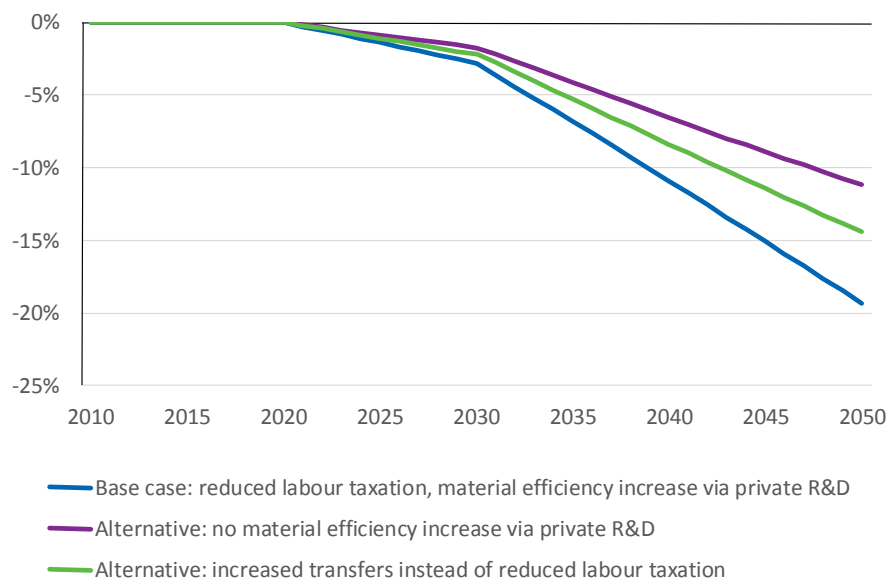
Table 19 Materials Tax (MEWA). GDP and Employment impacts in the EU in alternative scenarios.

Scenario	GDP			Employment		
	2030	2040	2050	2030	2040	2050
Base case: reduced labour taxation, material efficiency increase via private R&D	0.92%	3.44%	5.81%	1.11%	4.20%	7.16%
Alternative 1: no material efficiency increase via private R&D	0.11%	-0.10%	-1.80%	0.14%	0.36%	0.14%
Alternative 2: increased transfers instead of reduced labour taxation	-0.62%	-2.88%	-6.55%	-0.05%	-0.35%	-1.11%

The role of R&D as a key condition for sustaining the economic growth above the baseline trajectory after material use is heavily taxed is largely based on the investment channel. When the unit cost of material grows, firms must either increase prices of their products or reduce the production volume. This acts as a disincentive for capital accumulation and investments. The negative impact of this effect is partially offset by the green tax reform (reduced labour taxation). However, as materials and labour are weak substitutes, the

efficiency of this channel is limited. Therefore, for material intensive industries, the only way to keep the production volume intact is to invest in material efficiency. This process consumes part of the short term profits but in the long run pays-off freeing the resources for necessary capital accumulation. The more productive R&D process is, the more eagerly firms will engage in material efficiency investments. This increases GDP and investment compared to the scenario without accessible material efficiency improvement options. The overall impact of the policy on the material consumption is similar (13%-14% reduction) in both scenarios, but the macroeconomic outcomes are much more positive when the companies are able to adjust to material taxation through intramural R&D.

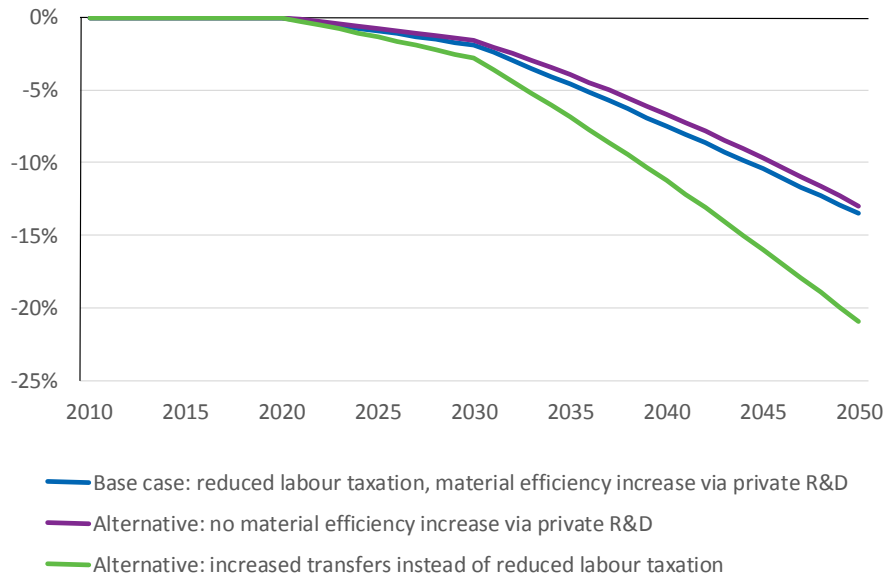
Figure 30 Materials Tax (MEWA). Change in material intensity of GDP in comparison to 'no policy' for different scenarios.



It is interesting to note an interplay between labour market developments and investments in material efficiency improvements in the model. Tax revenue recycling through direct transfers to households decreases incentives to seek employment among the working age population. In order to attract workers, companies have to increase wages. The labour costs increase and this provides an additional incentive for companies to invest in R&D focusing on labour efficiency improvement. As a result, there are less resources available for firms to invest in material efficiency. Thus, by increasing the price of both materials and labour, the combination of material taxation and increased transfers leads to lower material efficiency improvement than in the case of the green tax reform (decrease in labour taxes). In absolute

terms, however, the material consumption decreases the most when transfers are increased as a result of GDP drop.

Figure 31 Materials Tax (MEWA). Change in materials consumption in comparison to 'no policy' for different scenarios.



The sectoral impacts depend significantly on the assumptions on material efficiency potential. This is due to the concentration of R&D efforts in the sectors where the efficiency gains are the largest. In economic terms it means that investments in material efficiency help enterprises in the most material intensive industries to preserve their production level, but at the same time reduce the need to save materials.

The lack of opportunities for improving material efficiency leads to a significant drop in the production volume in the material-producing and material-intensive sectors, including mining, recycling and heavy industry. On the other hand, production increases in the labour-intensive agriculture, as well as extraction of fuels which are not covered by the material tax. Both effects are, however, to some extent offset in monetary terms by the opposite shifts in sectoral prices. Finally, the increase in transfers to households leads to a drop in activity level across all the sectors.

Figure 32 Materials Tax (MEWA). Change in the production volume on the sectoral level in 2050 in comparison to ‘no policy’ across scenarios with material efficiency improvement through R&D.

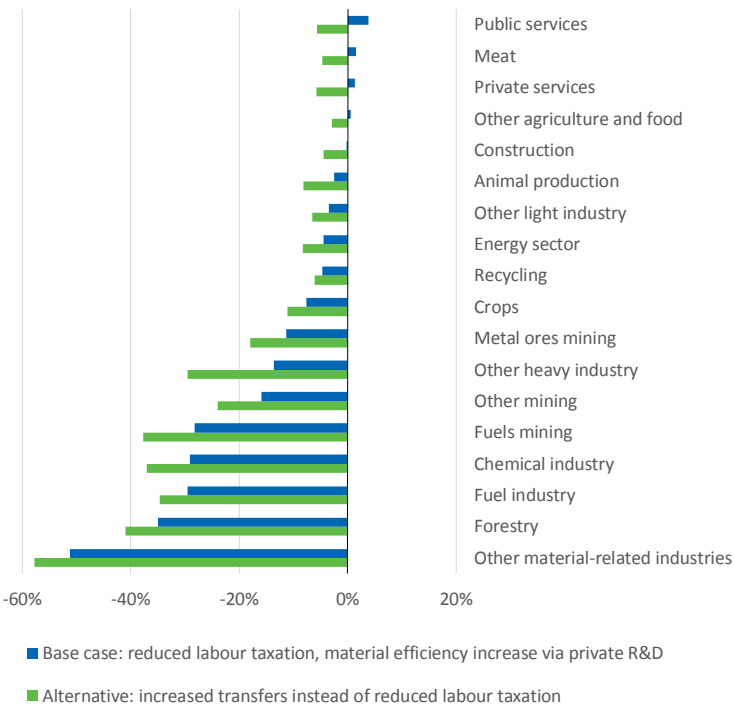
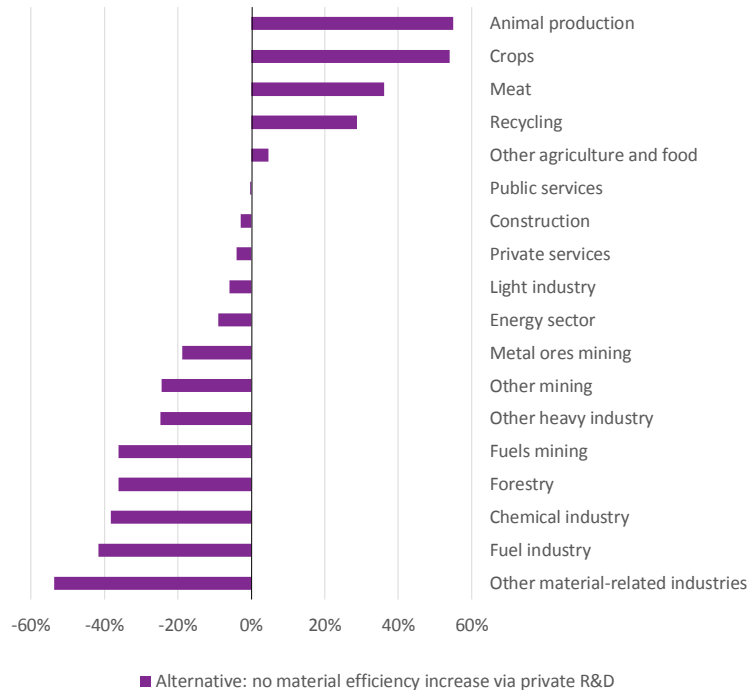


Figure 33 Materials Tax (MEWA). Change in the production volume on the sectoral level in 2050 in comparison to 'no policy' across scenarios without material efficiency improvement through R&D.



To conclude, the significant rise of material taxes may be detrimental for the European economy even if the tax gains are spent to reduce labour taxation. However, the investment in material efficiency R&D will be probably used by firms to offset the negative consequences of this measure, delivering the same environmental benefit in the form of reduced demand on raw materials, but securing the GDP growth at the same time. This conclusion depends, however, on the assumption that there are no physical, organisational, behavioural or other non-market barriers that could block the efficiency efforts of the industry in the considered technological perspective. In this context, complementary instruments in the policy mix (e.g. information and coordination measures) might play an important role in decreasing the transition costs by unlocking the potential of material efficiency improvements.

4.4.2 Green Fiscal Reform: Internalisation of External Environmental Costs

This instrument is meant to tax externalities resulting from the extraction and use of materials and fossil fuels, as a part of a broader green tax reform. In our simulations with the MEWA model, we have considered two alternative variants of this policy. The first is a flat rate 35% tax levied on all non-services sectors, as proposed by Ekvall et al. (2015). The second is a

differentiated rate tax that varies according to the average sulphur oxides, nitrogen oxides, and particulates emission intensities of particular sectors.

Table 20 Internalisation of Environmental Costs (MEWA). Flat and differentiated rate of taxation aimed at internalisation of externalities,

	Flat rate	Differentiated rate
1. Agriculture, forestry and food	35%	35%
2. Fuels mining	35%	39%
3. Metal ores mining	35%	39%
4. Other mining	35%	39%
5. Chemical industry	35%	34%
6. Fuel industry	35%	72%
7. Recycling	35%	25%
8. Other material-related industries	35%	60%
9. Light industry	35%	4%
10. Energy	35%	191%
11. Construction	35%	7%
12. Private services	0%	0%
13. Public services	0%	0%

Source: Ekvall et al. (2015) and WISE calculations based on Eurostat data

In line with the general design of green fiscal reform, we have assumed that the revenues from taxing the externality decrease labour taxation. However, due to the fact that the tax revenues are relatively large and the fall in labour taxation (defined as the sum of personal income tax and social security contributions) is substantial (from 30% to 4.4% in flat rate scenario and to 9.4% in a differentiated rate scenario), these simulations should be treated with caution. Furthermore, the modelled instrument is a part of broader green tax reform, which also includes significant material taxation. In order to balance additional revenues from these two sources, a green fiscal reform of proposed magnitude may need to include other types of taxes – like CIT or VAT. Thus, we present the scenario in which the additional revenues from the green taxes are used to reduce VAT. Such option is quite interesting from the decoupling perspective, because it greatly reduces the relative price of final consumption in comparison to the intermediate goods, fostering investment in material efficiency. At the same time, the rebound effect resulting from the increase in labour supply followed by an increase in investment to prepare additional workplaces is absent.

Figure 34 and Figure 35 show the results of simulations in different scenarios. The impact of the flat tax rate is visibly larger, because of the scale of the shock – it brings higher revenues to the state budget. The rise of employment in the scenario with labour tax as an offsetting instrument is higher than the increase in consumption or GDP – that is because of the decreasing productivity of labour, which is more significant in a flat rate scenario due to lower

investment surge. In other words, differentiated taxation, to some extent, forces stronger adjustments of employment through the increase in the production capital.

Figure 34 Internalisation of Environmental Costs (MEWA). Impact on macro aggregates with flat and differentiated rate – labour tax closure.

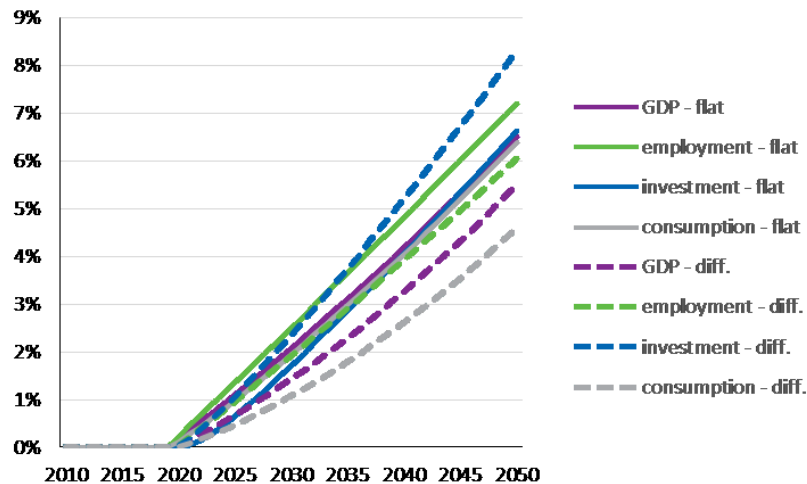
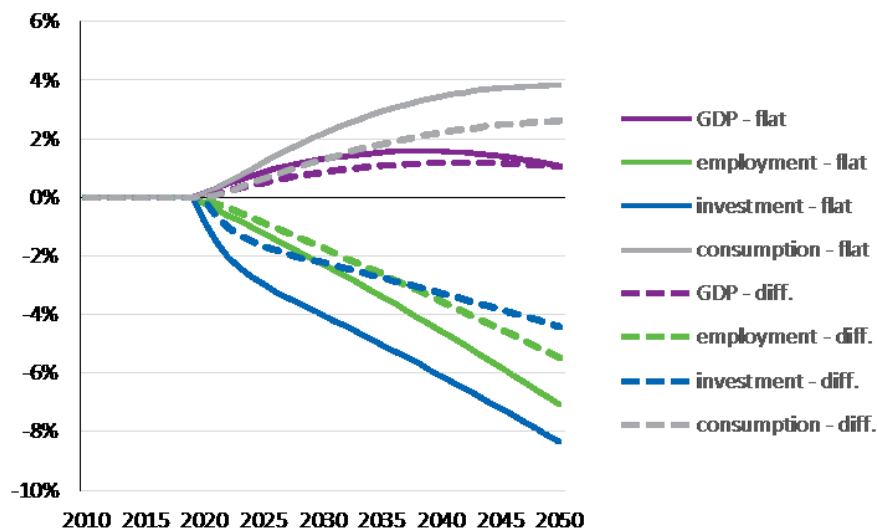


Figure 35 Internalisation of Environmental Costs (MEWA). Impact on macro aggregates with flat and differentiated rate – VAT closure.



The increase in the externality tax coupled with the reduction in the VAT levels impacts GDP positively, but the size of the gain is relatively small and comes mainly from the fall in the material intensity of the economy. As the production of consumption good is in this case more

profitable than using intermediate materials, firms invest large resources in R&D to increase their material efficiency, which translates into substantial GDP gains.

Figure 36 Internalisation of Environmental Costs (MEWA). Impact on materials, energy and fuels efficiency investment – labour closure.

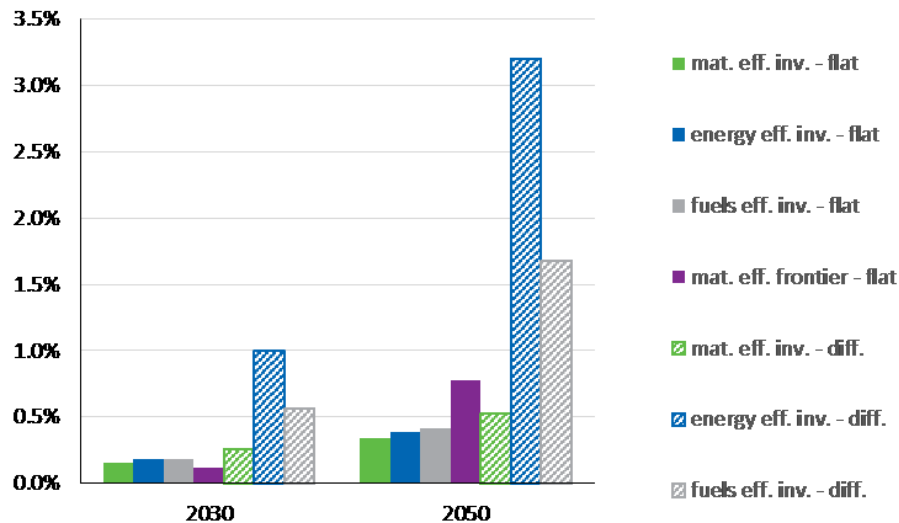
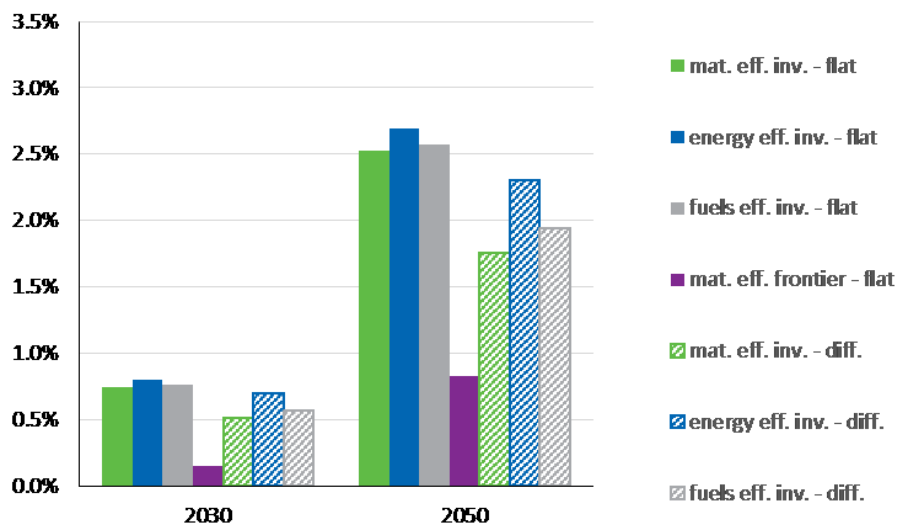


Figure 37 Internalisation of Environmental Costs (MEWA). Impact on materials, energy and fuels efficiency investment – VAT closure.



As it might be expected, the highest fall in production takes place in the material intensive sectors as the differentiated rates allow for more tailored interventions. Also, the fall in the production sold is much larger with VAT closure despite the rise of GDP – that is induced by

even larger reduction of the intermediate consumption possible thanks to the large increases in the materials efficiency.

Figure 38 Internalisation of Environmental Costs (MEWA). Impact on domestic production of different sectors in 2050 – labour closure.

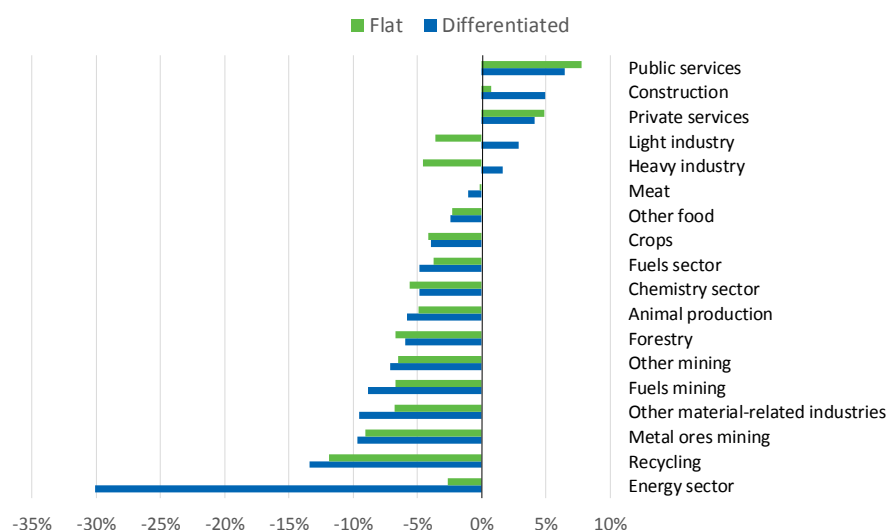
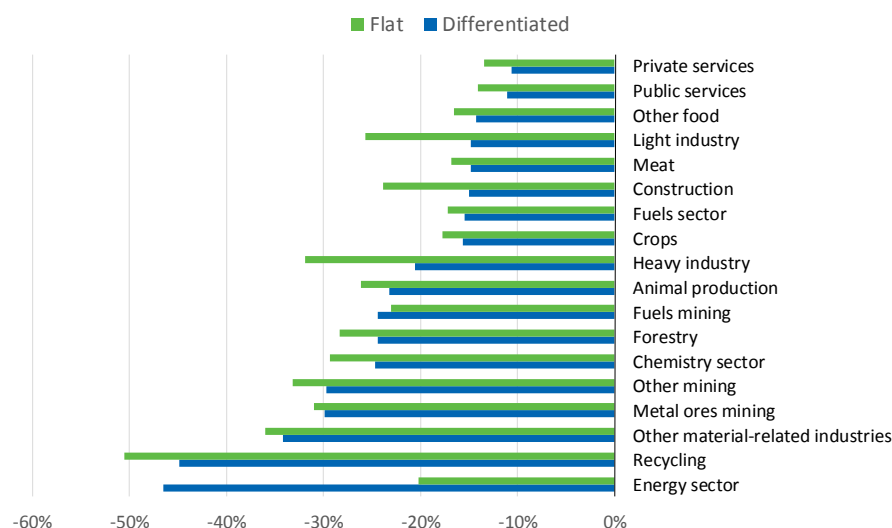


Figure 39 Internalisation of Environmental Costs (MEWA). Impact on domestic production of different sectors in 2050 – VAT closure.



To sum up, the overall policy recommendation is highly dependent on the policy goal. Using additional revenues to lower the taxation of labour brings about an increase in employment and GDP. These gains are much higher than in the case of VAT closure. However, if the primary concern of policy makers is a reduction in material intensity, the decrease in VAT financed by an increase in the material tax might be a more valuable option.

4.4.3 Increasing Spending on Research and Development

The MEWA model captures several types of efficiency investment, including measures which decrease material, emission, and energy intensity of the economy. Each kind of such technical improvement is modelled as described in section 3.2.3. Governments can engage in R&D, thus shifting the overall technological frontier. This will increase the productivity of investments in material, energy or emission efficiency that are performed by private sector. This can be understood as a public investment which increases the capacity of industrial researchers and engineers to improve either material, emission or energy efficiency as a result of private R&D expenditure.

In line with the description of this policy instrument given by Ekvall et al (2015), we focus on the effect of the increase in the public investment in material efficiency, which is doubled until 2020 and then kept constant.

Figure 40 Increase in R&D Spending (MEWA). Change in GDP in comparison to baseline for different closures.

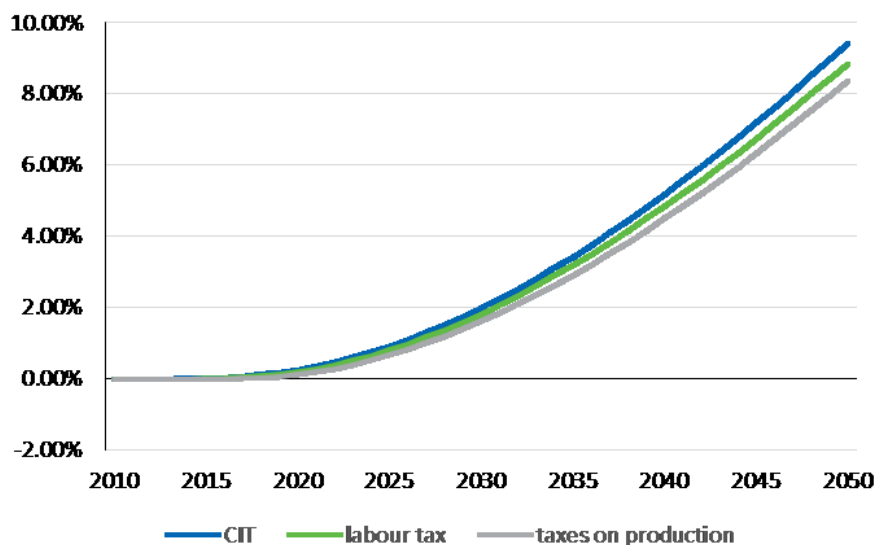
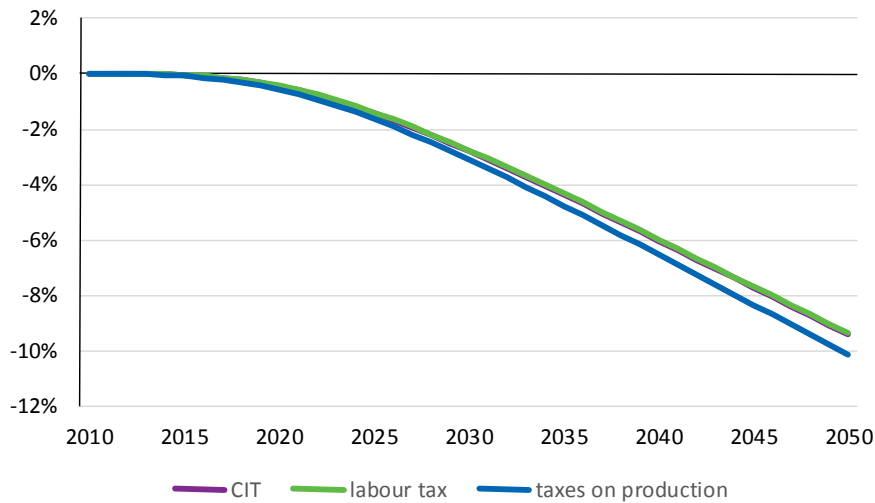


Figure 41 Increase in R&D Spending (MEWA). Change in materials intensity in comparison to baseline for different closures.



As it might be expected, a permanent doubling of public investment in R&D in the area of material efficiency significantly increases EU GDP. This support will gradually shift the technology frontier, incentivising firms to invest larger share of their own resources in the material-saving capital. Assuming that no additional policy instruments will increase the price of materials, and the efficiency of their utilisation increases as a result of public R&D investments, private firms should expand their production until the marginal productivity of materials equalizes with their purchase price. Therefore, the use of materials will also increase – the rebound effect will occur. Some efficiency gains will be translated to increase in capital and labour remuneration, as both production inputs will be needed to take advantage of the improved material efficiency frontier. Higher wages will attract labour supply, translating into larger employment and inducing the investments further.

Figure 42 Increase in R&D Spending (MEWA). Change in the GDP decomposed for the increase in the material efficiency and the use of materials, closure: CIT.

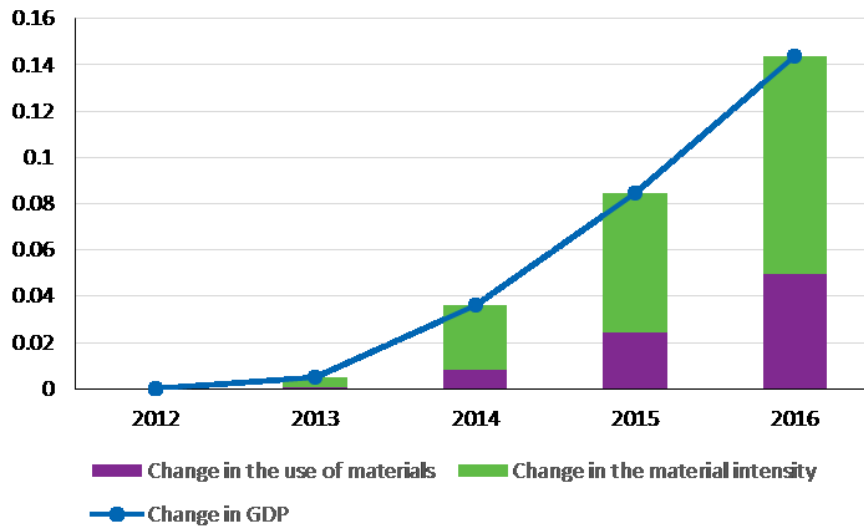
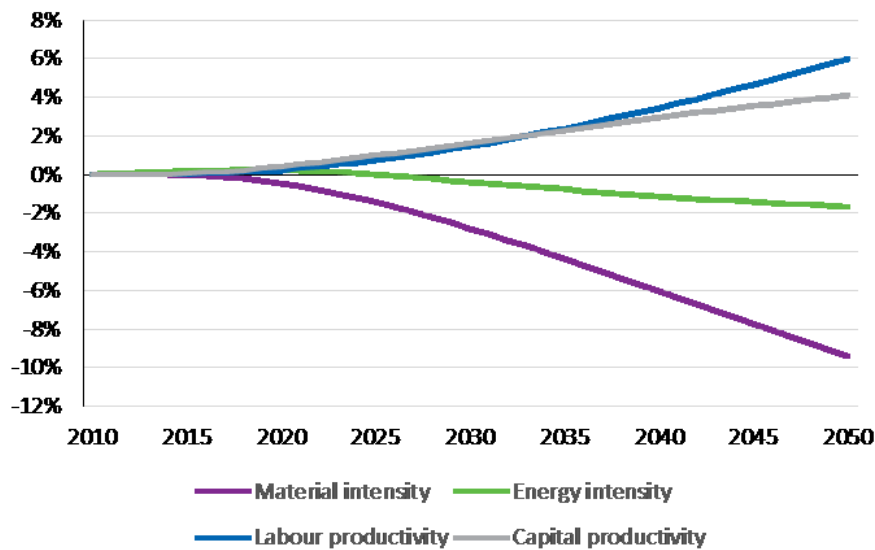


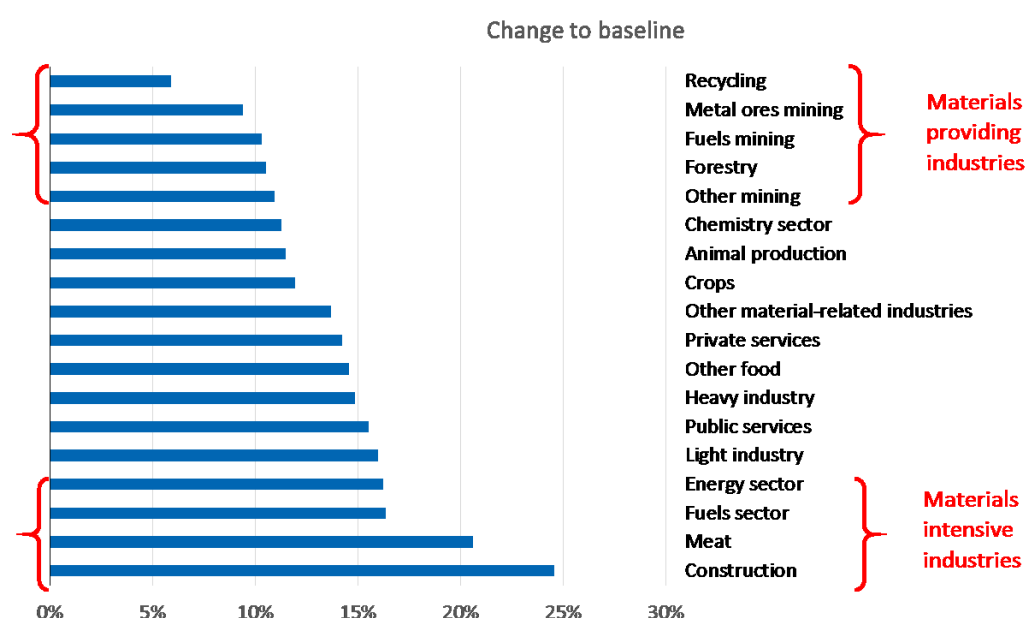
Figure 43 Increase in R&D Spending (MEWA). Change in the productivity of different production factors, closure: CIT.



The impact of material efficiency R&D on the economy hardly depends on whether it will be financed from the increase in labour taxation, corporate taxation or VAT. That is because the doubling of the state R&D investment will require only a minor change in the existing tax system – additional expenditure equals 0.4% of GDP. This amount is based on the model calibration which assumes a broad definition of research on material efficiency improvement (any research which leads to the creation of higher value added from the same amount of materials). This will translate into the almost 10% increase in the material efficiency and almost 14% rise in European GDP, which adds up to about 4% rise in total material

consumption within the EU. The change in the use of other production factors is visible, but due to the huge increase in capital, which also substitutes for energy and fuels, we should expect improvement of labour, energy and emission efficiency. Nevertheless, as these gains are consumed by the increase in the total GDP, both the use of energy and the level of emissions rise in absolute terms. The economic impact is the smallest in sectors that ‘produce’ materials (mining, forestry and recycling) and most significant in material intensive industries (especially construction, energy and fuels).

Figure 44 Increase in R&D Spending (MEWA). Change in the product of different sectors in comparison to baseline, closure: CIT.

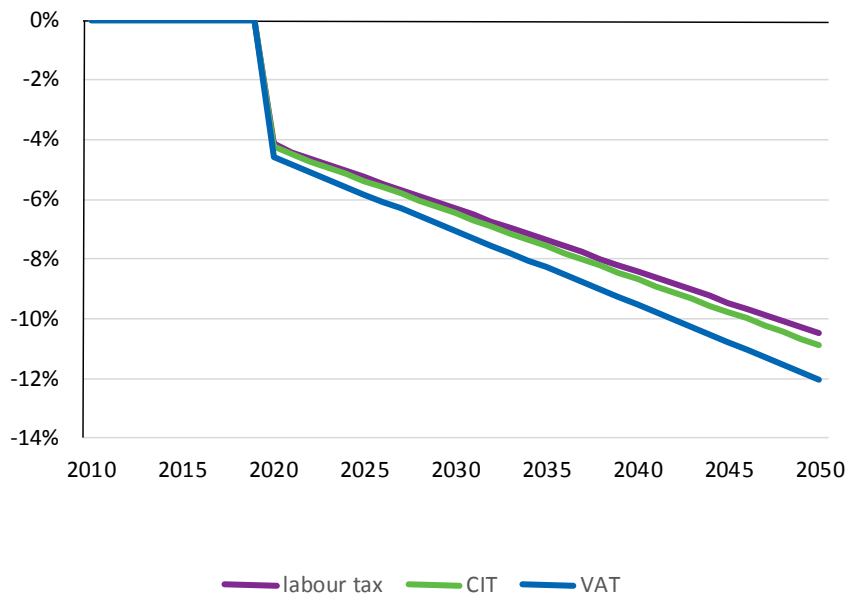


We conclude that the rise in the state R&D on material efficiency alone, will indeed contribute to the rise in GDP and welfare, but without additional measures aiming at increasing the costs of materials (special tax or command-and-control measures), it will lead to the surge in the use of materials, energy and other resources. This policy is therefore an important part of broader policy mix which aims at decoupling economic growth from the resource use, but without additional measures it will only achieve relative decoupling, while absolute resource consumption may, in fact, increase.

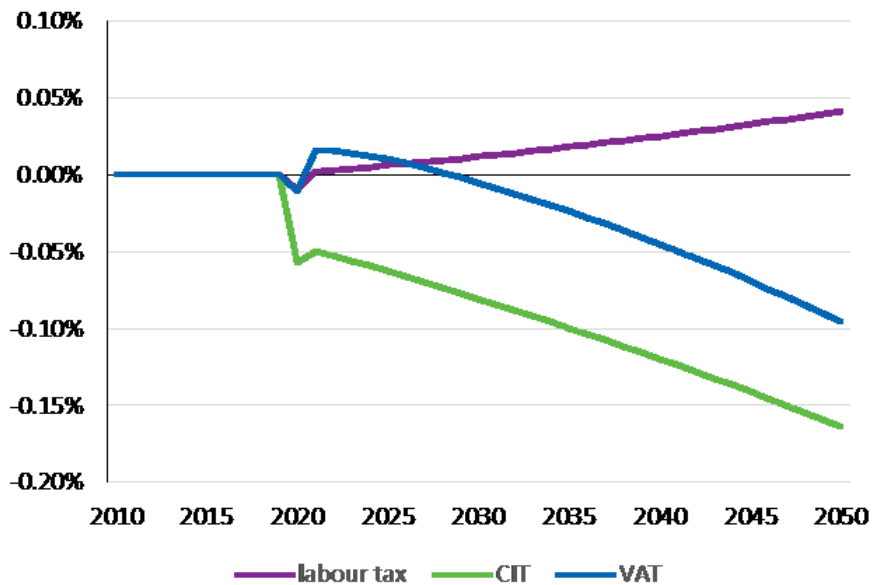
4.4.4 Strengthened Pesticide Reduction Targets under the Pesticides Directive

The modelling of strengthened pesticide targets with MEWA is focused on assessing the likely scale of impacts of introduction of the key instruments envisioned in the policy description: pesticide taxation. It is modelled as a tax on intermediate goods supplied by the chemical sector to the companies producing crops. For the purpose of this modelling exercise, we assume that a 20% sales tax on pesticides is introduced in 2020 in the whole EU, which then gradually rises to 50% in 2050. This pathway is consistent with a taxation range applied in 1998 in Denmark (33-54%) (Pedersen et al. 2012). Based on Eurostat I/O statistics and industry data, the share of pesticides in total sales by the chemical sector to agriculture in the EU was estimated at 40%. Thus, the assumed taxation of aggregate intermediate good supplied by the chemical sector to the crop-producing sector is assumed to be 8% in 2020, gradually rising to 20% in 2050.

Figure 45 Pesticide Tax (MEWA). Change in the use of pesticides in different scenarios.



Our results of the modelling exercise are in line with the previous findings about quite low elasticity of the use of pesticides to prices (on average estimates fall somewhere between 0.2 and 0.5, see Skevas et al. (2013) for details). In our simulation, about 10-12% drop in the pesticide use is achieved through gradual introduction of 50% pesticide tax (equivalent of 4-5% drop in the use of intermediate inputs from chemical sector). The range of the results reflects three scenarios differentiated by the use of pesticide tax revenue (reduction of labour taxation, reduction of CIT, reduction of VAT).

Figure 46 Pesticide Tax (MEWA). Change in GDP in different scenarios.

The value of pesticides used in the production of crops is quite small in comparison to the size of the economy as a whole, so the impact of pesticide taxation on GDP is limited and does not exceed the 0.2% of GDP. Similarly to green tax reform, when tax revenues are used to mitigate the labour tax, the impact on GDP is positive. On the other hand, if increase in the pesticide tax will be used to decrease CIT, we should expect fall in labour supply (as company profits are transferred to households, establishing firms is more profitable than working). Lastly, the VAT closure means that we may expect efficiency improvements, as intermediate goods will become relatively more expensive in comparison to the final consumption. Moreover, the indisputably negative effect of the introduction of pesticide tax can be seen in agriculture: domestic crops are substituted by import. Also, agriculture export is to some extent affected negatively by these regulations.

Figure 47 Pesticide Tax (MEWA). Change in the material intensity (materials-to-GDP ratio) for each scenario.

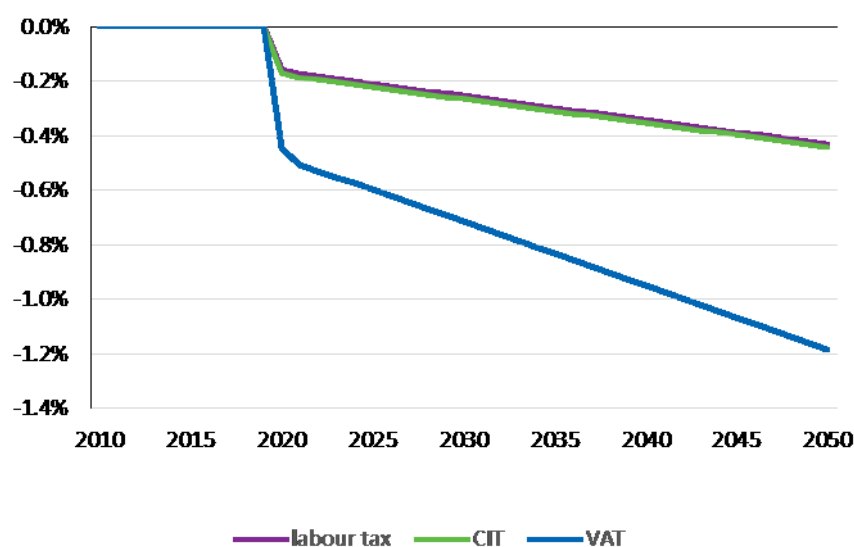
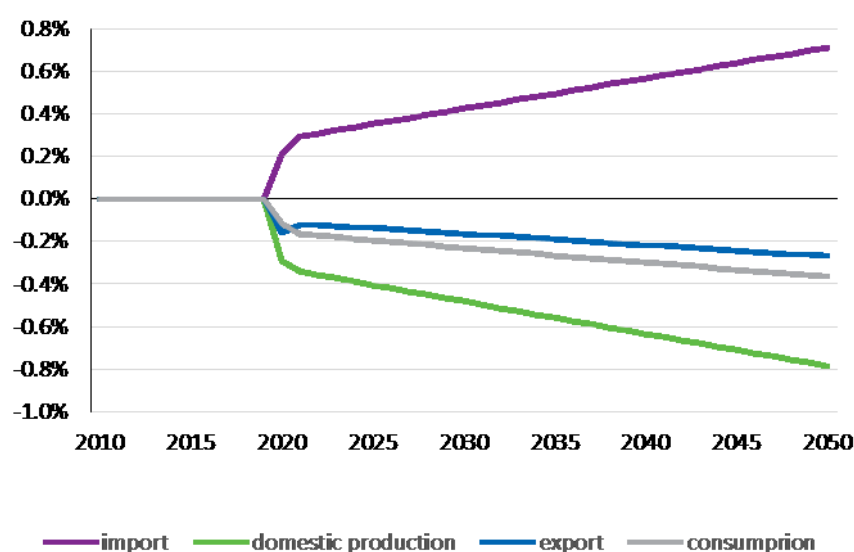
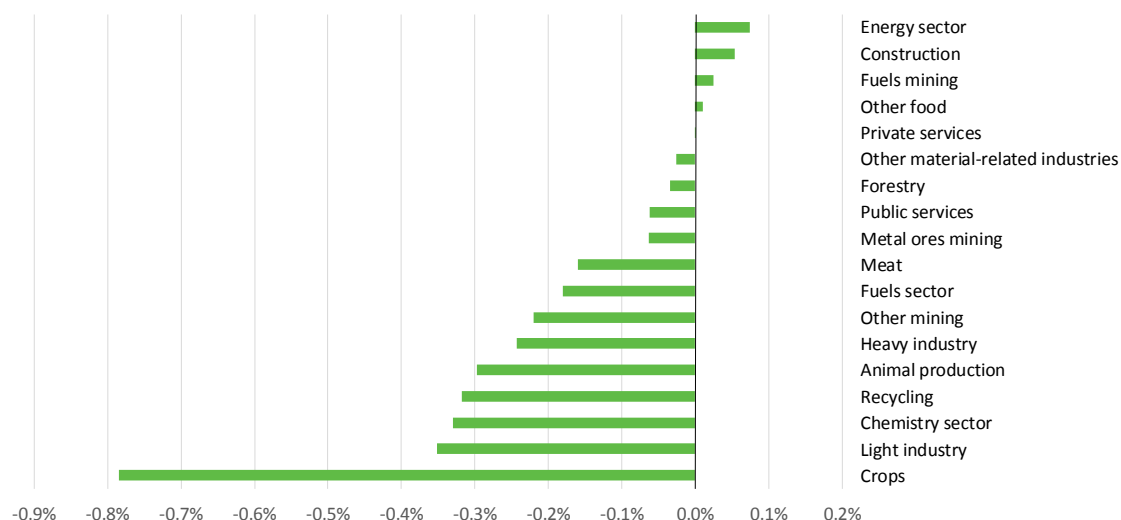


Figure 48 Pesticide Tax (MEWA). Change in aggregates for crops subsector (scenario: labour tax decrease).



Efficiency improvements resulting from an enlarged pesticide tax allow to decrease production in almost all sectors. The most notable exemption is energy sector, as fuels and energy are used to substitute pesticides in crops production.

Figure 49 Pesticide Tax (MEWA). Change in domestic production of goods produced by different sectors.



Summing up, the overall impact of the introduction of pesticides tax on the GDP is likely to be negligible. However, it may lead to some inter-sectoral adjustment and efficiency improvement is likely to be substantial and positive on the sectoral level.

4.4.5 VAT on Meat

In order to model the removal of the reduced VAT rates in the MEWA model, the country-level fiscal impacts had to be aggregated to the EU level. We have achieved this by calculating the weighted average gap between the reduced VAT on foodstuffs and standard, efficient VAT rate in the EU, which amounts to 13 p.p. Thus, the policy instrument is modelled as a one-off increase of the consumption tax on meat products by 13 p.p. in 2020, and the presented results refer to the EU as a whole. The increased tax revenues are used to finance public consumption which is in line with the policy fiche description that suggests using the revenues from this tax to finance information awareness campaigns and other environmental protection initiatives.

Abandoning the reduced VAT rate on meat will exert negative pressure on GDP. The reason is that this measure will decrease the purchasing power of workers, improving the relative attractiveness of leisure. As a result, the labour supply will fall. This effect can be alleviated if increased VAT revenues are used to finance a drop in the marginal taxation of labour.

Figure 50 VAT on Meat (MEWA). Change in macroeconomic variables in comparison to the baseline (public consumption closure).

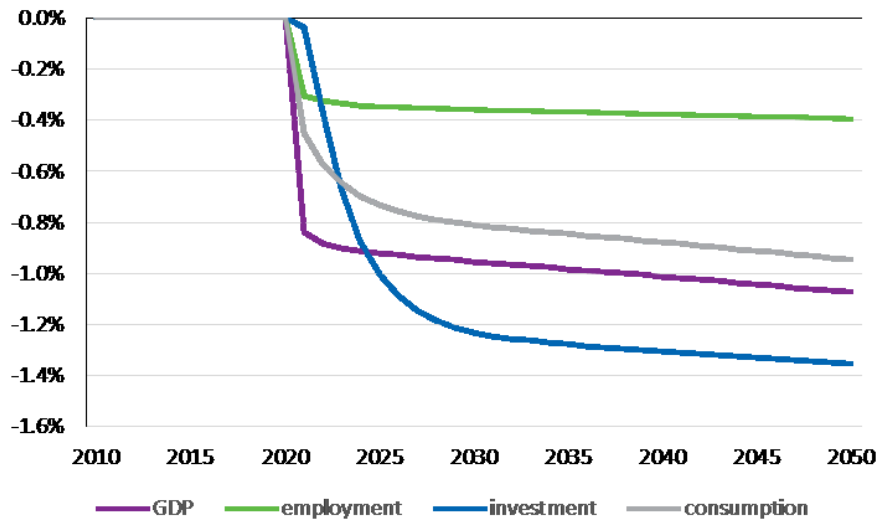
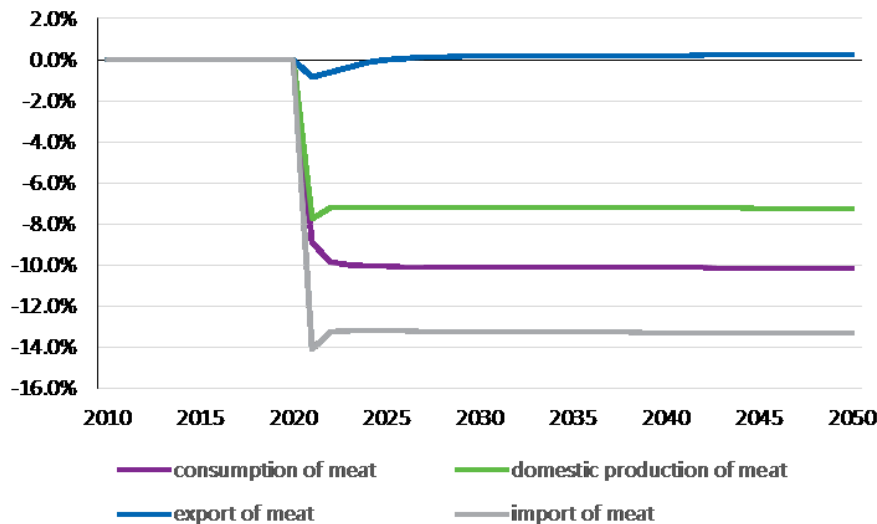


Figure 51 VAT on Meat (MEWA). Change in sectoral variables in comparison to the baseline.



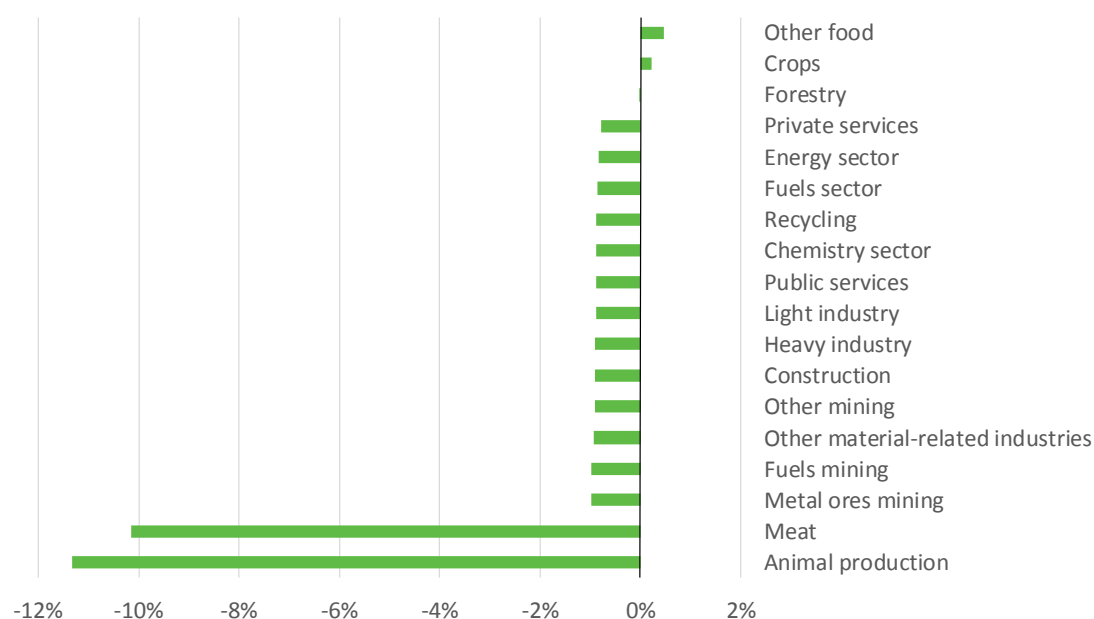
The results of the modelling exercise are in line with Oosterhuis et al. (2008) with 13 p.p. change in VAT for meat leading to about 10% fall in the consumption. The impact is at higher range of the estimates due to the accompanying information campaign, leading to further dietary changes.

The meat consumption and imports will be more affected than domestic meat production. The EU share in demand on the international meat markets is too small to significantly influence prices on the global level. On the other hand, European meat producers will face a noticeable drop in a domestic demand and confront with the excessive production capacities, which will

force them to cut meat prices. That will result in substitution of foreign meat by the domestic production. Meat export is exempted from VAT, so it barely reacts to this policy measure - slight temporary decrease occurs after the introduction of the policy due to the change in labour supply.

Thanks to the substitution of meat by other food products the production of the food sector will grow, but the change will be negligible (about 0.1%). The reason for that is threefold. Firstly, the consumption of other food is about six times higher than that of meat, so even a significant drop in the average intake of meat among European consumers will translate to small rise in the consumption of other types of food. Secondly, cheap meat will substitute other agriculture products as a production factor in a food industry. Thirdly, decrease in labour supply will diminish international competitiveness of domestically produced food, so decrease in export should be expected.

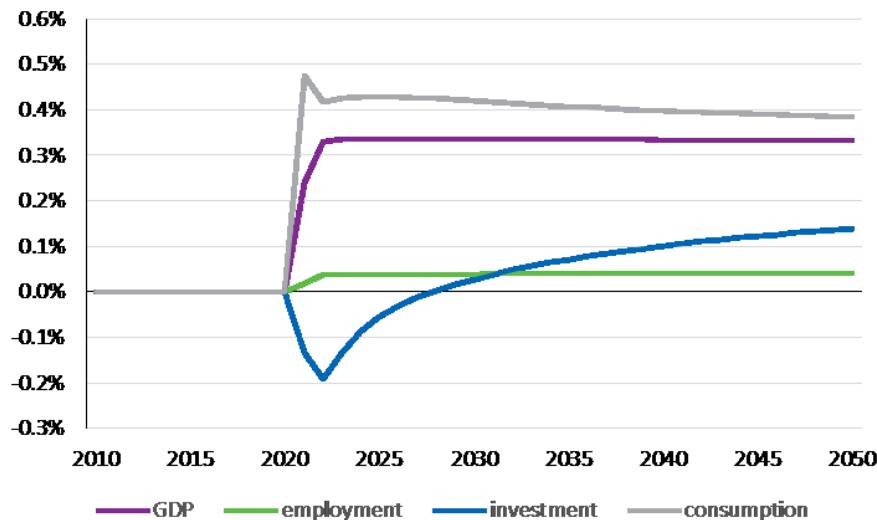
Figure 52 VAT on Meat (MEWA). Change in the domestic production of different sectors in 2050 in comparison to the baseline.



Two sectors that should be the most affected by this policy are meat and animal production. The production of other sectors will decrease, but the change will not be substantial (less than 0.5%). The change in the production of meat will be much greater than the decline in the animal production because the latter is much more frequently used as an intermediate good. The increase in VAT for meat to finance public activities such as promotional campaign is detrimental to the GDP. However, its impact is relatively small and could be easily neutralised through the decrease of labour taxes. This closure provides in fact an attractive alternative to public consumption closure proposed by Ekvall et al. (2015). When the meat tax revenues are

used within a green tax reform the negative impact of the policy on employment and GDP is reversed, although the impact on meat production remains largely unchanged.

Figure 53 VAT on Meat (MEWA). Change in macroeconomic variables in the alternative scenario of tax revenue recycling (decrease in labour tax) in comparison to the baseline.



Summing up, the VAT on meat will be detrimental to the economic growth in the EU if the revenues from it will be utilized to finance public consumption. On the other hand they can be spent more productively to finance green tax reform providing the useful alternative to the baseline design of the policy. Only two sectors cannot avoid the negative consequences of the taxation: animal and meat production. However, this performance is in line with the main purpose of the policy which is to limit the overall meat consumption in Europe.

4.4.6 Circular Economy Tax Trio

This policy envisages taxation of virgin materials, landfills and waste incineration to encourage recycling instead of raw material consumption in the EU. As described by Ekvall et. al. (2015) other goals of this policy mix include the internalisation of the externalities linked to raw materials consumption and limiting landfilling and incineration of municipal and industrial waste. On the input side, the major instrument in this policy mix is the tax on virgin aggregates extraction. However, the proposed marginal tax rate is relatively small and the taxation is limited only to the mines located within the EU borders whereas import is not to be taxed. Because of these features and the small scale of the mining sector in the European economy, the quantitative impact of the policy mix on GDP will not be large. In fact,

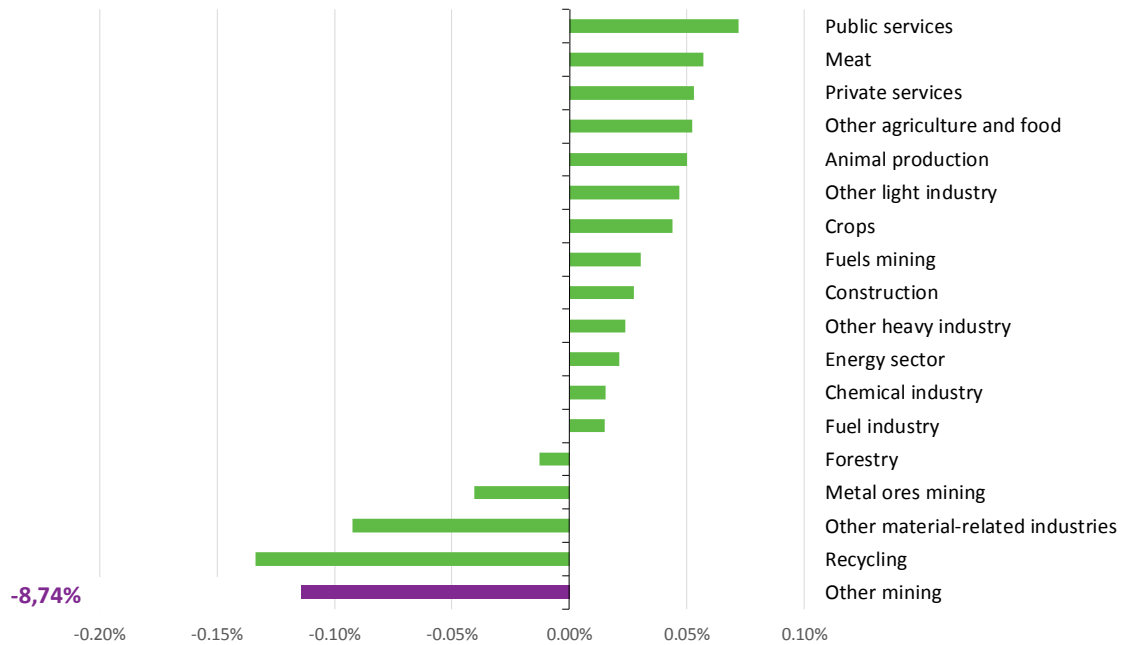
regardless of the considered fiscal closure, the EU GDP should rise by 0.08% above the baseline thanks to the better use of the small surplus generated through material savings and smaller labour taxation. Employment will also rise (0.06%) because of the small positive impact of the circular economy tax trio on the European labour productivity. Moreover, the policy instrument should also increase the material efficiency by about 0.1%, meaning that the decrease in material consumption due to the improved efficiency will be fully offset by the proportional increase in the production volume.

Table 21 Circular Economy Tax Trio (MEWA). Deviation of major macroeconomic variables with respect to 'no policy', 2020-2050 (%).

	2020	2030	2040	2050
GDP	0.04	0.05	0.07	0.08
Employment	0.04	0.05	0.05	0.06
Productivity	0.00	0.01	0.02	0.02
Investment	0.04	0.07	0.09	0.10
Consumption	0.03	0.05	0.06	0.08
Material use	-0.02	-0.01	-0.01	0.00
Material intensity	-0.06	-0.07	-0.08	-0.09

Not surprisingly the only sector that is significantly affected by the policy instrument is mining. Its production till 2050 drops by almost 9% compared to the baseline. However, the limited share of this sector in the European economy and the ability of other industries to substitute domestic raw materials with cheaper substitutes from import or recycling make this phenomenon purely sectoral. While in general the economy as a whole benefits on a regional basis this observation might be controversial. In fact, extraction of virgin aggregates provides significant contribution to the economies of some European regions. Therefore, the desirable supplement to the policy instrument should take a form of a regional, structural policy that would help affected communities to accommodate and counterbalance the negative consequences of the circular economy tax trio on their labour market and investment perspectives.

Figure 54 Circular Economy Tax Trio (MEWA). Change in the production volume on the sectoral level in 2050 with respect to ‘no policy’.



4.4.7 Enabling Shift from Consumption to Leisure

Shift from consumption to leisure is modelled as a change in the consumer preference parameter. Consumers maximize lifetime utility deriving its current value from consumption and leisure according to the following equation:

$$U = \frac{(C * LE^\omega)^{1-\sigma} - 1}{1 - \sigma}$$

where C is consumption and LE is leisure. If parameter ω increases leisure becomes more valuable for the representative agent and labour supply will fall. Such a shift leads to a lower GDP, but also increases lifetime utility.

The instrument enabling the shift from consumption to leisure shift is very difficult to model as its description is not very detailed and hence the potential shock to the economy is hard to quantify. In order to simulate the consumption to leisure shift we changed the ‘deep’ parameter of the model that reflects the relative marginal utility from consumption and leisure. This implementation in the model, however, remains somewhat arbitrary. Therefore, in the description of the results, we will focus on the economic mechanisms that will induce changes in the use of resources and not on the quantitative results as such.

Figure 55 Consumption-to-Leisure Shift (MEWA). Changes in GDP, consumption, employment and investment.

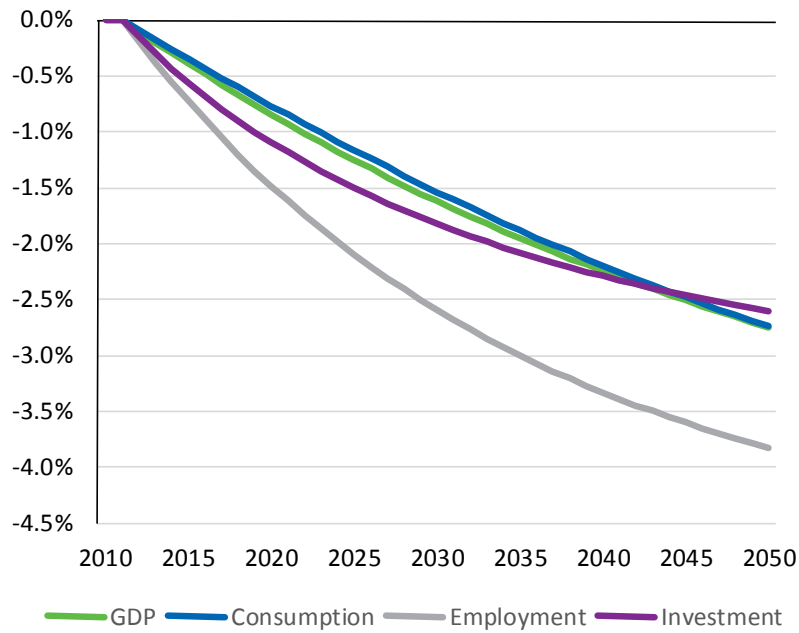
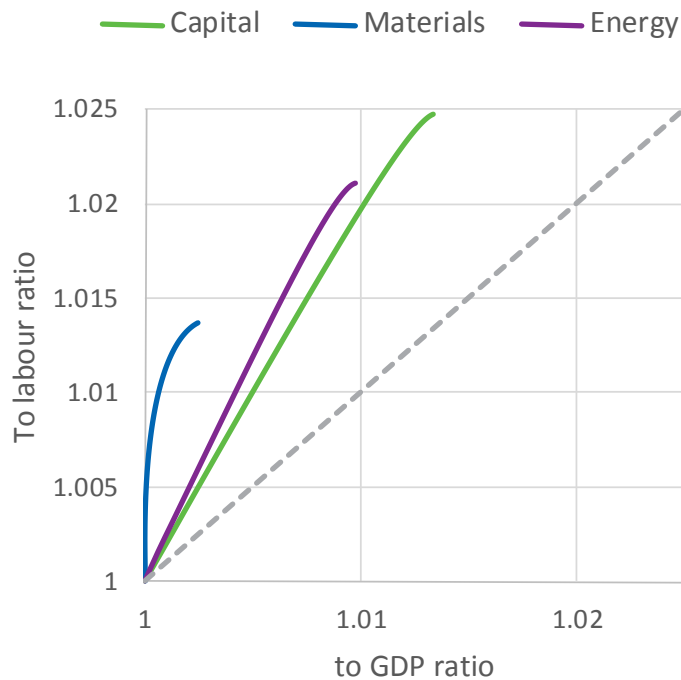


Figure 56 Consumption-to-Leisure Shift (MEWA). Change in capital, materials and energy-to GDP and to Labour ratio (2015=1).



The basic consequence of the shift is a decrease in the “motivation” to work and consequently a decrease in the labour supply. Therefore, the price of labour (wages) will increase, leading

to some substitution of labour by capital, energy and materials. That will increase the capital-to-GDP ratio, energy-intensity and material intensity of the economy, and induce even greater changes in the capital, energy and materials-to-labour ratios (see Figure 56). However, as the economy will produce less goods to be consumed, an absolute reduction of the use of energy and materials will occur in the long run.

Figure 57 Consumption-to-Leisure Shift (MEWA). Contributions of changes in import and export to the change in current account (% of ‘no policy’ GDP).

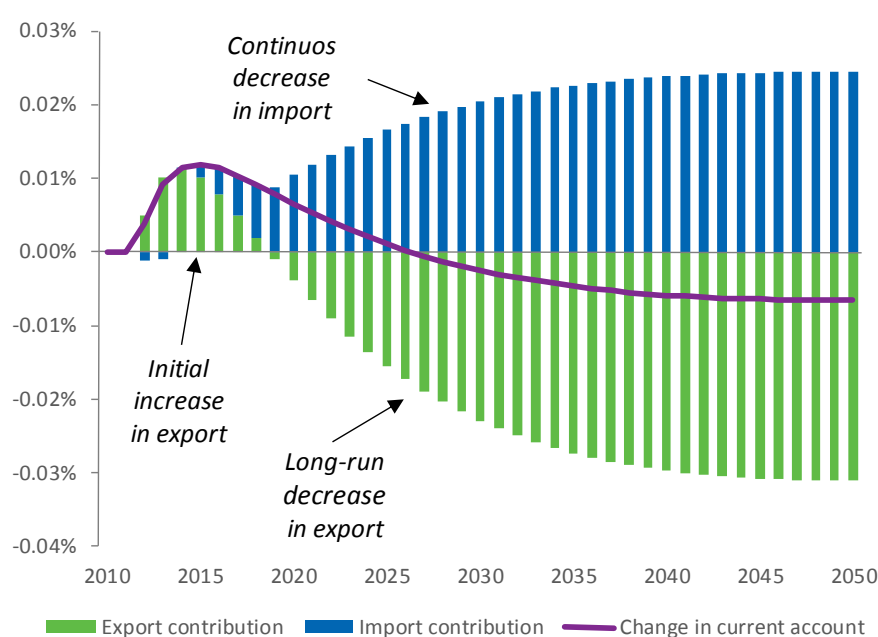


Table 22 Consumption-to-Leisure Shift (MEWA). Change in selected variables with respect to ‘no policy’.

	2020	2030	2040	2050
Wages	1.1%	1.7%	2.0%	2.0%
Interest rate	-0.3%	-0.5%	-0.5%	-0.5%
Energy use	-0.5%	-1.0%	-1.6%	-2.0%
Materials use	-0.8%	-1.5%	-2.1%	-2.5%
Energy intensity	0.5%	0.8%	0.9%	1.0%
Materials intensity	0.0%	0.1%	0.2%	0.2%

A shift from consumption to leisure will also generate interesting consequences for import, export and current account. Import will fall in line with domestic consumption, converging to a new steady state. However, as initially capital will become more abundant, some resources

will be shifted from investment goods towards export, leading to the positive change of current account immediately after the shift. However, in the long run exports will decrease as a result of a change in the relative terms of trade induced by the preference shift, leading to worsening of the current account.

Summing up, although enabling the shift from consumption to leisure will lead to some decrease of energy and materials used, it will also limit the productivity and hamper the competitiveness of the economy. Such change is also difficult to introduce and may require extensive promotional activities to affect individual choices. Therefore, other measures seem to be more useful in reducing the energy and materials use in the EU.

5 Summary per policy mix based on instrument assessment

The aim of this section is to provide a summarizing picture of the policies examined, exploiting the different insights provided by the different DYNAMIX modelling tools. Accordingly, those policy mixes analysed by more than one model are reported extensively. The reader interested in other policies tackled just by one model is addressed directly to the dedicated sections.

5.1 The Policy Mix for Metals and other Materials (PM-MOM)

5.1.1 Green Fiscal Reform: Materials Tax

The first indicator chosen to evaluate the policy is its effectiveness. In 2050 the material tax exerts a considerable compressing effect on the production activity of material intensive sectors, and fosters an overall dematerialization coupled with improvement in material efficiency in the EU economic activity (Figure 58). This ranges from the 12-20% as shown by the ICES and MEWA models to above 70% as shown by the MEMO II model.

It is interesting to note the crucial role of technological progress that is immediately visualized by the difference in results between the MEMO II and MEWA models and ICES. The former two models offer an endogenous description of technological progress and consequently of the dematerialization potential of economic systems. In other words, technological improvement is not independent upon the policy, but reacts to it as the tax provides a dynamic incentive to invest in more material efficient technologies. Accordingly, the policy is more (up to almost twice as much) effective. In the ICES model, which on the contrary features exogenous technological progress and constant input substitutability, this is not possible. Dematerialization is achieved by switching from materials to other input bundles, as long as feasible, but ultimately by reducing the economic activity. This higher rigidity translates into lower room to dematerialize and, in practice, also into higher policy costs.

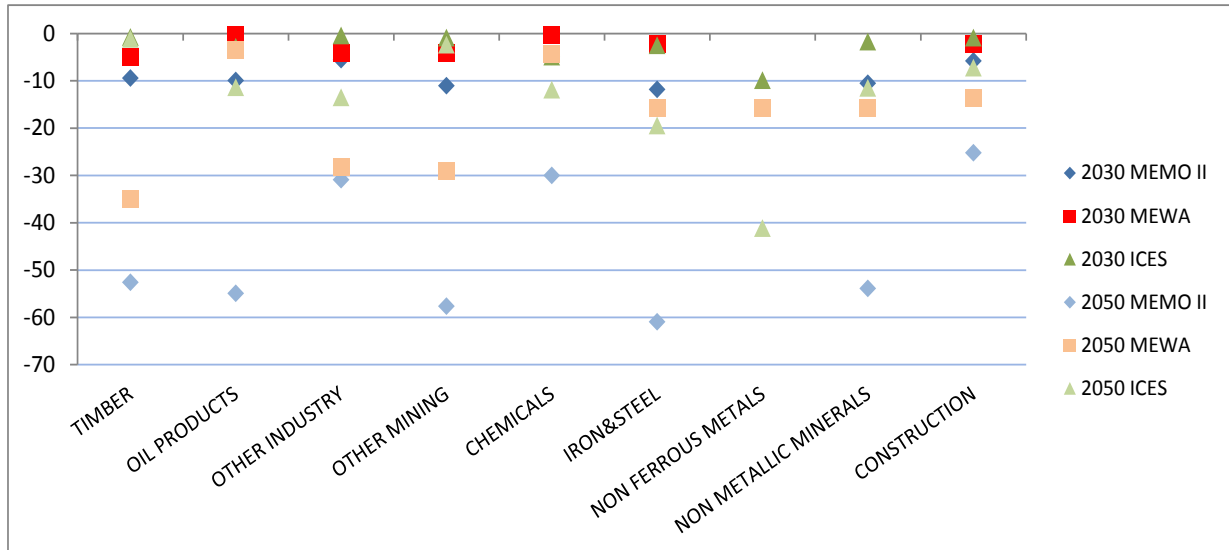
The policy design plays also a fundamental role as shown comparing EU GDP results across models (

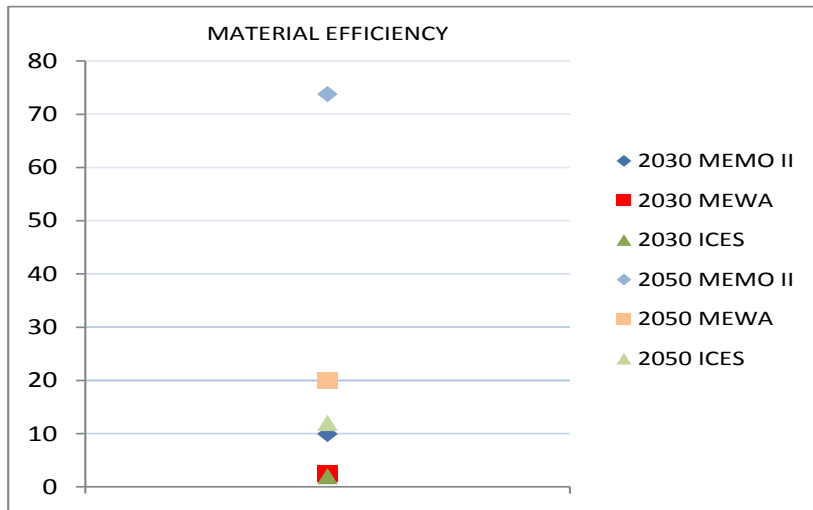
Figure 59). A sound use of tax revenues can indeed turn potentially huge policy costs, that in the case of exogenous technical progress and lump-sum rebate to households can reach the

-6% of GDP (as shown by ICES), to non-negligible gains: 2% of GDP if a 50% revenue recycling toward reduction in labour cost is pursued (as shown by MEMO II). Gains can be higher if the recycling is total and used to cut in labour taxes and partially to public support to R&D (MEWA results). The cut in labour taxes and the positive effects on GDP are then transmitted to employment which increases the 6 and 7% in 2050 according to MEMO and MEWA respectively.

In summary, the two success pillars of the material tax policy are the reactivity of technological progress to policy signals and the appropriate recycling of tax revenues. A further issue is worth noticing: in the presence of declining production of material intensive sectors, GDP and employment gains can be supported, only if the service sector expands adequately. This is a further aspect of structural change that needs appropriate governance. All these issues thus call for a proactive and far-sighted role of policy making that has to identify effective cooperation pathways with the private sector.

Figure 58 Materials Tax. Sectoral production: top; material efficiency: bottom. % change with respect to 'no policy' in the reference scenario.

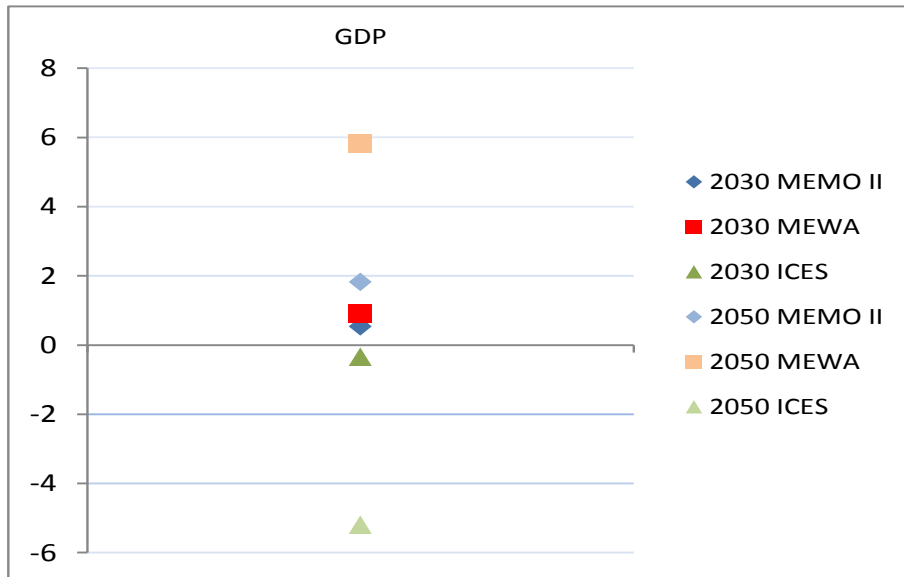




Note: Material efficiency expressed in MEMO II as value of output / material inputs (the data in the figure is the average across chemicals, metals, non-metallic minerals, manufacturing, energy and construction sectors); expressed in ICES and MEWA as material intensity of GDP.

In ICES tax revenues are rebated lump-sum to households, in MEMO II they are 50% recycled through cut in labour taxes; in MEWA they are 100% recycled through cut in labour taxes.

Figure 59 Materials Tax. GDP: % changes with respect to 'no policy' in the reference case.



Note: In ICES tax revenues are rebated lump-sum to households, in MEMO II they are 50% recycled through cut in labour taxes; in MEWA they are 100% recycled through cut in labour taxes.

5.1.2 Green Fiscal Reform: Internalisation of External Environmental Costs

The internalization of environmental costs is implemented either through a 35% tax levied on all non-services sectors, or via differentiated tax rates that vary according to the average sulphur oxides, nitrogen oxides, and particulates emission intensities of specific sectors.

There is a general agreement across the models, on the depressing effect of the policy on the production of material intensive sectors. There is a maximum expected decline of the 25% compared to the no policy baseline in 2050 in the construction sector according to MEMO II and of 5% in the chemical sector in MEWA. Output contractions tend to be smaller in MEWA as the simulation foresees a full recycling of tax revenues to cut labour taxation, which boosts employment, GDP, and, accordingly, rebounds positively on demand. In MEMO II only 50% of tax revenues are recycled into lower labour taxes, while the rest is rebated lump-sum to households.

This appears also the main justification for the different impacts on material efficiency and on GDP highlighted by the two models. In MEMO II in fact GDP declines and overall material efficiency of the economic system improves just slightly (Figure 60). In fact, the latter declines in material intensive sectors (Figure 27 of section 4.3.2). In particular, the policy induces a reduction in sectoral production which eventually turns to be higher than that in material use. This is also a consequence of the smaller stimulus to a 'dematerialization-oriented' technical progress offered by the policy. In MEWA, the opposite occurs. Full recycling sustains also demand and thus maintains the convenience to invest in material efficiency in the sectors hit by the taxation.

The two models are discordant about the effects of the flat and differentiated tax rates on main macroeconomic variables. In MEMO II, GDP losses are smaller and employment gains larger in the differentiated tax rate case. This occurs as an 'economic re-composition effect' prevails, and more labour intensive sectors, like manufacturing and construction, are less penalized under the differentiated tax regime. In the MEWA model a 'revenue raising effect' prevails. The flat tax produces higher revenues than the differentiated tax regime. Therefore, although the latter induces lower losses in more labour intensive sectors, the larger availability of revenues to recycle of the former allows larger economic gains.

To conclude, MEWA also analyses an alternative recycling scheme involving a reduction on VAT. It is shown that in this cases GDP and employment gain are much smaller, but the effectiveness in curbing material uses are larger.

In summary, the costs and effectiveness of the policy, greatly depend upon the design of the policy itself.

Figure 60 Internalisation of Environmental Externalities. % changes with respect to 'no policy' in the reference case. Sectoral production: top; material efficiency: bottom.

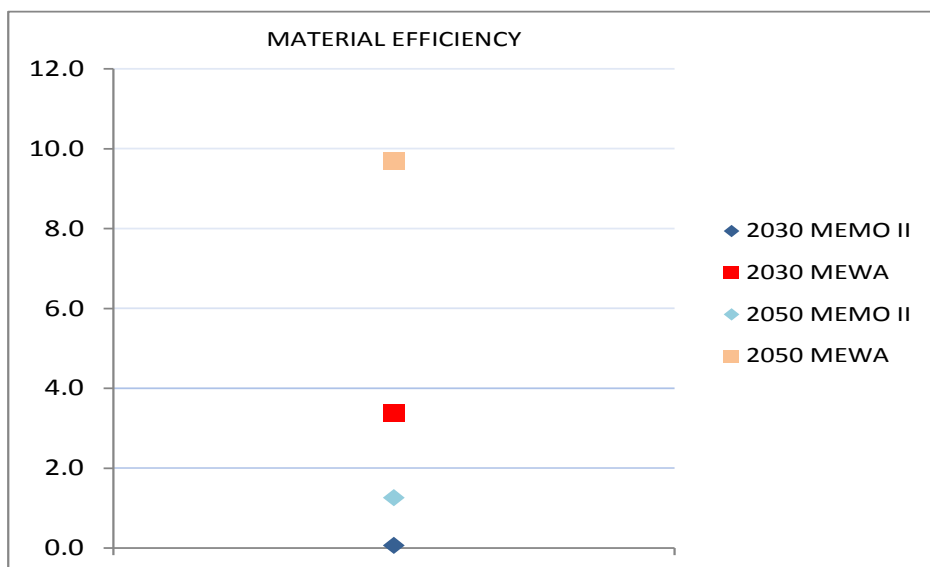
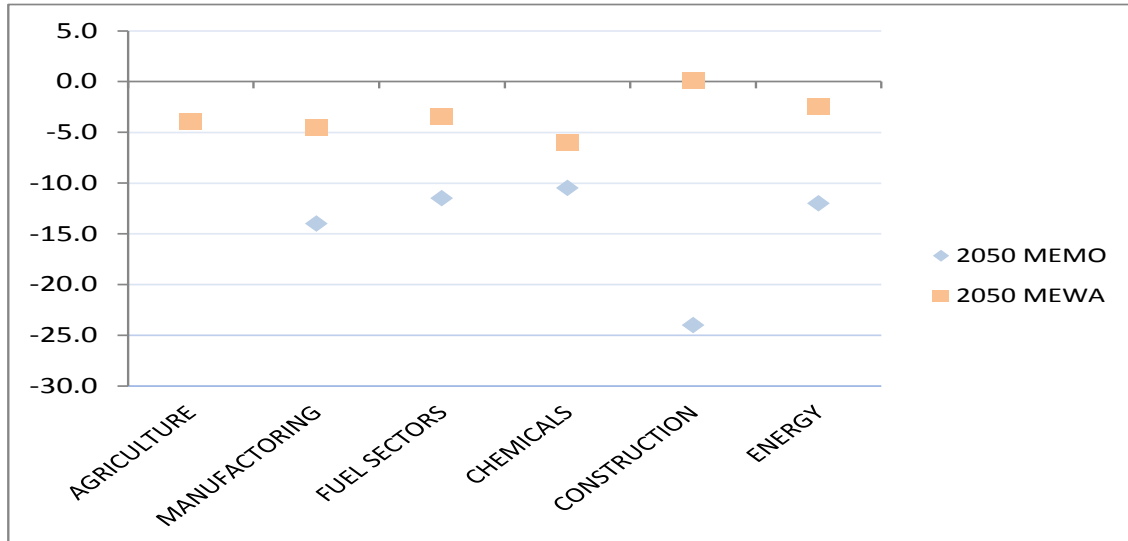
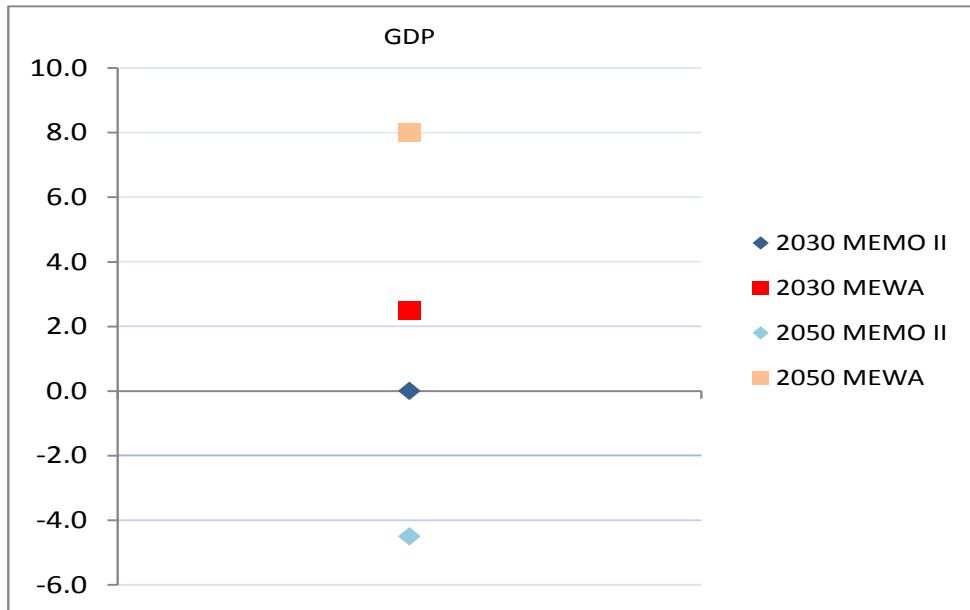


Figure 61 Internalisation of Environmental Externalities. GDP: % changes with respect to 'no policy' in the reference case.



5.2 The Policy Mix for Land Use (PM-LU)

5.2.1 Strengthened pesticide reduction targets under the Pesticides Directive

The policy on pesticides is implemented both in ICES and MEWA as a tax on the broader use of chemicals by the agricultural sectors.

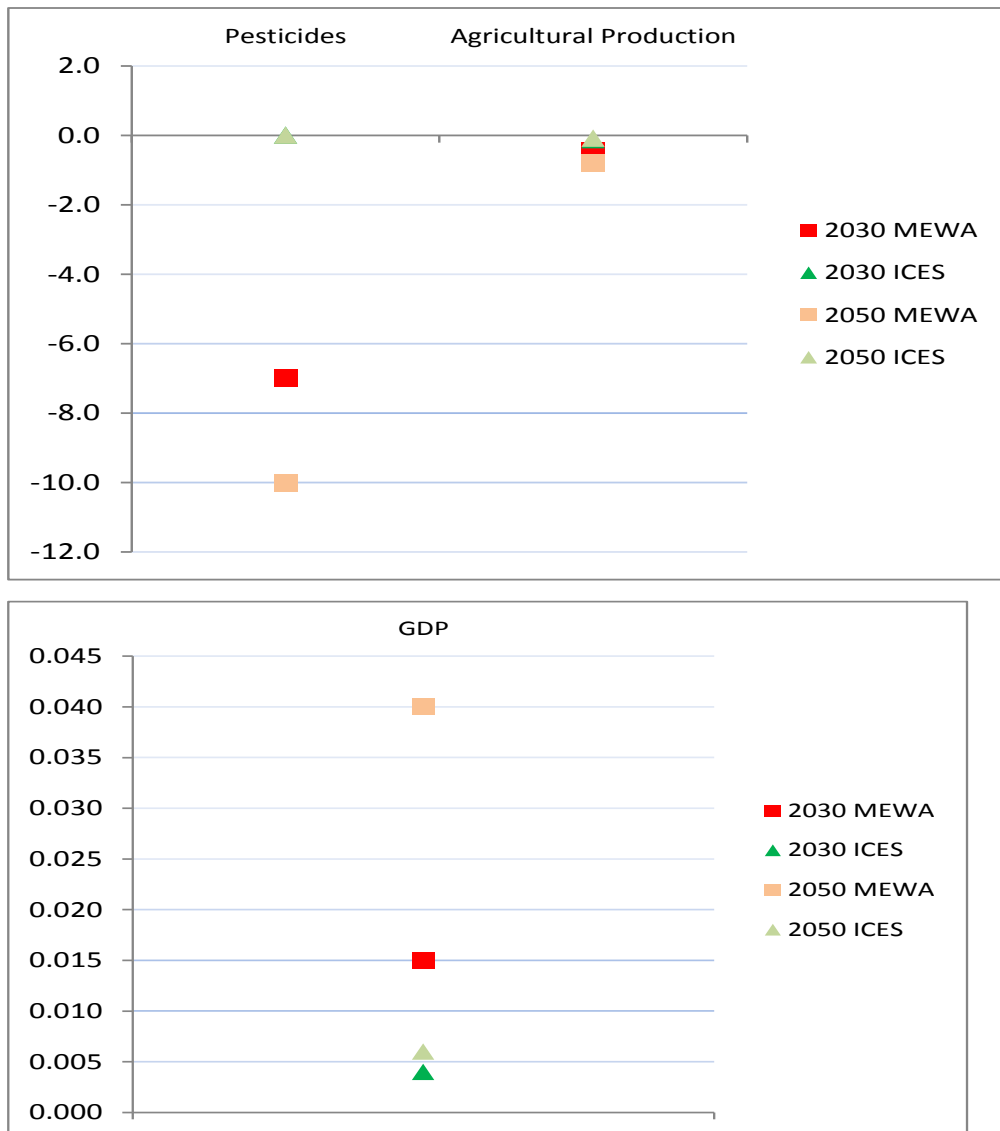
The direct impact of the tax on the use of chemical products in agriculture is relevant according to MEWA: -7% in 2030 and -10% in 2050. It is much more limited in ICES: -0.1% in 2030 and -0.05% in 2050. ICES thus features a much smaller substitutability of chemicals with other inputs in agriculture (Figure 62).

Both models agree on a limited effect of the tax on the EU agricultural activity (which in 2050 contracts by 0.08% and by 0.8% according to ICES and MEWA, respectively) and of an even smaller effect on overall EU GDP. This last in 2050 can in fact be slightly positive (0.006% and 0.04% according to ICES and MEWA respectively). In MEWA this is mostly induced by the spur to employment and economic activity of the cut in labor taxation financed by the pesticide tax revenues¹¹. In ICES, the tiny GDP gains are due to a rebound and sectoral re-composition effects of the economic activity.

¹¹ These positive effects indeed could vanish, and the pesticide tax could turn to be moderately depressing for GDP (featuring a maximum contraction of the 0.16% in 2050) if the fiscal reform were aimed to cut VAT or corporate income taxes rather than labour taxes.

Interestingly, ICES, which compared to MEWA provides a richer representation of the international trade relations of the EU countries, shows an increase, albeit small, in EU chemical sector production. This is explained by the increase in agricultural production outside the EU favored by the higher prices of EU agricultural commodities that brings about an increased demand of fertilizers and pesticides, including those produced in the EU which are exported.

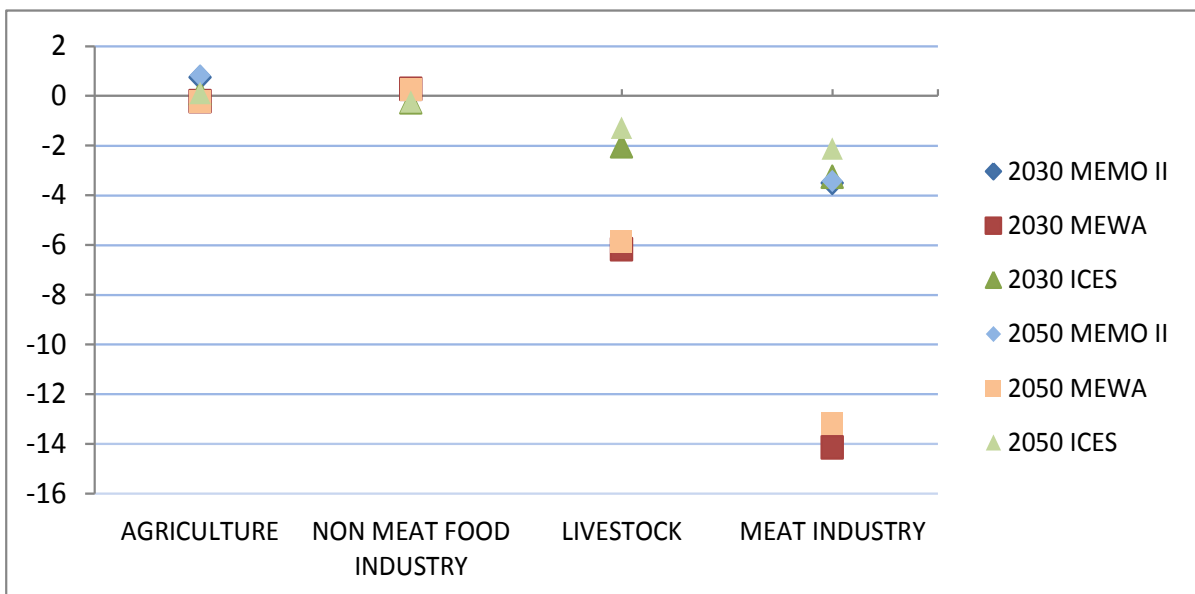
Figure 62 Pesticide Tax. % changes with respect to 'no policy' in the reference case. Sectoral production: top; GDP: bottom.

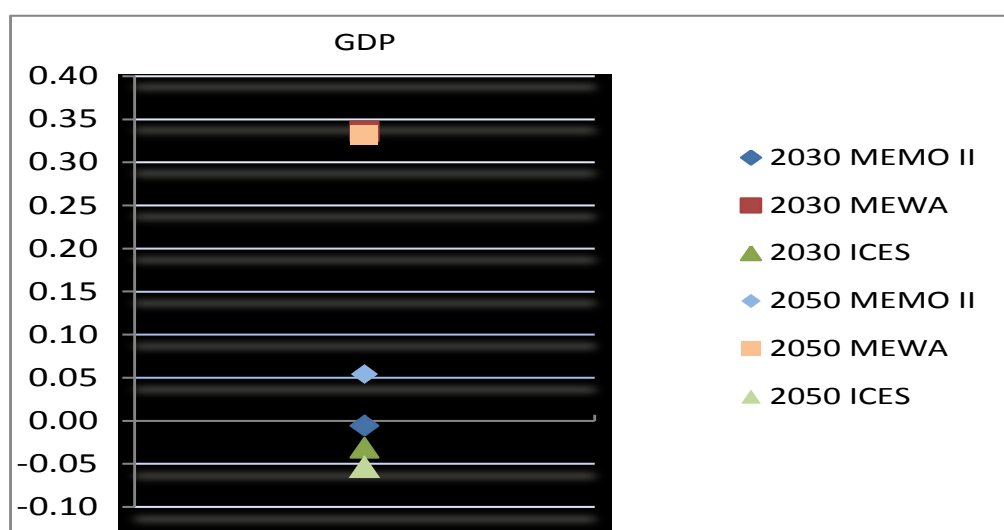


5.2.2 VAT on meat

The VAT on meat policy instrument, albeit addressing a fundamental and widespread habit like meat consumption, shares with the circular economy tax trio the narrow sectoral coverage of its action, and the small relative economic relevance of the targeted sector. The policy has, thus, mostly a sector-specific relevance and limited systemic impact (Figure 63). Raising the VAT on meat to the EU average level is moderately successful in reducing meat consumption and, to a lesser extent, given the possibility for EU producers to export outside the EU what is not demanded internally, meat production (between 2.5 and 14% in 2050 depending upon the model). According to the MEMO II and ICES models, the export trend is strengthened by the decrease in meat prices in the world market following the EU demand contraction, which in turn increases non-EU meat demand. In MEWA, EU exports (for all sectors including meat) slightly decline initially as the negative labour supply effect on production determined by the lower purchasing power of household income is prevalent. The policy then spurs the desired substitution toward the consumption of ‘non-meat’ based food. Nonetheless, given the size of non-meat compared to meat food consumption in the EU, the increase in non-meat food industry production is tiny (max 0.7% according to MEMO II in 2050) or potentially even slightly negative (-0.24% according to ICES). This result depends on the combination of a generalized demand contraction (lower GDP) and of higher input costs as meat products are used as intermediates also by the non-meat industry.

Figure 63 VAT on Meat. % change with respect to ‘no policy’ in the reference scenario. Sectoral production: top; GDP: bottom.





5.3 The Overarching Policy Mix (PM-O)

5.3.1 The Circular Economy Tax Trio

The circular economy tax trio policy targets virgin materials. Like the material tax policy, the circular tax design aims to foster a lower use of virgin materials and promote recycle and re-use, but with a much narrower scope as it focuses specifically on raw materials (excluding metals) extraction. This activity is hit through a tax on raw material purchases from the non-metallic transformation sector which on its turn is also penalized with an export tax.

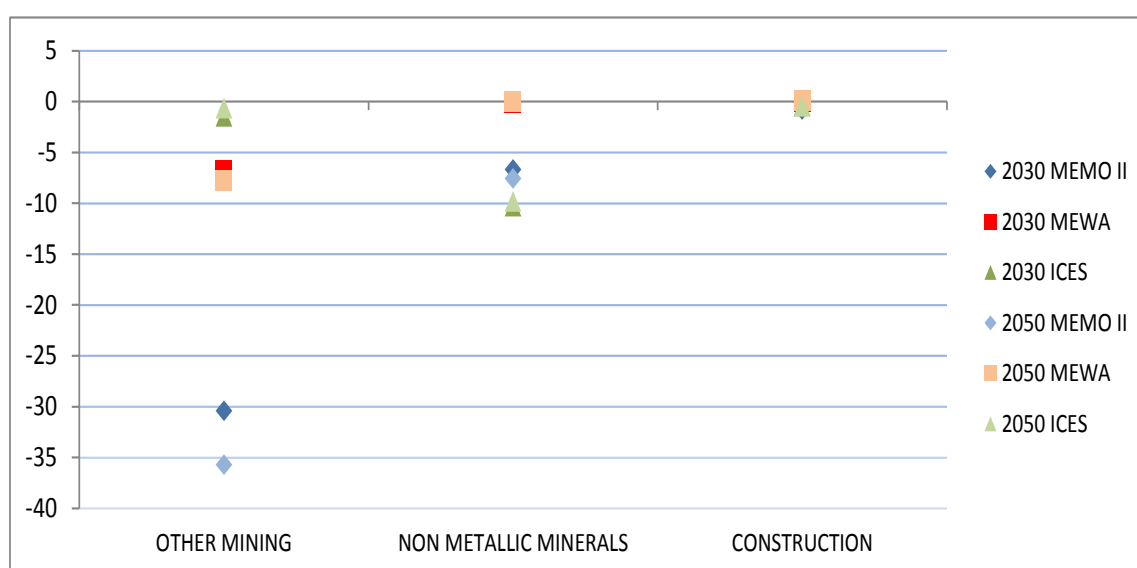
All in all, also in the light of the limited relative economic relevance of the mining sector in the EU, policy effects are particularly relevant for the raw-material intensive branches of the production system, but systemic effects, at the level of overall economic activity are small. The case of construction is topical. It absorbs raw materials either directly or indirectly, incorporated in the output from the non-metallic mineral transformation sector. Accordingly, one would expect that construction could be particularly concerned by the manoeuvre.

In fact, all the models agree in showing just a marginal policy impact. Maximum production loss in construction is 0.5% in 2050, highlighted by the ICES model (Figure 64). This is also a direct consequence of the policy design itself, which does not tax imports nor exports of non-European raw materials or intermediates. It thus allows constructions to find cheaper input substitutes in non-EU markets. Furthermore, improved recycling offers an additional source of input to the sector. Not surprisingly, mining (of non-ferrous minerals) and the associated transformation sector are more heavily affected. Mining could experience a production

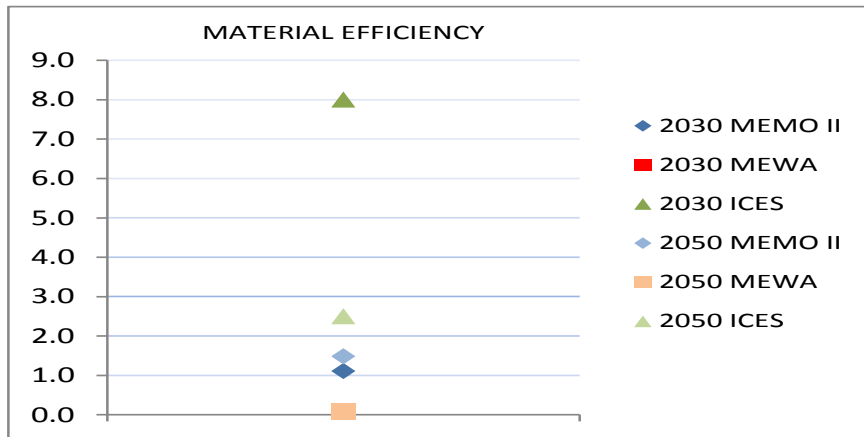
contraction in the range 7-35% according to MEWA and MEMO II.¹² The non-metallic mineral transformation sector declines roughly by 7-10% according to MEMO II and ICES. The MEWA model highlights almost null losses as the revenues generated by the tax are used to cut labour taxes, something which fosters employment and production. The overall dematerialization potential of the policy, especially in the long term is limited compared to that for instance of the material tax. The best result in 2050 is a 3% improvement with respect to the reference scenario in the MEMO II model.

Eventually, effects on GDP are tiny (Figure 65). They are slightly positive according to MEWA due to the recycling effect. The small gains however, witness the small volume of revenues available to be recycled and thus the moderate scope of the policy. ICES and MEMO II, in which revenues are on the contrary rebated lump-sum to households, demonstrate limited GDP losses.

Figure 64 Circular Economy Tax Trio. % change with respect to 'no policy' in the reference scenario. Sectoral production: top; material efficiency: bottom.



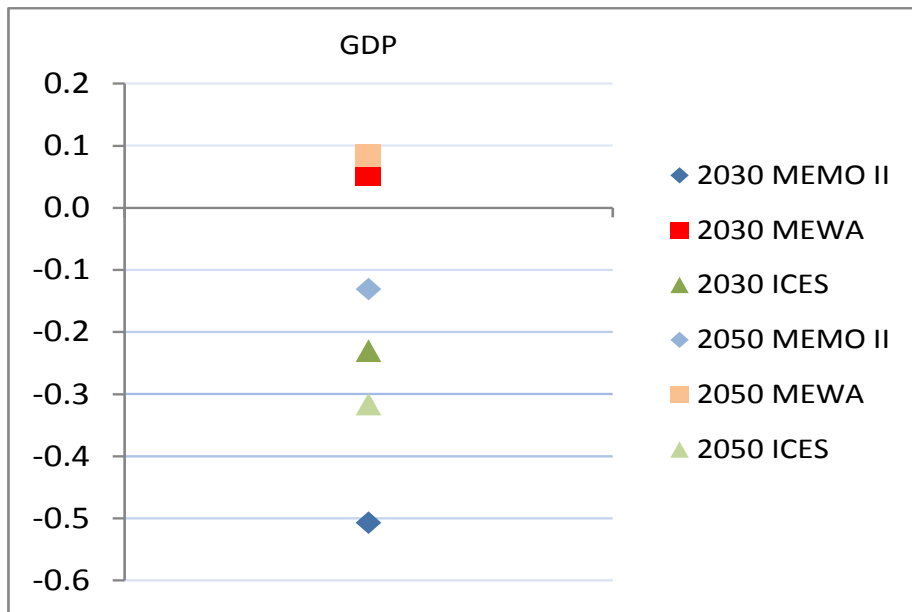
¹² In this comparison, ICES is not particularly informative, as its 'other mining' sector include also metal mining activity which is not targeted by the policy. Therefore effects on this larger aggregate are considerably smaller.



Note: Material efficiency expressed in MEMO II as value of output/value of material inputs (the data in the figure is the average across chemicals, metals, non-metallic minerals, manufacturing, energy and construction sectors); expressed in ICES and MEWA as inverse of material intensity of GDP. Accordingly a positive % change means that material intensity declines.

In ICES and MEMO II tax revenues are rebated lump-sum to households; in MEWA they are 100% recycled through cut in labour taxes.

Figure 65. Circular economy tax trio. GDP: % change with respect to 'no policy' in the reference scenario.



6 Summary of methodological/analytical framework findings

6.1 The metal policy mix

The quantitative assessment reported in this deliverable examined three different policies in the metals policy mix presented in Ekvall et al. (2015): a material tax, a tax aimed at internalising environmental externalities, and an increase in public spending on material efficiency R&D.

These policies are based on very different designs and implementation strategies, therefore, any inter-policy comparison is particularly challenging.

A common trait of these policies is however their breadth. They have direct and indirect effects on many sectors, and thus have impacts which are relevant not just at sectoral level, but are also clearly detectable on the overall EU GDP.

The first two policies are based on taxes. The strongest message from the analysis is that the cost of the policy crucially depends upon (a) the sensitivity of the production system to the dynamic incentive to dematerialize induced by the policy signal, i.e. ultimately upon the reaction (or availability) of technological progress (b) the use of tax revenues, i.e. on the implementation of an appropriate revenue-recycling scheme.

A combination of technological progress in response to the tax with a reduction in labour taxation can indeed, according to the modelled outcomes, end up stimulating economic growth (a maximum 8% GDP gain in 2050) and increasing material efficiency (in a range between 12 to more than 70% in 2050), reaping a material “double dividend”: more GDP and lower material use. Without these two factors, however, especially when taxes are rebated lump-sum to households, the policy can be particularly depressing for GDP, and, as a further drawback, might even worsen, rather than increase material efficiency in many material intensive sectors of the economy. This can happen when the reduction in economic activity outpaces the decline in material use at the sectoral level.

Recycling material tax revenues to reduce VAT also proves to be inferior in terms of GDP performance than the cut in labour taxes. However, in this case improvements in material efficiency are higher. The tax shift does indeed increase the relative price of intermediates

and reduces that of consumption, inducing a further stimulus to material efficiency. In this case there is a trade-off between effectiveness in material decoupling, and impacts on GDP.

All in all, the tax shift fosters a huge transformation of the production system. Therefore, even though, according to model simulations, net GDP gains can take place, material intensive sectors would be highly penalized, with a sharp contraction in economic activity (a good example is the iron and steel sector which may experience a production decline up to 60% when exposed to a material tax). This calls for a careful designing and planning of the policies devising a set of accompanying measures to smooth the most adverse social effects.

Interestingly, the increase (actually a doubling) in public investment for R&D dedicated to material efficiency, whether financed through increases in labour, corporate or value added taxation, seems to have the highest potential to boost GDP among the three policies here considered with reference to the metal policy mix. This occurs through the induced expansion of the production frontier that allows firms to eventually produce more with a lower material intensity of output. This policy is also the least burdensome for material intensive sectors. In fact, final material use can also increase, as an economic “rebound effect” materializes with the “production scale” effect being larger than the “material use decline” effect. This raises a caveat in the use of public funds: although supporting material efficiency R&D might seem the “optimal” policy to foster absolute decoupling, it should be accompanied by further regulation or incentives limiting material use or promoting dematerialized services.

6.2 The land policy mix

The land policy mix instruments that we assessed were strengthened pesticide reduction, an increase in the VAT on meat and a targeted information campaign to influence food behaviour towards less meat intensive diets. They address a group of sectors with a relatively limited contribution to EU value added. Thus, like the overarching policy mix (see below), the land policy mix is relevant at sectoral level, but much less at the aggregated economic level.

More specifically, raising the VAT on meat to the EU average VAT level can be successful in reducing meat consumption (between 2.5 and 14% in 2050). Meat industry exports generally increase following the decrease in world meat prices due to the contraction of EU demand. ‘Non-meat’ based food production in the EU could slightly increase (max. 0.7% according n 2050) or slightly decrease (-0.24%). This result might occur when a generalized demand contraction induced by the lower GDP meets higher input costs (as some meat products are used as intermediates also by the non-meat food industry). Again, final GDP impacts are

determined by the use of VAT revenues. If they are rebated lump-sum to households, GDP in the EU could decline by 0.05%; if labour taxes are reduced, GDP could increase by 0.35%.

Qualitatively similar effects on meat industry production (a contraction by 6% in the ICES model) and slight GDP gains (by 0.04% in the EU in 2050) would be induced by the information campaign to shift food consumption habits, based on our assumptions about the impact of the campaign on behaviour. Notably, the effect on GDP is positive, and not negative as in the VAT case, even without an accompanying reduction in labour taxes. This occurs as the recomposition of preferences is not induced by any active tax policy which ultimately impacts household income, but just by the “persuasion” of consumers. In this sense, inducing “just” a substitution and not an income effect, the action of the campaign is less invasive. Furthermore, it seems that the overall recomposition of the household consumption bundle ultimately induces some positive terms of trade effects. However, it has to be recognized that there is a huge uncertainty on the effectiveness of information campaigns and on the time they would need to accomplish the desired results. These issues are not considered in the current analysis though.

The pesticide tax, finally, can reduce the use of pesticides (up to 10% in the models) while exerting a limited effect on the EU agricultural activity (which in 2050 contracts of the 0.08% - 0.8%) and an even smaller one on overall EU GDP. When changes are so small, however, it is possible that indirect effects prevail over direct effects, thereby compensating the intended positive effects of the policy by simply shifting the burden abroad. For instance, in some simulations, an increase, albeit small, in EU chemical sector production is observed. This is explained by the increase in agricultural production outside the EU favored by the higher prices of EU agricultural commodities, which brings about an increased demand for fertilizers and pesticides, including those produced in the EU, which are exported more. This potential impact, in addition to the environmental impacts of increased production outside the EU in the event of a decline in EU production, suggests that the elements in the policy instrument which aim at ensuring that a reduction in pesticide use is not accompanied by a reduction in productivity are important, and should be further strengthened.

6.3 The overarching policy mix

The quantitative analysis of the overarching policy mix investigates two policies: a ‘circular economy tax trio’ that includes, among other things, a tax penalizing the purchases of extracted virgin materials by all sectors (taxing waste incineration and landfilling could not be implemented in the models), and a policy aiming to create conditions to improve the utility

from leisure allowing a behavioural shift away from (material) consumption towards the “non-monetary” part of utility.

Like the material tax policy (see above), the circular tax design aims to foster dematerialization, recycle and re-use, but with a much narrower scope as it focuses specifically on raw materials (excluding metals) extraction.

All in all, also in the light of the limited relatively economic relevance of the mining sector in the EU, policy effects are mostly felt by raw-material-intensive branches of the production system, while systemic effects are small. Not surprisingly, mining of non-ferrous minerals (experiencing a production contraction in the range of 7-35%) and the non-metallic minerals transformation sector (contracting 7-10% by mid-century) are the more heavily affected. Once again, revenue recycling mechanisms play some role. Nonetheless, the small volume of revenues available to be recycled does not allow for significant GDP and employment expansion. Similarly, the absence of recycling does not cause huge GDP impacts, although they remain slightly negative (-0.32% in 2050). The overall dematerialization potential of the policy, especially in the long term, is limited if compared to that for instance of the material tax, producing at best a 3% material efficiency improvement with respect to the reference scenario.

The basic consequence of the increase in leisure is the decrease in the labour supply. Therefore, the price of labour (wages) will increase, leading to some substitution of labour with capital, energy and materials. In the short run, this will increase the capital-to-GDP ratio, energy-intensity and material intensity. However, in the long run, as the economy will produce less goods to be consumed, an absolute reduction in the use of energy and materials will occur along with the decline in GDP. Exports will also be penalized with potential negative consequences on the current account.

7 Conclusions

The purpose of deliverable D6.2 is to support with a quantitative economic assessment the evaluation of a set of policies scrutinized within the DYNAMIX project, aiming to promote decoupling of resources use from GDP and material efficiency within the EU.

The analytical tools used for the investigation are three macro-economic models, ICES, MEMO and MEWA, all belonging to the category of Computable General Equilibrium modelling, but with complementary characteristics. More specifically: they all provide a sectoral representation of the EU economic system and endogenous price formation. In practice, they can assess direct and indirect policy effects on the whole economic system and the full macroeconomic feedbacks, beyond the sector initially subjected to the policy intervention. However, ICES representing the EU with a country detail, is better suited to capture intra and extra EU trade effects. MEWA and MEMO consider the EU as a single region, but differently from ICES, offer a more realistic representation of technological change, feature forward looking agents and have a richer representation of labour supply choices.

The first two policies examined - a material tax and a tax aimed at internalising environmental externalities - are based on different designs and implementation strategies. Nonetheless, their common trait is the breadth. They have direct and indirect effects on many sectors, and thus have impacts clearly detectable on the overall EU GDP.

The strongest message from the analysis is that the cost of the policy crucially depends upon (a) the sensitivity of the production system to the dynamic incentive to dematerialize induced by the policy signal, i.e. ultimately upon the reaction (or availability) of technological progress and (b) the use of tax revenues, i.e. on the implementation of an appropriate revenue-recycling scheme.

A combination of technological progress in response to the tax with a reduction in labour taxation can indeed, according to the modelled outcomes, end up stimulating economic growth (a maximum 8% GDP gain in 2050) and increasing material efficiency (in a range between 12 to more than 70% in 2050), reaping a material “double dividend”: more GDP and lower material use. Without these two factors, however, especially when taxes are rebated lump-sum to households, the policy can be particularly depressing for EU GDP (up to -5%), and, as a further drawback, might even worsen, rather than increase material efficiency in

many material intensive sectors of the economy. This can happen when the reduction in economic activity outpaces the decline in material use at the sectoral level.

All in all, the tax shift fosters a huge transformation of the production system. Therefore, notwithstanding final net GDP gains, material intensive sectors would be highly penalized (a good example is the iron and steel sector which may experience a production decline up to 60% when exposed to a material tax). This calls for a careful designing and planning of the policies devising a set of accompanying measures to smooth the most adverse social effects.

Increasing public investment for R&D dedicated to material efficiency, whether financed through increases in labour, corporate or value added taxation, seems to have the highest potential to boost GDP among the three policies and is also the least burdensome for material intensive sectors. In fact, final material use can also increase, as an economic “rebound effect” materializes with the “production scale” effect being larger than the “material use decline” effect. This raises a caveat: although supporting material efficiency R&D might seem the “optimal” policy to foster absolute decoupling, it should be accompanied by further regulation or incentives limiting material use or promoting dematerialized services.

Despite the obvious differences, the tax to foster pesticide reduction, the increase in the VAT on meat and a targeted information campaign to influence food behaviour towards less meat intensive diets, address a group of sectors with a “low weight” in term of EU value added. Thus, their relevance is prominently sectoral.

Raising the VAT on Meat to the EU average VAT level can be successful in reducing meat consumption (between 2.5 and 14% in 2050). Meat industry exports are expected to increase in response to the decrease in world meat prices following the contraction of EU demand while effects on ‘Non-meat’ based food production in the EU is ambiguous but anyway moderate (0.7%, -0.24% in 2050 depending on the model). Potential declines in ‘Non-meat’ based food production might occur when the demand contraction induced by the tax on household budget meets higher input costs as some meat products are used as intermediates also by the non-meat food industry. Again, final GDP impacts are determined by the use of VAT revenues. If they are rebated in a lump sum to households, GDP in the EU could decline by 0.05%; if labour taxes are reduced, GDP could increase by 0.35%.

Comparable effects on meat industry production (a contraction by 6% in the ICES model) and slight GDP gains (by 0.04% in the EU in 2050) would be induced by the information campaign to shift food consumption habits. Notably, the effect on GDP is positive, rather than negative as in the VAT case, even without an accompanying reduction in labour taxes. This occurs as the recomposition of consumers’ preferences is not induced by any active tax policy which

ultimately impacts household income, but just by the “persuasion” of consumers. In this sense, inducing “just” a substitution and not an income effect, the action of the campaign is less invasive. However, it has to be recognized that there is a huge uncertainty on the effectiveness of information campaigns and on the time they would need to accomplish the desired results. These issues are not considered in the current analysis though.

The pesticide tax, finally, can reduce the use of pesticides (up to 10% in the models) while exerting a limited effect on the EU agricultural activity (which in 2050 contracts of the 0.08% - 0.8%) and an even smaller one on overall EU GDP. When changes are so small, however, it is possible that indirect effects prevail over direct effects. For instance, in some simulations, an increase, albeit small, in EU chemical sector production is observed. This is explained by the increase in agricultural production outside the EU favored by the higher prices of EU agricultural commodities, which brings about an increased demand for fertilizers and pesticides, including those produced in the EU, which are exported more. Eventually, the policy would not induce a decrease in the negative externality, but its de-location abroad. Thus, these unintended secondary effects should be dealt with specific corrections.

Like the material tax policy, the circular tax design aims to foster dematerialization, recycle and re-use, but with a much narrower scope as it focusses specifically on raw materials (excluding metals) extraction. In the light of the relatively limited economic relevance of the mining sector in the EU, policy effects are mostly felt by raw-material-intensive branches of the production system, while systemic effects are small. Not surprisingly, mining of non-ferrous minerals (experiencing a production contraction in the range of 7-35%) and the non-metallic minerals transformation sector (contracting 7-10% by mid-century) are the more heavily affected. Once again, revenue recycling mechanisms play some role. Nonetheless, the small volume of revenues available to be recycled does not allow for significant GDP and employment expansion. Similarly, the absence of recycling does not cause huge GDP impacts, although they remain slightly negative (-0.32% in 2050). The overall dematerialization potential of the policy, especially in the long term, is limited if compared to that for instance of the material tax, producing at best a 3% material efficiency improvement with respect to the reference scenario.

The last policy examined, is the shift towards more “leisure consumption”. Its direct consequence is the decrease in the labour supply. Therefore, the price of labour (wages) will increase, leading to some substitution of labour with capital, energy and materials. In the short run, this will increase the capital-to-GDP ratio, energy-intensity and material intensity. However, in the long run, as the economy will produce less goods to be consumed, an absolute reduction in the use of energy and materials will occur along with the decline in

GDP. Exports will also be penalized with potential negative consequences on the current account.

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