Competitiveness modelling for air quality policies in the EU

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ABSTRACT

On 19/12/2013, European Commission (EC) adopted the "The Clean Air Policy Package", where it proposes new air pollution reduction objectives for the period up to 2030, as well as instruments to deliver those objectives. Before the European Commission can propose a new initiative, it mandatorily has to conduct an Impact Assessment, evaluating the potential economic, social and environmental consequences. This paper explains in detail the modelling done with a Computable General Equilibrium model, GEM-E3, for the Impact Assessments accompanying this recent EU policy proposal. The GEM-E3 model is a recursive dynamic computable general equilibrium model which covers the interactions between the economy, the energy system and the environment. In general the paper illustrates how quantitative modelling can directly contribute to real world policy decisions by providing an assessment of socio-economic impacts of air quality policies.

INTRODUCTION

In March 2014 the UN World Health Organization (World Health Organization, 2014), released a study reporting that in 2012 around 7 million people died –one in eight of global deaths- as a result of air pollution exposure. WHO states[4] that "this finding more than doubles previous estimates and confirms that air pollution is now the world's largest single environmental health risk", and that "reducing air pollution could save millions of lives".

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[1] *The views expressed are purely those of the author and may not in any circumstances be regarded as stating an official position of the European Commission.*

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[4] http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/

While over the last couple of decades the EU air quality policy (European Commission 2005a, 2005b) has shown important progress in curbing emissions of harmful pollutants such as fine particulate matter, sulphur dioxide, lead, nitrogen oxides, carbon monoxide and benzene, ambient concentrations of several pollutants are still beyond levels that could be considered safe. Fine particles and ozone, in particular, still present significant health risks and the air quality guidelines of the WHO are generally not being met. Many EU Member States are still falling short of agreed EU air quality standards, with high costs for the healthcare system and for the economy at large. For the long term, the EU's Environment Action programme set the objective to achieve levels of air quality that no longer give rise to significant negative impacts on and risks to human health and the environment.

With the dual objective to achieve as soon as possible compliance with existing air quality legislation, and to make substantial further progress towards the EU's long-term objective, the European Commission (EC) adopted on 19/12/2013, the "The Clean Air Policy Package"[5] (European Commission, 2013). The strategic framework of the Package is set out in the communication 'A Clean Air Programme for Europe'. Among other components, the package also includes two legislative proposals: one introduces EU-wide emission limits for medium combustion plants[6], the other revises the National Emission Ceilings Directive by setting stricter national emission ceilings in 2030 for the four currently regulated pollutants (SO_2, NO_x, VOCs and NH_3) and by adding ceilings for primary PM2.5 and methane (CH_4).

Before the European Commission can propose a new initiative, it mandatorily has to conduct an Impact Assessment, evaluating the potential economic, social and environmental impacts[7]. This impact assessment of the "Clean Air Policy Package" includes an ex-ante analysis of an update of the EU's strategy on air pollution and the development of accompanying legal proposals and non-regulatory actions.

This paper explains in detail the modelling done with a Computable General Equilibrium model, GEM-E3, for the related Impact Assessment. In general the paper illustrates how quantitative modelling can directly contribute to real world policy decisions. In particular, the GEM-E3 model is used to assess the macro-economic and competitiveness effects of different policy options. The effects analysed include GDP, sectoral activity, exports and imports, employment, private consumption and welfare.

For the "The Clean Air Policy Package" (European Commission, 2013), the GEM-E3 model analyses the broader economic impacts beyond the emission abatement costs delivered by the GAINS model. These include, among others, the indirect effects of purchasing the abatement technologies, final

[5] The 2013 proposal reviews of the Thematic Strategy on Air Pollution from 2005 (European Commission, 2005a) which established objectives for the protection of health and the environment from the adverse impacts of air pollution.

[6] Medium Combustion Plants (MCP) are those with rated thermal input comprised between 1 and 50 MW. Larger plants are regulated by the Industrial Emissions Directive (formerly Large Combustion Plants Directive); smaller plants are generally within the scope of the Ecodesign Directive

[7] http://ec.europa.eu/smart-regulation/impact/index_en.htm

demand and employment as well as on the competitiveness of the various sectors. In general terms, expenditure on pollution abatement is a cost for the sectors that need to reduce pollution, resulting in higher production costs for the complying sectors that would lead to reduced domestic consumption and a loss of international competitiveness. However, the installation of abatement technologies is also an economic opportunity for the sectors that produce these technologies. In this context, the Commission's core objective was to evaluate the overall balance of these counteracting drivers and identify whether or not any of the potential negative impacts would be significant.

The main aim of this exercise is thus to assess the broader, both direct and indirect economic impacts of the air quality policies. Our approach mainly focuses on the indirect effects of the abatement-related expenditures on final demand and employment as well as on the competitiveness of the abating sectors. We also demonstrate that the improved labour productivity thanks to avoided morbidity has positive macro-economic impacts on the European economy, possibly even exceeding the costs of the policy. However, we do not repeat this for all the other direct economic benefits that are part of the Impact Assessment (European Commission, 2013), such as reduced damage to buildings, the reduced loss of agricultural crops, and the lower expenditures for healthcare. The latter is included in Mayeres and Van Regemorter (2008), Nam et al (2010) and Matus et al (2008) who assess the welfare losses related to air pollution.

<u>Models</u>

A typical Impact Assessment of the EC is supported quantitatively by a 'modelling toolbox', consisting of various (often highly specialized) model types, which are sometimes connected with a soft link. In the context of the aforementioned proposal the most important model for the analysis of impacts is the air pollution mitigation model GAINS. The latter feeds the GEM-E3 model with different scenarios of abatement costs for 5 key air pollutants (PM2.5, SO2, NOx, VOCs, NH3) in order to conduct a complete assessment of the socioeconomic impacts. This analysis did not include measures to reduce methane emissions[8].

The GAINS model

The GAINS model is an bottom-up integrated assessment model of air pollution; that is, it covers the whole cause-effect chain of air pollution and allows stakeholders to identify cost-effective portfolios of control measures that achieve a set of given environmental objectives (Amann et al, 2011). The GAINS model has been used previously in a variety of policy applications, in particular in motivating and specifying the emission ceilings of the Gothenburg Protocol of the Convention on Long-Range Transboundary Air Pollution in 1999 and its revision in 2011.

GAINS estimates and projects emissions of all major air pollutants, such as sulphur dioxide (SO_2), nitrogen oxides (NO_x), fine particulate matter (PM2.5), ammonia (NH_3) and volatile organic compounds (VOCs), as well as of the Kyoto greenhouse gases. Air pollutant emissions lead to detrimental effects on human health (e.g. loss in life-expectancy and risk of illness due to exposure

[8] Although the Commission proposal includes methane ceilings, those are established on the basis of reductions that would be achievable by taking only measures with positive return on investment (e.g. biogas plants where they are economically viable). As a consequence, the measures to reduce methane may be expected to positively contribute to the overall macroeconomic impact of the Clean Air Package

of fine particles and ozone) and ecosystems (such as acidification and eutrophication, resulting in loss of biodiversity). The application of control technologies can reduce the emissions of pollutants, and the GAINS model database contains efficiency and cost characteristics of several thousands of such control technologies, as well as information on their use under current policies.

For the Impact Assessment (European Commission, 2013) the European Commission has employed the model for a number of purposes. First, GAINS provided an emission projection for each member state and each pollutant, based on assumptions about future energy consumption, as well as industrial and agricultural activities (Amann et al, 2012a, 2012b, 2012c, Borken-Kleefeld and Ntziachristos, 2012). This baseline emission projection reflects not only national and EU energy and agricultural policies, but also policies for air pollution control as they are currently implemented or firmly planned. On the basis of this baseline scenario GAINS was then used to estimate impacts of pollution on human health and ecosystems (Amann et al, 2012d, Kiesewetter et al, 2013).

The model was then used to establish the scope for further reductions beyond the current legislation. This analysis took into account specific application limits for various control technologies; such limits may be the consequence of turnover rates of capital stock or may result from practical limitations in the implementation of technologies. The current legislation and maximum feasible reduction scenarios determine the range of plausible and achievable scenarios.

For a set of ambition levels, which in turn were motivated by cost-benefit considerations, GAINS then provided portfolios of cost-effective measures for each member state that, taken together, provide the environmental objectives at lowest cost (Amann et al, 2012e, 2013). Furthermore, throughout the design process the web interface GAINS model and database served as an open access tool for stakeholder consultations.

The GEM-E3 model

General model description

The GEM-E3 version[9] (Capros et al, 2013) used for this exercise is calibrated on year 2004 based on the GTAP 8 database and represents the EU together with 10 major world economies individually linked through endogenous bilateral trade. The GTAP data is aggregated to 21 sectors (of which 4 energy resource sectors, 5 energy intensive sectors and 3 separate transport sectors), and complemented with 10 power technologies.

GEM-E3 offers consistent evaluations of the distributional effects of policies for the various economic sectors and agents across the countries. The model is able to compare the welfare effects of various environmental instruments, such as taxes, various forms of pollution permits and command-and-control policies.

[9] There are two versions of GEM-E3: GEM-E3 Europe and GEM-E3 World. They differ in their geographical and sectoral coverage, but the model specification is the same. The European version covers 24 EU countries (all EU countries, except for Luxemburg, Malta and Cyprus) and the rest of the world (in a reduced form). It is based on EUROSTAT data. See www.gem-e3.net.

The economic agents optimise their objective functions (utility for households and production cost for firms) and determine separately the supply or demand of capital, energy, labour and other goods. Market prices adjustments guarantee a global equilibrium endogenously and simultaneously to the year that the policy under analysis is implemented as a policy shock to the model.

The production of the firms is modelled with a nested CES neo-classical production function, using capital, labour, energy and intermediate goods with considerable sectoral detail.

The model is recursive-dynamic, driven by the accumulation of capital and investment. The amount of capital is fixed within each period. The investment decisions of the firms in the current period affect the stock of capital in the next period. Labour is immobile across national borders. Technological progress is explicitly represented in the production functions.

The demand for goods by the consumers, firms (for intermediate consumption and investment) and the public sector constitutes the total domestic demand. This total demand is allocated between domestic goods and imported goods, using the Armington specification.

Government behaviour is exogenous. The model distinguishes between 9 categories of receipts, including indirect taxes, environmental taxes, direct taxes, value added taxes, production subsidies, social security contributions, import duties, foreign transfers and government firms. It is possible to consider various systems of revenue recycling.

Methodology

The economic assessment of air pollution abatement policies can be made in different ways and using different methodologies. In this section, we outline two possible main general approaches.

In the first approach, the polluting emissions are explicitly incorporated in the model. An exogenous constraint of these emissions generates a shadow cost (dual variable) which directly affects the decisions of economic agents. Equally, introducing a tax changes the behaviour of the economic agents such that the emission levels reduce. With this approach, emissions can be reduced in three ways: a) end-of-pipe abatement technologies, the cost and emission reduction potential of which is determined by detailed bottom-up marginal abatement cost functions, b) by substitution of fuels that may reduce energy-related emissions, and c) by a decline in production as a result of the increased cost of production. The modelling work with GEM-E3 has followed this approach for greenhouse gasses (only) in the recent 2030 Framework for Climate and Energy policies (European Commission, 2014). This approach is also followed by Mayeres and Van Regemorter (2008), which endogenizes the health feedback of air pollution in a CGE framework.

However, the current analysis for air quality policies has followed a second approach. We do not explicitly model the air emissions, and hence do not implement an exogenous constraint or taxation as policy measure. Here, the cost of the policy is calculated through the direct incorporation of the emission abatement expenditures of sectors and households in GEM-E3. These abatement expenditures originate from the output of the bottom-up GAINS model for air quality. Thereby, instead of using an estimated function approximating the marginal abatement costs (MAC) of the bottom-up measures, this approach has all the benefits of using the exact expenditures as calculated by GAINS and ensures consistency between the two models. For example, the single pollutant MAC curves are unable to capture the capacity of a simultaneous reduction of multiple pollutants by a single technology thereby their use may potentially result in an overestimation of real costs. Further the second approach guarantees full harmonization between the different modelling frameworks, GEM-E3 and GAINS that are involved in the Impact Assessment of the European Commission (EC, 2013).

A CGE framework calculates the direct and indirect effects. As direct effects, the abatement expenditures per sector and pollutant from GAINS are incorporated in GEM-E3 as 'obliged production expenditures' for the sectors that have to reduce their air pollution emissions. This abatement cost is added to the unit cost of production of the abating sectors, hence affecting the price equilibrium and the production levels of these sectors. At the same time, the abatement expenditures for households are introduced in the CGE framework as compulsory abatement consumption which does not increase their welfare but still reduces their disposable income. This leads to an overall reduction of the consumption level. Abatement expenditures do not account for additional investments so as not to create additional capital stock available for the whole economy (in accordance with the assumption that capital is mobile across sectors) or increase the GDP.

At the same time the abatement expenditures, both from firms and households, create demand for abatement technologies increasing the demand for good produced by the sectors that make these environmental technologies. This additional demand generates an economic opportunity for the manufacturers of abatement technologies which is created by environmental policies. Pollutant-specific abatement matrices with constant coefficients allocate the demand for abatement technologies to the various sectors that supply these technologies, which is subsequently added to domestic demand of the sector that provides the abatement technology. These matrices have been designed in collaboration with experts of the European IPPC Bureau[10]. These abatement matrices are an important driver of economic impacts of emission abatement policies, as intermediate and final demand of abatement goods is structured according to these coefficients.

The most important sectors producing air pollution abatement technologies are ferrous and non-ferrous, chemical sector, electric goods, (general) equipment goods, transport equipment goods and construction. Liquid fuels (oil) in transport and electricity are used to let the technologies run.

The analysis includes also a number of variations on the air policy scenarios where the health feedback effects from the avoided air pollution related morbidity and mortality are introduced in the model. This has been done by increasing the active population that is available on the labour market, as presented in Table 2, (Holland, 2014).

Reference Scenario

In a CGE framework, a typical analysis for policies in the mid- or long-term (here in 2030) compares counterfactual scenarios with a reference scenario. A reference scenario describes how the global economy could look like in the next couple of decades. This involves clear assumptions on the main drivers of economic growth, such as active population, technical progress and agent's expectations. For inter-model consistency all models of the 'modelling toolbox' that support an Impact Assessment need to be harmonized to a common reference scenario.

[10] This matrix has been designed in collaboration with experts of the European IPPC Bureau (*eippcb.jrc.ec.europa.eu/*).

For this exercise the GEM-E3 model was calibrated consistently to the 'Reference Scenario 2013' of the 'EU Energy, Transport and GHG Emissions Trends up to 2050'[11] for the EU28.

For the countries outside the EU, the economic projection is based on the 'World Economic Outlook' (IMF 2012) on the short term, and the 'Energy and Climate Outlook 2012' (MIT 2012) for the period 2020-2050. The population and active population follow the latest UN and ILO projections.

The GEM-E3 reference assumes that all current policies and legislated future policies are taking place. In particular, source controls established in current legislation, along with legislation included in the "2020 Climate and Energy Package", as for example the renewable, ETS and non-ETS targets. Energy-related projections, such as electricity supply shares and fuel prices have been calibrated to the PRIMES and POLES[12] reference scenarios, for EU and non-EU regions respectively. The price of natural gas decouples from oil and due to increasing exploitation capacities of conventional and unconventional reserves, shows a lower rate of increase compared to oil price. Energy intensity is assumed to decrease rapidly for the European economy in line with the European objectives of energy security and climate change mitigation.

Policy Scenarios

This paper analyses the policy scenarios that were included in the Impact Assessment of "The Clean Air Policy Package" (European Commission, 2013), as well as on the final policy option that was adopted by the European Commission. The focus of the assessed polices lies to Europe's long-term goal of achieving air pollution levels down to the WHO guideline levels for the protection of human health and eliminate the excess of critical loads of harmful pollutants for the protection of ecosystems.

Four policy scenarios of additional technical reduction measures are assessed as those were produced by the IIASA GAINS model for the purposes of the Impact Assessment (Amann et al, 2014). The different scenarios refer to the different levels of the "Gap Closure" percentage, namely the percentage by which the new objectives would close the gap between the reference policy (0%), on the one hand, and the result of applying all technically available abatement measures (100%), on the other (the Maximum Technically Feasible Reduction, or MTFR109) (European Commission, 2013) and are thoroughly described in the Impact Assessment of "The Clean Air Policy Package". It is important to note that the input of sectoral abatement expenditure from GAINS model is based on technical measures available in 2012 and does not include any consideration of cost adjustment due to learning-by-doing and learning-by-research, nor does it assume any changes in energy structures or behavioural changes of consumers. Thus, we have opted for an end-of-pipeline approach of implementation in the GEM-E3 model which may possibly lead to overestimation of costs.

In particular, we analyse the final scenarios of cost-effective options to improve air quality in Europe as those are presented in Amann et al. (2014). Scenario B1 refers to a 25% Gap Closure for health impacts due to PM2.5 (PM-health), Scenario B2 to a 50% Gap Closure for PM-health, Scenario B3 to

[11] http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2050_update_2013.pdf

[12] The latest POLES reference scenario is consistent with the 2012 IEA World Energy Outlook New Policies Scenario

a 75% Gap Closure for PM-health, while Scenario B7 refers to 70% Gap Closure for PM-health in 2025, which was the gap-closure level agreed by the college of the European Commission in December 2013. The B7 in 2025 corresponds to a 67% Gap Closure in the year 2030[13], which has been proposed by the Commission as the binding reduction commitment year, in order to "fully harvest the co-benefits from the climate policy target for 2030 that has been proposed by the European Commission in its Communication on the 2014 Energy and Climate Package"(Amann et al, 2014). As a result, and in order to harmonise our analysis with the Impact Assessment and the final agreement of the European Commission, the focus-year of the discussion for scenarios B1-B3 is 2025 while for B7 it is 2030.

Examples of sectoral cost-effective technical measures for each policy scenario of the Impact Assessment include stricter PM2.5 and NOx control for the power generation sector, improved stoves, pellet boilers and dust filters for the fuel combustion of the domestic sector, wet flue-gas desulphurisation and stricter PM2.5 controls for industrial combustion, selective catalytic reduction and stricter control for industrial process-related emissions, tightening of emission standards for light duty vehicles beyond Euro 6 for the transport sector and substitution of urea fertilizer, reduced open burning of agricultural residuals and covered storage of manure for the agriculture sector. The measures mentioned above are among those presented in Table 12 of the European Commission 2013 Staff Document.

In Table 1, the total EU-28 costs imposed on the GEM-E3 firms and households for all abated pollutants are presented for each respective policy scenario as well as for the reference case. It is important to note that for each policy scenario only the additional costs associated with the emission reduction effort above the Reference are presented. The shock imposed on the GEM-E3 model is the net effort that results after deducting form the total scenario abatement expenditures, the costs attributed to the reference scenario. In addition, "no regret costs" provided by the GAINS analysis (i.e. negative costs) have been removed for the purposes of the CGE analysis. In the Reference scenario follows the currently imposed legislation on Air Quality which focuses on the transport and electricity supply sectors. This is both due to the cost-efficient measures available for the abovementioned sectors but also due to the more centralised production of the above, resulting in a more straightforward implementation of end-of-pipe measures. On the contrary, in the policy scenarios GAINS model output indicates that the most cost-efficient sectors to undertake further emission reductions are households and agriculture followed by the energy intensive industries. As explained in the Impact Assessment (EC, 2013), the varying distributions for policy options reflects the limited further potential in sectors that have been regulated (e.g. transport and power supply sectors) in the past, and the larger potential in those that have not. As can be seen from the net abatement expenditure associated with each policy scenario, the final proposal of the European Commission (B7) lies between the effort required in options B2 and B3.

[13] In policy terms, more than by the gap closure percentage number, each scenario is defined by the set of cost-effective technical measures delivering the emission reductions. The same technical measures are associated with 70% gap closure in 2025 and 67% gap closure in 2030, the 3% gap closure difference being the result of structural changes (e.g. some reduction in the use of solid fuels) occurring on the baseline in the five intervening years.

Table 1: Abatement effort required by GEM-E3 sector, by policy scenario, in M€ per year as an increase of expenditure compared to the Reference scenario (source: GAINS model)

EU-28 Abatement expenditure (million €2010/yr, increase compared to reference)	Reference (yr 2025)	Reference (yr 2030)	B1 (yr 2025)	B2 (yr 2025)	B3 (yr 2025)	B7 (yr 2030)
Agriculture	7701.425	7942.8952	66.196	339.898	1420.821	892.178
Coal	162.34071	113.75458	0.000	0.000	0.006	0.002
Crude Oil	0	0	0.624	0.678	0.983	0.875
Oil	786.92016	764.41798	32.909	103.702	340.841	196.525
Electricity supply	9276.459	6845.7638	16.367	75.986	263.716	146.720
Ferrous and non ferrous metals	2666.6588	2676.2236	11.552	104.270	230.357	219.337
Chemical Products	2007.0679	2036.9386	12.528	36.343	173.026	121.743
Other energy intensive	1507.1756	1572.8079	14.415	83.061	387.925	255.680
Transport equipment	1248.8471	1202.3434	0.000	0.000	1.276	0.000
Consumer Goods Industries	2384.4751	2409.3667	4.883	15.018	97.406	90.942
Construction	2745.3004	2871.263	0.000	0.906	24.634	20.865
Transport	48620.274	56120.788	0.258	2.955	19.188	4.824
Market Services	1097.9118	965.79065	13.318	24.018	54.142	35.274
Non Market Services	0.7762626	0.7762626	2.158	2.158	3.247	2.942
Water transport	385.32652	404.83636	1.036	1.434	101.370	104.702
Households	8522.54	8150.3612	53.509	418.397	1496.457	1223.076
Total	**89113.498**	**94078.327**	**229.752**	**1208.824**	**4615.395**	**3315.684**

With regards to the health benefits from air pollution control Table 2 shows the rate of increase of the EU-28 active population. This increase results in direct economic benefits since the available factors of production of the European economy become more abundant. The increase is analogous to the abatement effort.

Table 2: Health benefits from air pollution control, as a rate of increase of active population (based on Holland, 2014)

Increase of active population	B1_Health	B2_Health	B3_Health	B7_Health
EU-28	0.0145%	0.0277%	0.0436%	0.0383%

Results

Aggregate results for all policy scenarios

For the purposes of discussion of the general equilibrium results, each policy scenario is presented in two alternative sub-scenarios; a first one only taking into consideration the emission abatement expenditures of sectors and households (B1-B3, B7) and a second one also incorporating the positive feedback of health benefits to the economy (B1_Health-B3_Health, B7_Health). In that way, one can decompose the two different shocks, namely the abatement expenditures and the increase of labour productivity.

Table 3 presents the aggregate impacts of the examined air pollution policies on the European economy in terms of % difference from the Reference scenario. It should be taken into consideration that the reported EU-28 imports and exports exclude intra-EU trade. In the case of B1, B2, B3 and B7 scenarios (i.e. excluding the positive feedback of health benefits), the magnitude of impacts is in line with the magnitude of the initial shock of abatement expenditures and in particular, it can be seen that the impact on GDP (excluding possible positive health effects) is in all scenarios equal to around -0.85 of the abatement expenditure expressed as a percentage of GDP. Thereby, GDP in B1 and B2 scenario is almost unchanged, in B3 scenario it slightly decreases by -0.026%, while in B7 scenario, which corresponds to a lower abatement effort than that of B3, GDP shows a decrease of -0.018% compared to the Reference case. When the health effects on labour productivity are incorporated in our analysis, the GDP improves in all the corresponding scenarios, even leading to small but positive figures in most policy options apart from scenario B3_Heatlh, where the GDP remains almost unchanged. The scenario option which is finally proposed by the European Commission, B7_Health, has a very small positive effect on the GDP (+0.005% compared to Reference levels in 2030).

The decrease in GDP in the B1-B3 and B7 scenarios is due to a fall in private consumption and a small deterioration of the balance of trade. Household consumption falls as a result of the reduction of the disposable income, in order to comply with the required abatement expenditure, but also as a result of higher production costs of the goods produced by the abating sectors. In particular, the policies result in an increased cost of energy, hence leading to a higher reduction with regards to the consumption categories related to transportation, heating and cooking and other energy related services. The unit cost of energy for production increases analogously to the abatement effort as refineries and power industry pass-through the expenditure for air pollution control technologies to their output price.

Higher GDP levels seen in the policy scenarios that incorporate both abatement expenditures and health effects on labour productivity are mainly a result of the higher availability of human capital in the economy, and hence higher employment levels. The leads to a higher disposable income and, hence the higher household consumption and investment increases GDP, while leaving the European net trade balance largely unchanged. The improvement of labour productivity from air quality policies result in a reduction of the unit cost of labour, thus providing a more cost-efficient substitute for energy, the unit cost of which has increased as a result of the policies. The latter effect leads to a reduction of the unit cost of production, which combined with an increase in the total European disposable income due to the increase of the active population, results in an increase of private consumption and welfare. In addition, investment demand also increases as prices for investment goods decrease more than the price of capital as compared to the reference case. Lastly, in the case of B7_Health scenario, the net trade balance is unchanged as both exports and imports are increasing from reduced production costs and increased overall household demand respectively.

Table 3: Impact of different air pollution abatement targets on EU-28 GDP, GDP components and Employment, expressed as % change from Reference scenario, year 2025 for B1-B3_Health scenarios, year 2030 for B7 and B7_Health, GEM-E3 JRC

% change from Reference	B1	B1_Health	B2	B2_Health	B3	B3_Health	B7	B7_Health
Abatement expenditure (% of GDP)	0.002	0.002	0.008	0.008	0.032	0.032	0.021	0.021
Gross Domestic Product	-0.001	0.007	-0.007	0.009	-0.026	-0.002	-0.018	0.005
Investment	0.000	0.005	0.000	0.010	-0.001	0.014	0.001	0.015
Public Consumption	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Private Consumption	-0.002	0.008	-0.010	0.010	-0.037	-0.007	-0.025	0.003
Exports	-0.001	0.011	-0.003	0.019	-0.009	0.023	-0.009	0.021
Imports	0.001	0.000	0.006	0.004	0.025	0.022	0.019	0.017
Employment	0.000	0.016	0.000	0.031	0.002	0.048	0.001	0.042

Sectoral results for the European Commission proposal for 2030

In order to facilitate a better overview and discussion of the results, this section focuses only on the results of the final European Commission proposal for the upcoming legislation, namely on scenarios B7 and B7_Health for 2030.

In Figure 1, the impacts on the sectorial production on the EU-28 level are presented. The agriculture sector shows a decrease of -0.12% in terms of production since, as indicated in Table 1, this sector carries a significant share of abatement expenditure in all policy scenarios[14]. On the other hand, the energy intensive sectors (e.g. Chemical products, Ferrous and non-ferrous and the Other energy intensive sectors), that also bear significant abatement costs and an increased unit cost of energy, show a rise of production as they also deliver intermediate and final goods for firms' and households' pollution control. Other sectors that benefit from the increased demand of abatement products, in accordance with the abatement matrixes of GEM-E3, are the Transport equipment, Construction, Electric goods, Other Equipment goods and Electricity supply. The latter is used both as an abatement good for several air pollution abatement techniques[15], and as an intermediate input for the production of other abatement goods such as products of the Chemical Industry.

[14] Note however that the negative impacts in the agricultural sector are likely to be overestimated for the following reasons: 1) The shock responses of this sector are modelled as in a full free-market sector, whereas cross-border tariff adjustments (or equivalent measures) are commonplace to mitigate impacts on agricultural production. 2) This modelling did not endogenise the crop yield increases delivered by the implementation of the Clean Air Package thanks to lower ground-level ozone concentrations. Those were assessed in the range of 250M€/year, roughly compensating 50% of the 0,12% output drop reported here (Holland 2014). 3) Some of the pollution abatement measures that farmers would have to put in place could be subsidised through the 2nd pillar of the EU's Common Agricultural Policy (Rural Development funding)

[15] E.g. electrostatic precipitators for PM reduction (Brandley, 2005), non-thermal plasma technique for NO_x emission reduction (EPA, 1999), non-evaporative cooling system and Venturi scrubber techniques for NH_3 abatement (Handley et al, 2001)

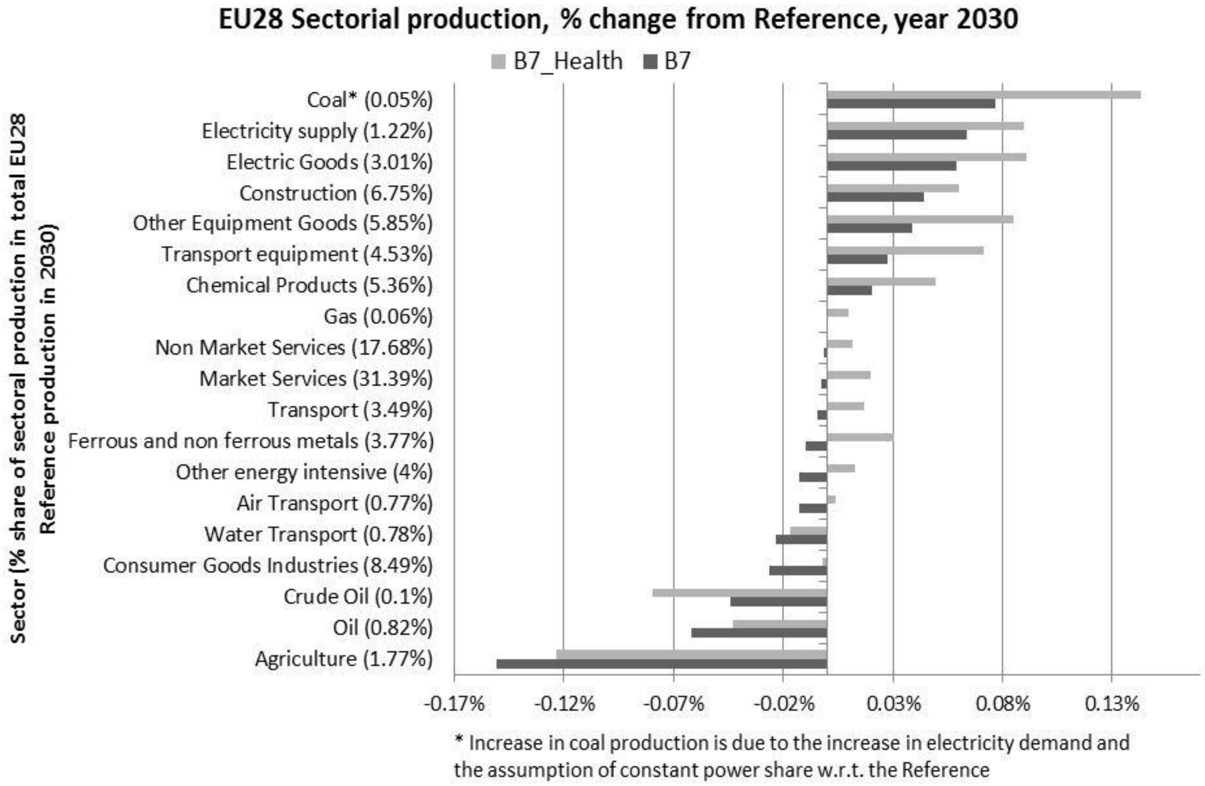

Figure 1: EU-28 Sectorial Production as a change from Reference case, year 2030 for scenarios B7-B7_Health, GEM-E3 JRC

With regards to trade, the impact of the examined environmental policies on sectoral European imports and exports as a percentage change from the Reference case is presented in Figure 2 and Figure 3. It should be taken into consideration that intra-EU trade is not presented in order to depict the impacts of air pollution abatement policies on European competitiveness. The European net trade balance is unchanged in the B7_Health scenario while net European imports increase by 0.14% in the B7 scenario.

Significant EU exporting sectors, like the Electric Goods, Transport Equipment and Other Equipment industries show a slight increase of exports due to the reduction of the unit cost of production in both B7 and B7_Health scenarios. This reduction in the unit cost of production is not only due to the health benefits which is found only in B7_Health scenario but also due to the release of human capital from the abating sectors, which in turn becomes available for other sectors in order to substitute capital or labour. For energy intensive sectors the increase in their production shown in Figure 1 can be explained as the increase of domestic demand for abatement products. Domestic demand for abatement products is also partly served by imports, as shown in Figure 2.

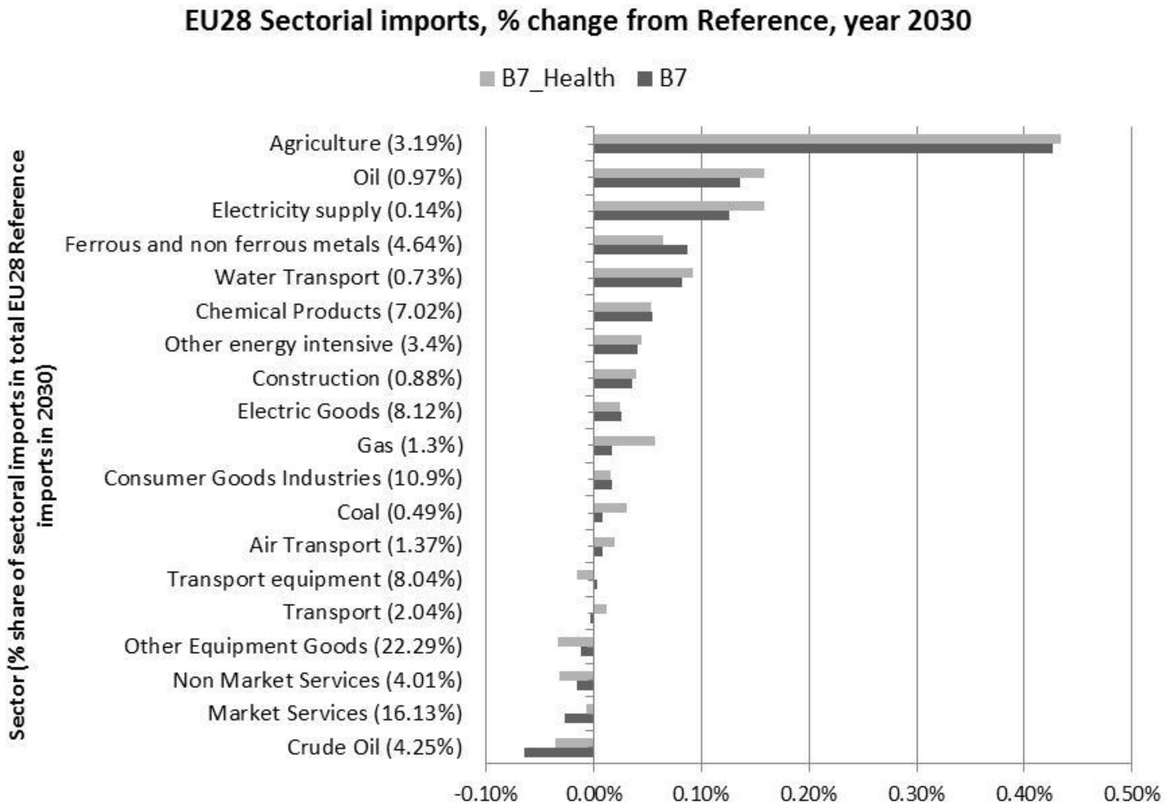

Figure 2: EU-28 Sectorial imports as a change from Reference case, year 2030 for scenarios B7-B7_Health, GEM-E3 JRC

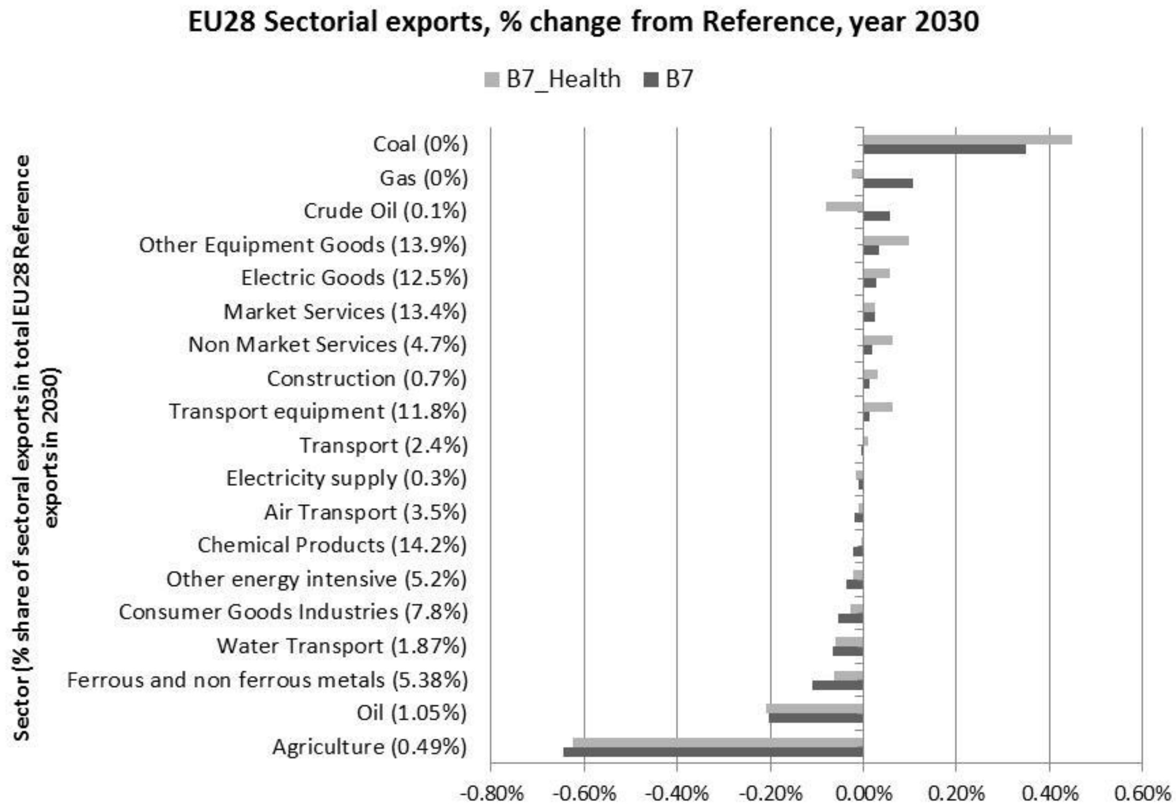

Figure 3: EU-28 Sectorial exports as a change from Reference case, year 2030 for scenarios B7-B7_Health, GEM-E3 JRC

Employment changes are very small in the B7 scenario (almost 3000 jobs) reflecting the labour intensity differences between sectors that install abatement technologies and sectors providing them. However, this effect is more substantial in the B7_Health scenario (close to 100000 jobs equivalents) both due to the increase of the (available) labour force resulting from the health benefits of the environmental policies (equal to 76000 equivalents in 2030[16]) but also due to the secondary positive effects of the latter on the economy that lead to a net job creation of 24000 in 2030. The aggregate GEM-E3 sectors that also provide abatement goods (e.g. Construction, Transport equipment and Other Equipment goods) represent a significant share of EU employment and due to the increase in domestic production and the lower unit cost of labour, employment increases in these sectors as well as in the service sectors.

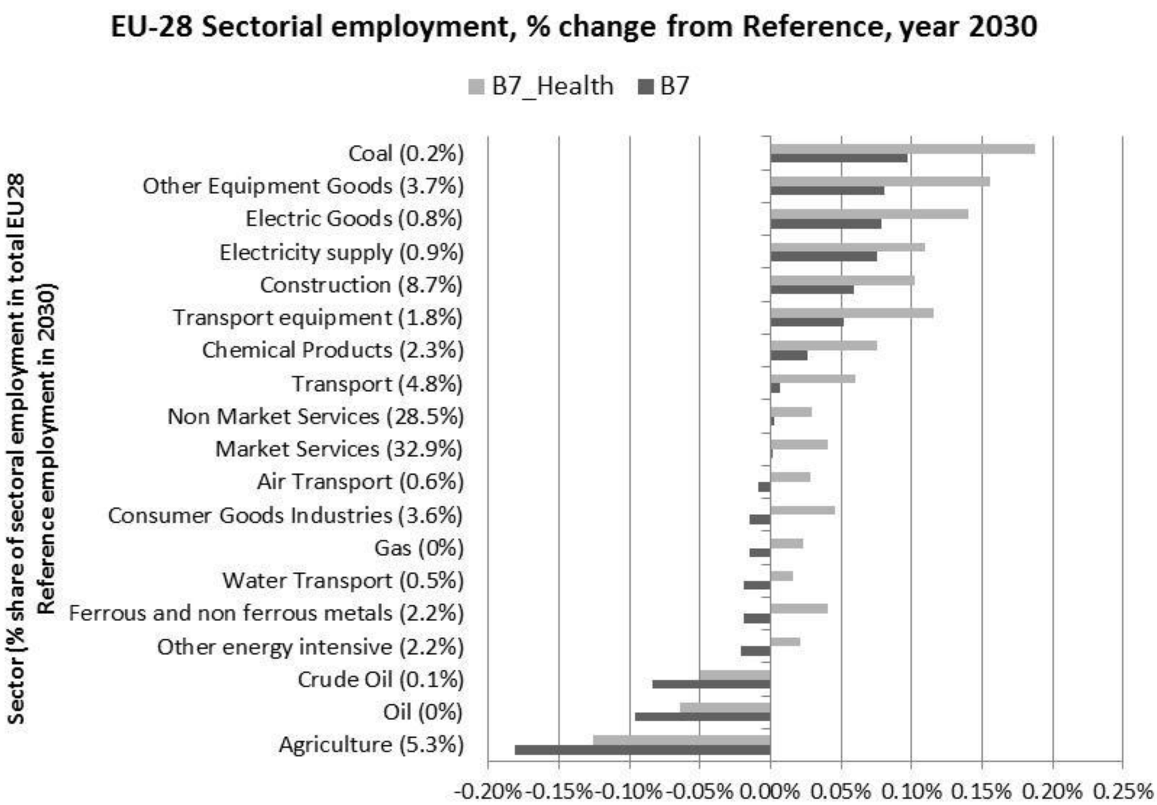

Figure4: : EU-28 Sectorial Employment change from Reference case, year 2030 for scenarios B7-B7_Health, GEM-E3 JRC

Conclusions and further research proposals

The GEM-E3 model has been used to quantify the socioeconomic impacts of the "The Clean Air Policy Package", proposed by the EC in December 2013. More particularly, it was used to assess the main impacts on sectoral production, demand, trade competitiveness and employment. This article presents the scenarios analysed in the corresponding Impact Assessment as well as the final compromise proposal by the EC. The soft-link and harmonization between GEM-E3 and the GAINS

[16] The 76000 job equivalents can be interpreted, among others, as a lower rate of absence due to air pollution related illness.

model allow for a consistent analysis of the air policy scenarios, while exploiting the best available modelling tools for the impact assessment.

The analysis of with the GEM-E3 model does not only show the direct effects of the policy but also the indirect effects. We show that the expenditure on pollution abatement is a cost for the sectors that reduce their emissions. The higher production costs for the complying sectors lead to slightly reduced domestic consumption and a very small loss of international competitiveness. The expenditures done by the households slightly reduce their disposable income for other types of consumption. However, the expenditure in abatement technologies is also an economic opportunity for the sectors that produce these technologies. In particular, the abatement expenditures mainly flow to sectors like Transport Equipment, Electric goods, Electricity production and Construction.

Further, we demonstrate that the improved labour productivity thanks to air quality improvements has positive macro-economic impacts on the European economy, possibly even dominating the costs of the policy. Thus even without taking into consideration the rest of the direct benefits resulting from the proposed policy (such as reduced eutrophication, acidification, etc.), the implementation of the 'Clean Air Policy Package' may be beneficial for the European economy.

In this exercise we have demonstrated the relevant role of physical benefits delivered by the policy on the economy by including the endogenous feedback of morbidity reduction on labour productivity. However, further feedback mechanisms could be envisaged, such as: reduced premature mortality on the duration of working life and on aggregate demand; reduced healthcare costs on the burden on the health system; reduced crop losses due to ground-level ozone concentrations on agricultural yields. Also, the use of financial instruments to subsidise some of the pollution abatement measures (e.g. agro-environmental measures through the EU's Rural Development Programme) could deliver important policy insights on the distributional impacts.

Moreover, a further field of analysis related to the proposed policies involves the impacts of implementation of air pollution control measures in other world regions on the European terms of trade. By committing to improve air quality and combat climate change, Europe is developing a competitive industry of green technologies and a potential first-mover advantage could lead to further positive effects to the economy when other continents start to use these technologies.

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