Thematic report: Macroeconomic models including specifically social and environmental aspects

Deliverable No. 8

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Abstract

A significant reduction of the global environmental consequences of European consumption and production activities are the main objective of the policy simulations carried out in this paper. For this purpose three different modelling approaches have been chosen. Two macroeconomic models following the philosophy of consistent stock-flow accounting for the main institutional sectors (households, firms, banks, central bank and government) are used for quantifying the impact of several different policies. These policies comprise classical tax reforms (pricing of resources and emissions) as well as policies aiming at behavioural change in private and public consumption and at technological change (energy and resource efficiency and renewable sources). A Dynamic New Keynesian (DYNK) model is used for a comparison between classical green tax reform and taxing direct and indirect (footprint) energy and resource use of consumers. An important leading principle of the modelling work is the simultaneous treatment of economic (GDP, employment), social (income distribution, unemployment) and environmental issues.

The paper shortly describes the different modelling approaches and highlights the most important features for the evaluation of the impacts of different policies. Then the different policy scenarios that are carried out with each model are described. The policy scenarios are not directly comparable between the different models, but show some similarities. The simulation results of the different policy scenarios are then analyzed and discussed.

Two important conclusions can be drawn from the simulation results:

(i) important trade-offs and synergies exist between the different economic, social and environmental goals

(ii) simple policy scenarios mainly putting all the effort in one simple instrument (e.g. tax reform) are not likely to achieve an optimal result. A combination of instruments is most likely to achieve results satisfying the different economic, social and environmental goals.

1. Overview of modelling approaches

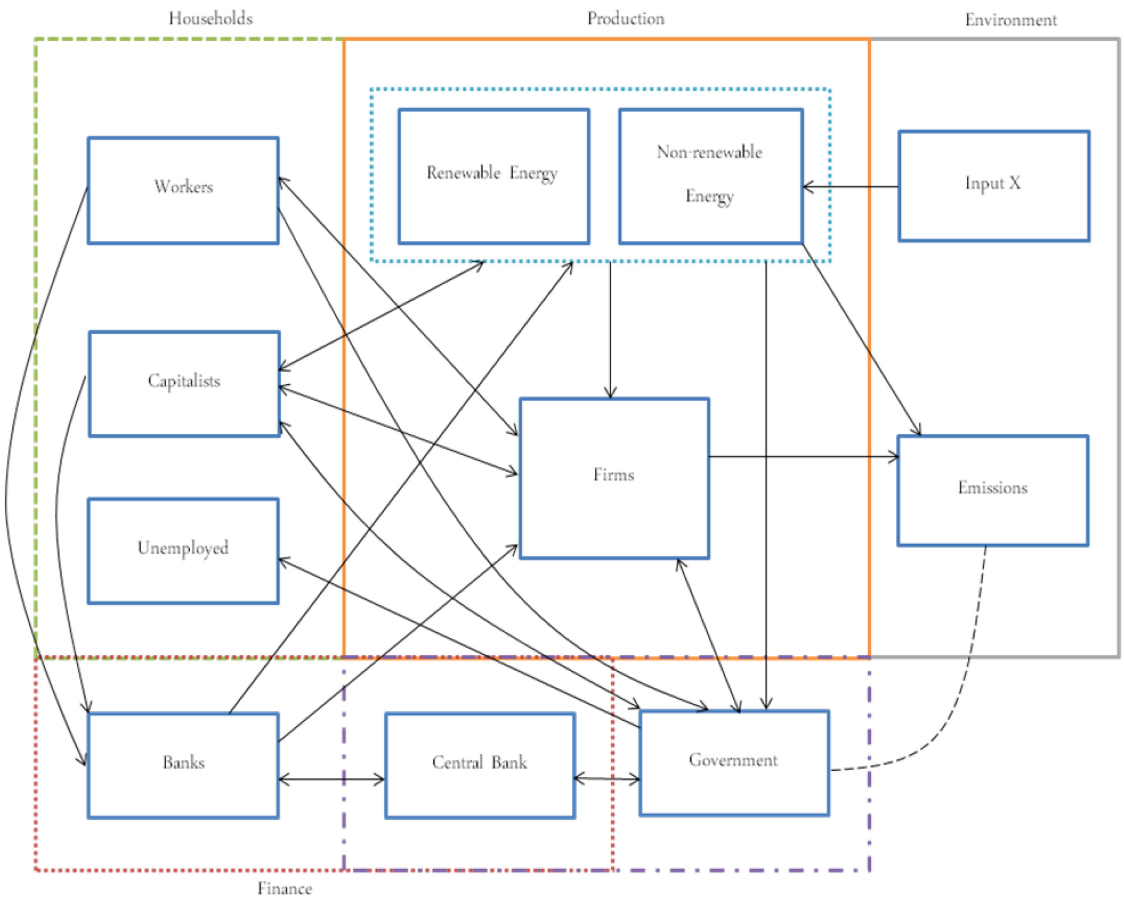
The stock-flow consistent macroeconomic model

Naqvi (2015) presents a macroeconomic model, following the accounting framework presented in Godley and Lavoie (2007). The institutional sectors dealt with in this model comprise: production, households, government, the finance sector and the environment. Economic activities are tracked in two monetary accounts, a balance sheet and a transition flow matrix.

The balance sheet contains the net worth of the economy across different institutional sectors at the end of a time period. Interactions between agents result in flows between two time periods which are summarized in the transition flow matrix. Double entry accounting restrictions imply that all rows and columns of this matrix must add up to zero.

The production sector produces both capital and consumption goods and output is determined through demand by household consumption, government expenditure, and firm investment. The model is therefore demand-driven and describes the main Keynesian multiplier processes, based on the circular flows (Figure 1). The budget constraints for these demands are set by the banking system that determines deposits, loans and advances to form a complete circular flow economy. The production process requires three complimentary inputs; capital, labour, and energy. Capital is generated through investment, worker households provide labour, while energy is supplied by energy producers. This allows the firms and the energy sector to be dual-linked through energy demand and prices. Energy supply is generated from an exogenously determined mix of non-renewable and renewable energy.

Figure 1 **Flows in the stock-flow consistent macroeconomic model**



Source: Naqvi (2015)

Naqvi (2015) differentiates two household classes in order to account for differences in the functional income distribution. Capitalists as owners of capital, who earn profit income, and workers as owners of labour, who earn wage income if employed or unemployment benefits if unemployed. Real disposable income determines consumption levels while savings are kept in commercial banks. Commercial banks give out loans to the production sector. If the demand for loans exceeds deposits, commercial banks can request advances from the central bank which results in the creation of endogenous money (Moore, 1988; Starr, 2003; Keen, 2014; Lavoie, 2014). The government earns tax revenue from firms, households and the financial sector which it uses to fund public sector investment and unemployment benefits.

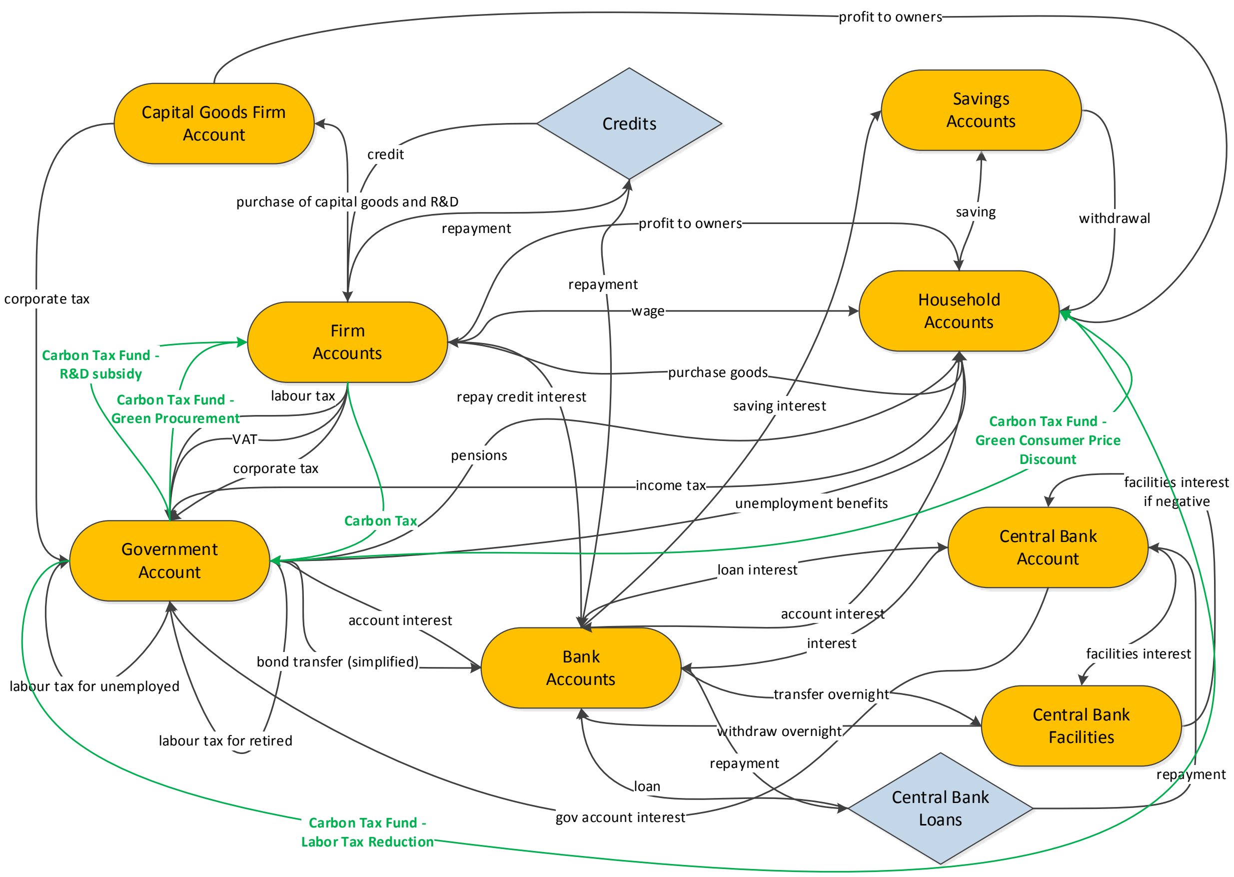
The stock-flow consistent agent-based macroeconomic model

The model of Rengs et al. (2015) encompasses a full macro-economy that evolves from bottom-up according to agent-based methodology (Tesfatsion and Judd, 2006; Gilbert, 2007), building upon the framework presented in Rengs and Wäckerle (2014). Its computational simulation follows a stock-flow structure that is consistent with the balance sheet approach (Godley and Lavoie, 2012). It includes the following sectors: households, firms, banks, central bank and government. All sectors are disaggregated, except central bank and government, in the sense that they are composed of a multitude of agents and their interactive dynamic relations. The model is close in spirit to recent models by Cincotti et al. (2010), Delli Gatti et al. (2011), Riccetti et al. (2013) and Chen et al. (2014). Moreover, in terms of scale and scope it is roughly comparable with the models by Seppecher (2012) with a focus on labour markets, Dosi et al. (2013) emphasizing capital goods, banking and innovation, and Lengnick (2013) with a simplified general purpose model. The approach considers the economy as a complex evolving system that organizes itself endogenously. This is reflected by notions like non-equilibrium dynamics, (in)stability, systemic risk and vulnerability. The various types of agents in the model include households, firms, the banking system (commercial and central bank), and the government (Figure 2).

Households choose their seller in a boundedly rational way, based on their preferences, and differentiating between needs and wants. Consumption behavior follows social processes, characterized by the dynamics of imitation and status-seeking behavior (conspicuous consumption à la Veblen, 1899). This on the one hand follows Veblen's general suggestion of trickle-down effects in social structure (Trigg, 2001) due to working class consumers imitating capitalist class consumers, and on the other hand is inspired by Leibenstein (1950), who specified consumption dynamics as resembling a bandwagon effect (imitation of other consumers) and contrasted it to the status-seeking Veblen effect (luxury consumption) and snob effect (consumption striving for rare goods – "exclusiveness"). Consumption behavior is thus not static but a co-evolving process between behaviors of consumers and social structure; i.e. a dynamic interplay between individual aspirations (need/want), status-seeking behavior, wealth and imitation dependent on emergent social structure driven by interactive evolution of populations of different classes of consumers.

A second group of agents are firms, which produce final goods using inputs of capital and labour. They employ a firm-specific production technology, with respect total factor productivity and emissions per output unit being heterogeneous among firms. Firms start with a number of differently scheduled credits (each with their own duration) emulating the reinvestment necessary to uphold the constant capital level to counter depreciation. The profits of the firm accumulate in its current account over a whole fiscal year (12 months). At the end of the year funds are set aside for research and development (R&D) investments and corporate taxes are applied to the remaining amount.

Figure 2 **Flows in the stock-flow consistent agent-based macroeconomic model**



Source: Rengs et al. (2015)

The banking system comprises commercial banks and the central bank. Banks keep current accounts, savings accounts, and grant firm loans. They pay and charge interest for these different financial services applying distinct rates, limited by central bank interest rates. The central bank keeps current accounts as well as deposit facilities for banks, involving the paying or charging of interest.

The government serves various roles in the model. It makes transfers to unemployed and retired households, and collects taxes on labour, income and capital gains, corporate profits made by banks and firms and the capital good firm, and value-added of sales. As unemployment benefits and pensions are downward rigid, the government has no means to cut costs and has to deficit spend if necessary. If indebted, it pays interest to banks and households (in relation to their wealth) as a proxy for government bonds.

The environmental extension involves modelling CO_2 emissions of the processes of firms producing goods, and policies to curb these emissions as well as stimulate relevant environmental innovations and achieve neutral or positive employment effects. The model does not account for climate change and its feedback to the economy, but is closer to the climate policy assessment models, often using a general equilibrium format (Jorgenson et al., 2008; Naqvi, 2014).

The Dynamic New Keynesian (DYNK) model

This model approach bears some similarities with the DSGE (Dynamic Stochastic General Equilibrium) approach, as it explicitly describes an adjustment path towards a long-run equilibrium. The term 'New Keynesian' refers to the existence of a log-run full employment equilibrium, which will not be reached in the short run, due to institutional rigidities. These rigidities include liquidity constraints for consumers (deviation from the permanent income hypothesis), and wage bargaining (deviation from the competitive labour market). Depending on the magnitude of the distance to the long-run equilibrium, the reaction of macroeconomic aggregates to policy shocks can differ substantially. The model describes the inter-linkages between 59 industries as well as the consumption of five household income groups by 47 consumption categories. The model is closed by endogenizing parts of public expenditure in order to meet the mid-term stability program for public finances in the EU 27.

The DYNK model describes households as dynamic optimizers according to the permanent income hypothesis, but subject to liquidity constraints, so that savings need to be built up for financing consumption and consumption depends partly on disposable income as in a Keynesian consumption function. This modelling philosophy follows the lines of the 'buffer stock model' of consumption (Carroll, 1997), and includes the consumption of durables and nondurables (Luengo-Prado, 2006). Consumers in this model maximize the present discounted value of expected utility from consumption of nondurable commodity and from the service provided by the stocks of durable commodity. Disposable household income, including profit income, is only one source of consumption. Total resources for consumption of households are given by the variable 'cash on hand' that includes part of the durable stock and financial assets. One part of the durable stock has to be hold in liquid assets as it cannot be used as a collateral for household debt, the other part enters in 'cash on hand'. Financial assets of households are built up by saving after durable purchasing has been financed, given the constraint for lending. This framework is stock-flow consistent as it shows the accumulation of durables and assets from savings and lending of households.

The banking sector and firms are not included explicitly in the DYNK model, but only the flows between the household and the government sector are shown in detail. The following taxes are charged on household income: social security contributions, which can be further decomposed into an employee and an employer's tax rate and income taxes. The wage rate is the wage per hour and *wa*ge bargaining between firms and unions takes place over the employee's gross wage. All the income categories are modelled at the level of quintiles of household incomes:

The production side in the DYNK model is analysed within the cost and factor demand function framework, i.e. the dual model, in a Translog specification. The representative producers in each industry all face a unit cost function with constant returns to scale that determines the output price (unit cost) for given input prices. The input quantities follow from the factor demand functions, once all prices are determined. The Translog specification chosen in the DYNK model comprises different components of technological change. Autonomous technical change can be found for all input factors (i.e. the factor biases) and also as the driver of TFP (total factor productivity), measured by a linear and a quadratic component. The Translog model is set up with inputs of capital (*K*), labour (*L*), energy (*E*), imported (M^m) and domestic non-energy materials (M^d), and their corresponding input prices p_K, p_L, p_E, p_{Mm} and p_{Md}. This production structure is consistently linked to the input-output core of the model.

The labour market in the DYNK model is represented by wage curves for each industry. These functions describe the responsiveness of hourly wages to labour productivity (industry, aggregate), consumer prices, hours worked per employee, and the rate of unemployment. The inclusion of the variable 'hours worked per employee' corresponds to a bargaining model, where firms and workers (or unions) bargain over wages and hours worked simultaneously (Busl and Seymen, 2013). Labour supply is given by age and gender specific participation rates of different age groups within the population at working age (16-65) and evolves over time according to demographic change (age group composition) and logistic trends of the participation rates. Therefore, labour supply does not react endogenously to policy shocks.

The public sector balances close the model and show the main interactions between households, firms and the general government. Taxes from households and firms are endogenized via tax rates. The expenditure side of government is made up of unemployment transfers and other transfers to households, public investment and public consumption. Additionally, the government pays interest with an exogenous interest rate on the stock of public debt. The change in this public debt is equal to negative government net lending. The model is closed by further introducing a public budget constraint, specified via the stability program for public finances of the EU 27 that defines the future path of government net lending to GDP. Due to the introduction of this net lending to GDP constraint, public consumption is then derived as the endogenous variable that closes the model.

2. Features of macro-economic modelling for the environment

Several innovative aspects of the models presented in the last section are relevant for the policy simulations undertaken. These aspects include the introduction of stock-flow consistent modelling as well as detailed modelling of behaviour of agents, depending on social dynamics.

Two further aspects are specifically relevant for modelling the economy/environment interactions:

- consistent linking of physical flows (energy, resources, emissions) to monetary aggregates in consumption and production
- explicit treatment of technical change, including induced and directed technical change

Starting point for the policy simulations is the introduction of biophysical constraints in the modelling framework. The next step is designing policy scenarios that allow for meeting these constraints while simultaneously evaluating the socio-economic impact (employment, income distribution) of these policies. The simultaneous treatment of economic, social, and environmental goals is the leading principle of the policy simulations.

One specific feature of the modelling work is the simultaneous treatment of physical and monetary aggregates, and the analysis of social (income distribution, employment, labour market variables) as well as economic (GDP, gross output, prices, external balance, public budget) impacts of environmental policy scenarios. The policy instruments analysed empirically also exceed the usual environmental policy analysis. Besides pricing of externalities (tax policies) they include measures aiming at behavioural changes in consumer demand, R&D subsidies and other green investment policies.

Another crucial issue of the modelling scenarios is the viability of ‘green growth', i.e. the achievement of environmental goals implying an absolute reduction of emissions or energy and resource use while GDP is still growing. This is mainly a question about the magnitude and direction of technological change. Two different versions of this 'green growth' phenomenon could be thought of. One is the general compatibility of positive GDP growth with an environmental policy scenario where emissions and energy/resource use are reduced continuously. The other one is that this environmental policy is even accompanied by higher GDP growth than a baseline scenario with this policy and where the environmental targets therefore are not achieved. This second version of the 'green growth' hypothesis can be seen as a 'double dividend' scenario of environmental policy, where output is even boosted.

2.1 Consistent linking of physical flows to monetary aggregates

The agent-based macroeconomic model developed by Rengs et al. (2015) and the stock-flow consistent macroeconomic model of Naqvi (2015) link environmental variables (greenhouse gas emissions) to output, but allow for emission free or low emission technologies (e.g. renewable) that can substitute for emission intensive production processes. In Naqvi (2015) the real economy is integrated with the environment through two channels. First, energy production requires a non-renewable input that depletes over time and second, Greenhouse Gas (GHG) emissions, generated through the production process, accumulate in the atmosphere. In one scenario the repercussions of the environmental impact on the economy are taken into account via the introduction of a damage function. This is implemented via a feedback from the emissions to the depreciation rate of the capital stock.

In Rengs et al. (2015) firms emit CO_2 over the course of their production process depending on the employed emission reduction technology. Half of the initial firm population starts with slight emission reduction technology and the other half starts without emission reduction. The emissions per output (carbon intensity as a measure of pollutiveness) can alter over time through "green or environmental innovation". Investment in R&D leading to innovation is assumed to have an immediate effect either on carbon intensity of the respective firm's output or on total factor productivity. In other words, innovation is an individual process with a small role given to spillovers, a side effect of R&D. Since there are two different technology branches (emission reduction vs. total factor productivity), both may benefit from spillovers. The highest spillover effect will occur if all firms perform research on the same technology branch, and achieving a much higher improvement in technology than without spillovers. Spillover effects depend on the sum of R&D investments in that branch.

The DYNK model developed by Kratena and Sommer (2014) deals with environmental flows on a disaggregate level of consumption and production activities. That comprises consumption of energy commodities that are emission relevant as well as the use of energy in the production processes of the economy.

The energy demand of households in the DYNK model comprises fuel for transport, electricity and heating. According to the literature on the rebound effect (e.g.: Khazzoom, 1989), the energy demand is modeled as (nominal) service demand and the service aspect is taken into account by dealing with service prices. The durable stock of households (vehicles, houses, appliances) embodies the efficiency of converting an energy flow into a service level linked by the efficiency parameter of converting the corresponding fuel into a certain service. Any increase in efficiency leads to a decrease in the service price and therefore to an increase in service demand ('rebound effect').

Production in the DYNK model is described by an input-output core model of 59 industries and commodities, which is consistently linked to a Translog cost function for aggregate factors of production. This model block determines factor demand in real terms (hours worked or employees for *L* and physical energy units for *E*). Physical input demand in the DYNK model comprises energy inputs in physical units (TJ) by user and energy category as well as material flows in physical units (1,000 t) for domestic extraction, imports and exports by material flow category. The aggregate *E* is split up into aggregate fuels *i* (coal, oil, gas, renewable, electricity/heat) in a Translog sub-model. The physical energy inputs are finally dealt with at the level of 17 energy categories applying fixed sub-shares by industry and energy category. The physical inputs are the link to GHG emissions by industry, applying a fixed emission factor per energy unit.

For material flows a different treatment for domestic material extraction and for trade flows of materials needs to be applied, due to the statistical concepts and data structures. Domestic extraction of material flows is linked to the gross output of the eight primary industries (agriculture, forestry, fishing, and the several mining industries). The external trade of the material flows in physical units is derived from physical trade volumes linked to exports and imports in monetary units.

2.2 Treatment of technical change

Naqvi (2015) introduces technical change as augmentation factors for the inputs of capital and energy. That corresponds to the concept of the factor bias of technical change. For policy simulations, these factors are simply changed exogenously as compared to their baseline values.

In the model of Rengs et al. (2015) firms can improve either through total general ("non-green/non-environmental") factor productivity (i.e. a technological progress scale parameter in the production function) or via green innovation (affecting the carbon emissions per output). These two options are exclusive, with the firm decision about which type of R&D to invest in depending on past performance (profits). Generally firms engage in research and development only if there is enough money left within the firm or if the firm is profitable enough to get a credit from the bank. The costs of R&D are the same for both strategies (general and green innovation), defined as a fixed fraction of the firm's current production capital. Innovation takes the form of upgrades of machinery, which is bought at the end of the year and is effective immediately at the beginning of the new fiscal year (bought from the capital goods firm). To simulate the increasing technical difficulties and costs of reducing emissions per output unit, it is assumed that the consecutive reduction of emissions gets less effective in a non-linear way. This is in line with the widely accepted assumption in economic analysis of environmental policy that marginal abatement costs are rising in the level of abatement.

The DYNK model incorporates technical change that is relevant for the environment in several parts of the model. One is the energy efficiency of durable stock of households (vehicles, houses, appliances) that is also given exogenously and develops in line with the evolution of the durable stock and can be changed for policy simulations.

The other model part where technical change relevant for the environment is incorporated is the production block. There different components of technological change, all modeled via a deterministic time trend, are taken into account. One is autonomous technical change for all input factors (i.e. the factor biases), and the other source of autonomous technical change that only influences unit costs is total factor productivity (TFP). Vogel et al. (2015) have extended this framework towards a model with directed and induced technical change and compare this specification with the model with a pure deterministic trend. In this alternative model, the level of technology is explained by both stocks of knowledge in energy- and labour-saving fields and a time trend capturing knowledge in remaining fields. This sets the stage for the models of induced technological change, which relate technological change in energy- and labour-saving fields to policy variables that could shift the bias away from saving labour towards saving energy. This formulation will be used in a subsequent deliverable to derive the impact of changes in the policy variables on factor demand via their impact on innovation, thereby linking the two parts of the analysis and quantifying the effects of shifting the bias of technological change.

3. Model simulation results

The stock-flow consistent macroeconomic model

In this modelling framework, several exogenous variables, representing technology options and behavioural changes can be altered exogenously in order to evaluate the impact of these scenarios. Not all policy scenarios do also include the definition of concrete policy instruments and their integration into the model.

Naqvi (2015) carries out five policy experiments with a model version calibrated to the EU economy.

- The first experiment looks at a de-growth scenario based on the limits to growth-hypothesis (Meadows and Club of Rome, 1972; Jackson, 2009; Victor, 2012).This hypothesis suggests that policy driven reduction in output will result in lower energy use and subsequently lower emissions (*LowCon*).
- The second experiment (*DmgFunc*) introduces a damage function that endogenizes the depreciation of capital stock to the level of emissions (Tol, 2002; Stern, 2007; Hope, 2011; Nordhaus, 2011; Rezai et al., 2012).
- The third experiment (*HiRenew*) highlights the costs of shifting to a higher share of low-emissions high-cost renewable energy (Trainer, 1995; Dincer, 2000; Tahvonen and Salo, 2001; Varun et al., 2009).
- The fourth experiment (*TaxF and TaxH*) introduces carbon taxes on firms and households (Herber and Raga, 1995; Marron and Toder, 2014).
- The fifth experiment (*InnoK and InnoE*) discusses technological innovation and resource efficiency that aims to address issues of growth in an absolute decoupling scenario (Binswanger, 2001; Yang and Nordhaus, 2006; Herring and Roy, 2007).

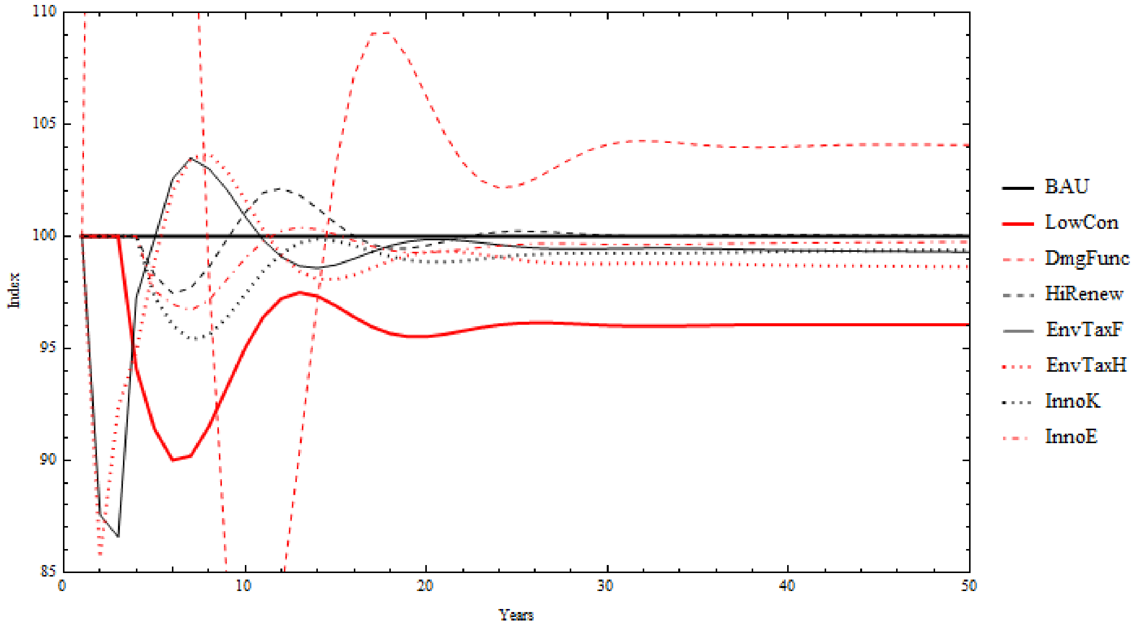
The model outputs track output and growth with other key macroeconomic indicators including unemployment, income and income distributions, prices, energy, and emissions. The experiments are described in Table 1. Figure 3 and Figure 4 show that almost all simulation roughly stabilize to the pre-shock level of output and unemployment, with the exception of the LowCons and the DmgFunc experiments. Whereas the lower output in the LowCons case is due to the postulated reduction in consumption expenditure and thus demand, the DmgFunc experiment results in higher output. This is due to the fact that increasing the depreciation of capital raises the investment requirement for firms. Since investment is part of final demand and credit financing is available due to endogenous money, output rises and unemployment decreases. That, in turn, means that the costs of higher depreciation do not affect the economy negatively in this scenario design.

Table 1 **Main results of policy experiments**

	Growth		Distributions		Environment	
	Output	Unemp.	Incomes	Inequality	Energy	Emissions
LowCons	↓	↑	↓	↓	↓	↓
DmgFunc	↑	↓	↓	↑	↑	↑
HiRenew	-	-	-	-	-	↓
TaxF	-	-	↓	↑	-	-
TaxH	-	-	↓	-	-	-
InnoK	-	-	↑	↓	↓	↓
InnoE	-	-	↑	↓	↓	↓

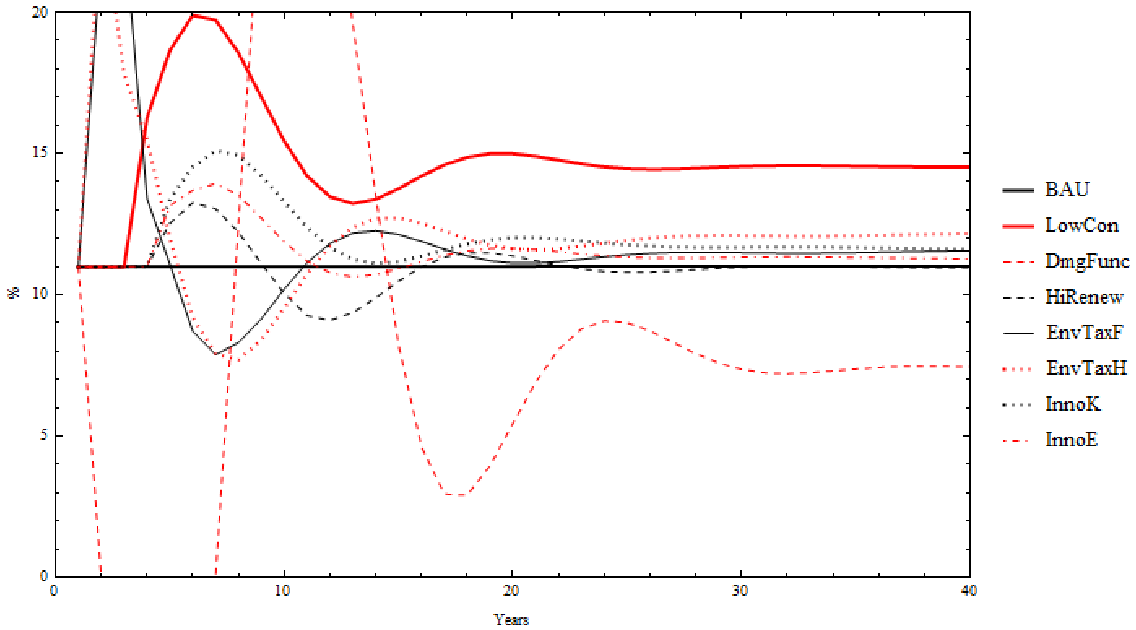
Source: Naqvi (2015). Within 2% of BAU, ↓ > 2% decrease, ↑ >2% increase

Figure 3 **Real output impact of policy experiments**



Source: Naqvi (2015)

Figure 4 **Unemployment rate impact of policy experiments**



Source: Naqvi (2015)

Table 1 summarizes the results for all the experiments. It shows that neither the link between output and distribution, nor the one with the environment is predetermined. In particular, while the connection between output and unemployment conforms to the standard formulation of Okun's law, the income level and the functional income distribution are not as clear-cut. Regarding environmental aspects, the absolute decoupling of energy use and emissions from output can be observed in this model in some cases. The lower output in the low consumption scenario (LowCons) case coincides with higher unemployment and lower incomes, but also lower energy consumption and reduced emission, as expected. This scenario can therefore not be seen as a case of 'green growth'. It also leads to a lower inequality between capital and labour income as a result of lower profit margins for capitalists that decline more than the wages. The higher output resulting from higher investment in the endogenous damage function (DmgFunc) experiment is accompanied by lower unemployment and higher energy use and more greenhouse gas emissions. It also goes along with lower real disposable income and lower worker income relative to capitalist income, which are a result of the price dynamics. The higher level of loans increases prices as firms push the cost of loan repayment on to the consumers for both energy (through demand) and for final goods (higher financing costs), which leads to the lower real disposable income of households and redistributes away from workers.

In the higher renewables share (HiRenew) case, which assumes a switch to renewable energy, output, all three aspects of distribution and energy use are unchanged. Emissions, however, decline, because of the less polluting energy production. A number of minor adaptations accompany the restructuring of the capital stock away from non-renewable energy producers and towards renewable energy production, such as a slight increase in the price of energy and thus of final goods and some redistribution towards capitalists. However, these effects are small, so that the decline in emissions takes place virtually ceteris paribus with regard to the variables investigated here. An environmental taxing on households (TaxH) and firms (TaxF) increases with higher GHGs. As a result, real disposable income declines reducing output. Unemployment rises while energy use and emissions fall slightly below BAU level. The difference between the two experiments lies in the effect on real incomes, which fall more when households are directly taxed as opposed to firms. On the other hand the functional income distribution worsens in the firm tax scenario while improving slightly in the household tax.

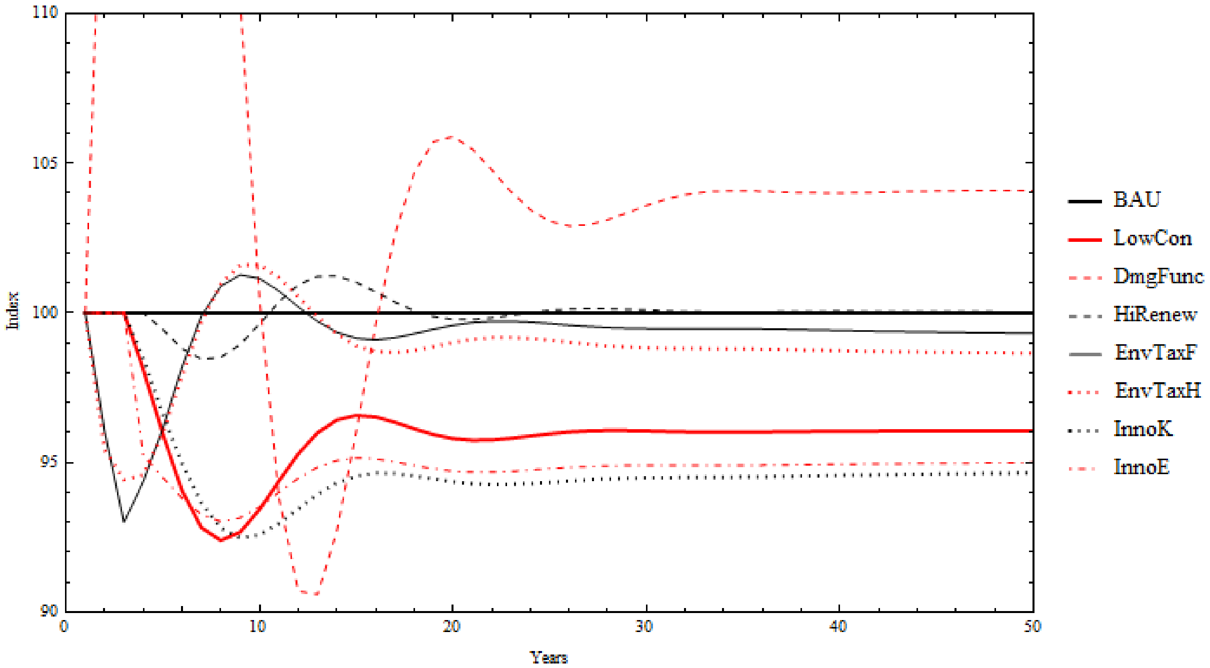
When firms are taxed (TaxF), prices for both energy and final goods rise as the tax burden is passed on to consumers. As a consequence, real incomes fall in the TaxF experiment but less than in the TaxH experiment. Thus capitalists partially increase the demand for goods through higher profits subsequently worsening the functional income distribution while keeping the output demand almost unchanged.

The final two experiments, innovation in capital (InnoK) and energy efficiency (InnoE), reduce both energy demand and emissions while maintaining a stable output and stable unemployment. At the same time, real incomes rise and the ratio of capitalist to worker disposable income falls. These experiments thus come closest to a full synergy between all three targets: output, distribution and environment. The dynamics behind this result are the following: The InnoK simulation lowers the capital required for goods production, and thus indirectly the energy demand. The InnoE scenario shows similar outcomes although the transmission mechanism is a simple price adjustment process resulting from a decline in energy costs.

The scenarios analysed in Naqvi (2015) therefore emphasize the role of technological change, both for energy efficiency as well as for emission free technologies (renewables). In these scenarios of (exogenous) technological change the environmental goals can be achieved without giving up economic dynamics (GDP) or worsening the labour market outcome.

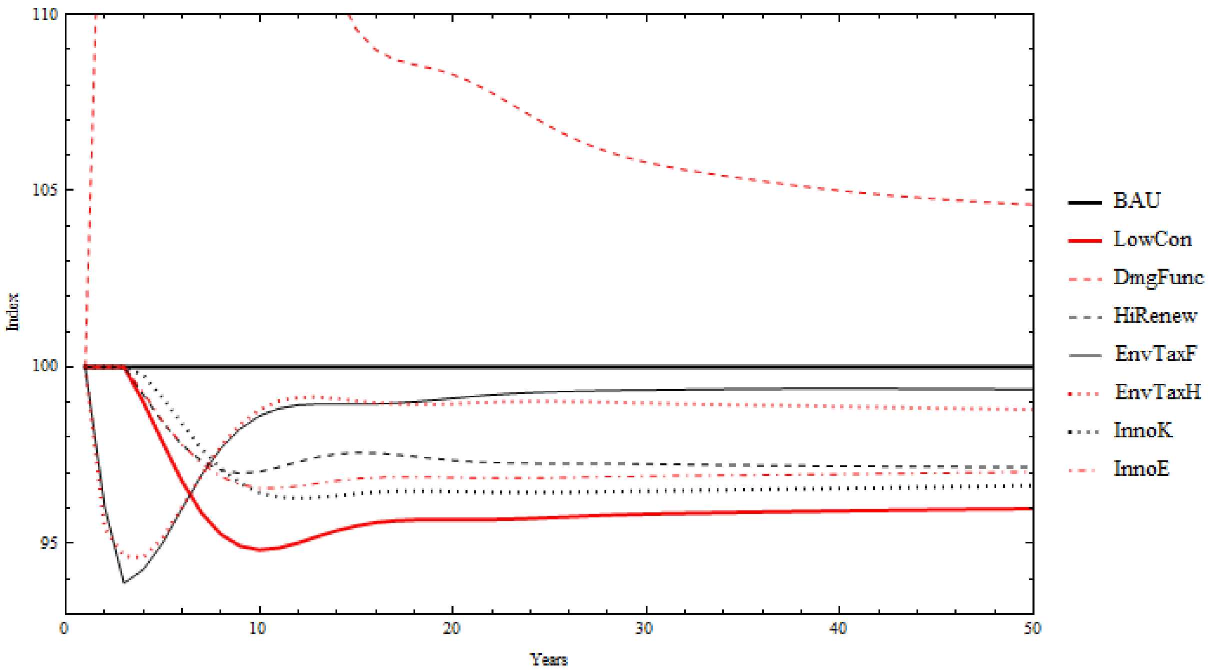
The simulation results at the same time show only small feedback effects and interactions between the technical change affecting the environment and the economy. This is more in line with the results from partial models of the energy system than with results from CGE or other economic impact assessment models.

Figure 5 **Energy demand impact of policy experiments**



Source: Naqvi (2015)

Figure 6 **GHG emission impact of policy experiments**



Source: Naqvi (2015)

The stock-flow consistent agent-based macroeconomic model

In this model framework, the government can implement a price incentive via carbon taxes. The revenues accumulate in a "carbon tax fund" during the fiscal year, which is used to fund a number of policy instruments that are carried out in the following fiscal year. The government can thus employ various policy instruments to either reinforce or complement the effect of the primary climate policy (carbon taxes), such as: directly support (subsidies) of green innovation, reducing labour taxes (creating employment), stimulating diffusion of less carbon-intensive products (product subsidies to consumers), or even combining these instruments. Innovation subsidies are widely regarded as an instrument of technology policy that is complementary to carbon taxes, in the sense that both are needed to foster a transition to a low-carbon economy. The reason is that carbon taxes alone will select the most cost-effective current technology, e.g., wind instead of solar PV, or a particular type of PV over another, even if it is uncertain whether this is the (environmental or economically) best technology in the long run. To keep a potentially attractive technological trajectory (e.g., solar PV) open, i.e. avoiding early lock-in, one can subsidize its R&D.

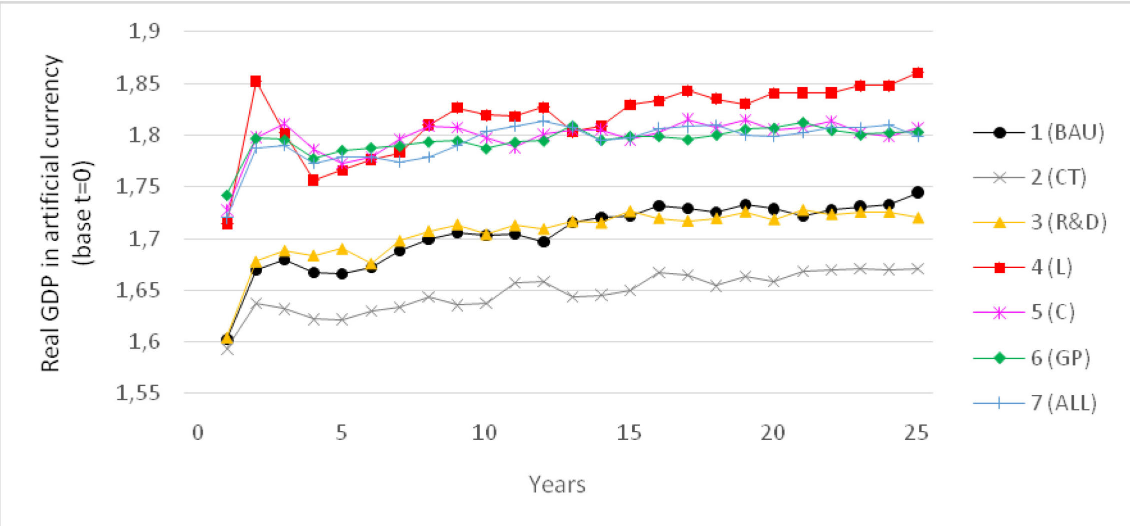
This model is first used to construct a business-as-usual (Scenario 1) without any policy setting, which serves as a reference scenario for assessing the various policy scenarios. A first policy scenario is aimed to test a carbon tax, i.e. a tax on CO_2 emissions without employing any additional climate policies (Scenario 2). As the government has no means to reduce or increase its general spending (unemployment subsidies and pensions) willingly, these additional tax revenues have no effect on its behavior.

- Research & development (Scenario 3): if a firm follows a green innovation trajectory, its R&D costs are subsidized. This can take the form of subsidies for the installation of green filters, for example. The total amount of R&D subsidies provided by the government will be approximately equal to the revenue of the carbon tax. Individual firms receive subsidies in relation to their R&D costs, weighted by the marginal effectivity of the improvement. Thus, if two firms have equal R&D costs (i.e. who have the same production capital), the firm that will achieve a higher emission reduction by R&D will get a higher subsidy.
- Labour tax reduction (Scenario 4): this is the much discussed idea of a shifting from labour taxes to carbon (CO_2) taxes. This would alter the incentives for innovation from stimulating improvements in labour to carbon productivity, with potentially beneficial effects for environment and labour market.
- Consumer product subsidy (Scenario 5): a subsidy to lower consumer prices for less carbon-intensive products, to stimulate their rapid diffusion.
- Green procurement (Scenario 6): the government buys relatively much less carbon-intensive (greener) products. This is operationalized by letting the government search randomly half of the population of firms producing relatively clean products, and sorting them according to carbon intensity. The lower the distance to the cleanest firm the more the government purchases (and it buys thus the most from the cleanest product).

- All climate policy instruments actively used (Scenario 7): the carbon tax revenues are divided in equal parts among the different climate policy instruments at the end of each year.

Figure 7 shows the annual development of real GDP. Real GDP is measured as the aggregated final demand by households and the government, adjusted by the weighted mean price for every year. At a first glance we see that the introduction of a carbon tax dampens GDP over the whole course of the simulation, in comparison to BAU. However, the collected revenues from this tax can bring back GDP to BAU once it is used for R&D subsidies (Scenario 3). All other policy scenarios work as a demand shock for the economy and boost GDP up in contrast to BAU. In Scenarios 4 to 7, even the initial value of GDP is significantly higher than BAU, since expectations of all actors are adjusted correspondingly from the start. The highest real GDP development is reached within Scenario 4, i.e. the flat labour tax reduction on the household side that translates into higher purchasing power.

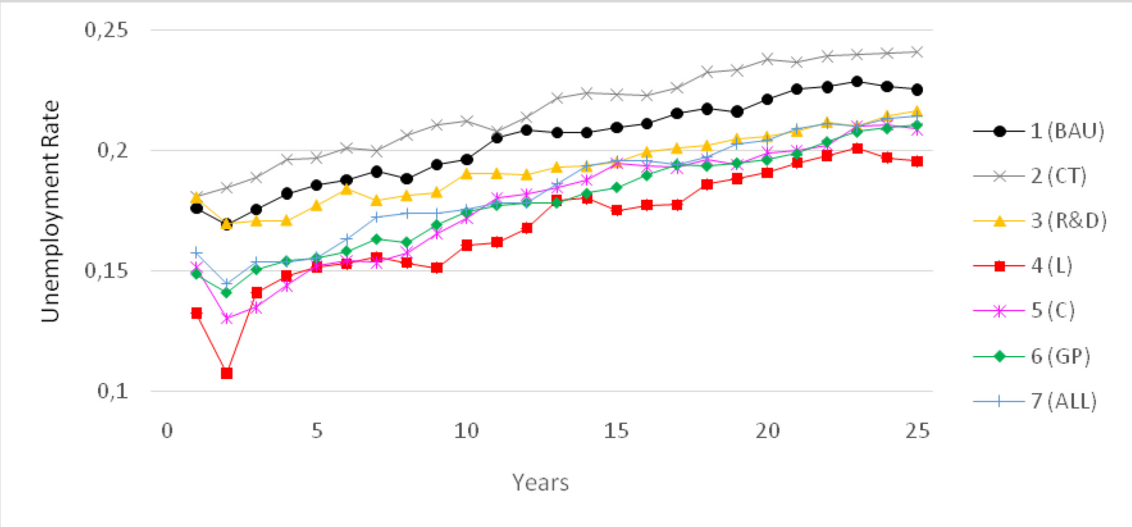
Figure 7 **Real GDP impact of policy scenarios**



Source: Rengs et al. (2015)

In terms of unemployment we can immediately observe strong differences among the chosen scenarios. Figure 8 highlights that the unemployment rate has a bandwidth for fluctuations up to 4% among the scenarios. The carbon tax Scenario 2 (CT) has the highest unemployment rate starting with 18% and developing till 24% after 25 years. This notion indicates that a carbon tax without any particular dedication for its revenues creates a significant problem for the labour market that needs to get addressed. The tax makes the price of carbon-intensive products more expensive and aggregate demand is shocked by this policy, translating into lower production. In our case all Scenarios 3 to 7 with a combined policy perform even better than BAU, a surprising result in face of the diversity of economic channels we have addressed with them. The best performing scenario in terms of employment (lowest unemployment) is given in Scenario 4 (L), using all carbon tax revenues to reduce labour taxes. This is what one might expect, but it should be noticed that the difference with Scenarios 5 to 7 are not that huge. The latter three are performing quite similarly in terms of unemployment, which is intuitive as they all contribute to stimulating diffusion, whether through private or public consumption, or both. Finally Scenario 3 (R&D) performs very well in terms of unemployment, more than we have expected. In the first 10 to 15 years of simulation the unemployment rate is quite close to BAU, but then the R&D subsidies pay off and the scenario catches up with Scenarios 5 to 7. Still, Scenario 7 (ALL) does not stand out that much. The reason is that (equally) distributing carbon tax revenues over all mentioned complementary instruments dilutes the impacts of each compared to their effect in policy scenarios where all revenues are spent on a single instrument.

Figure 8 **Unemployment impact of policy scenarios**



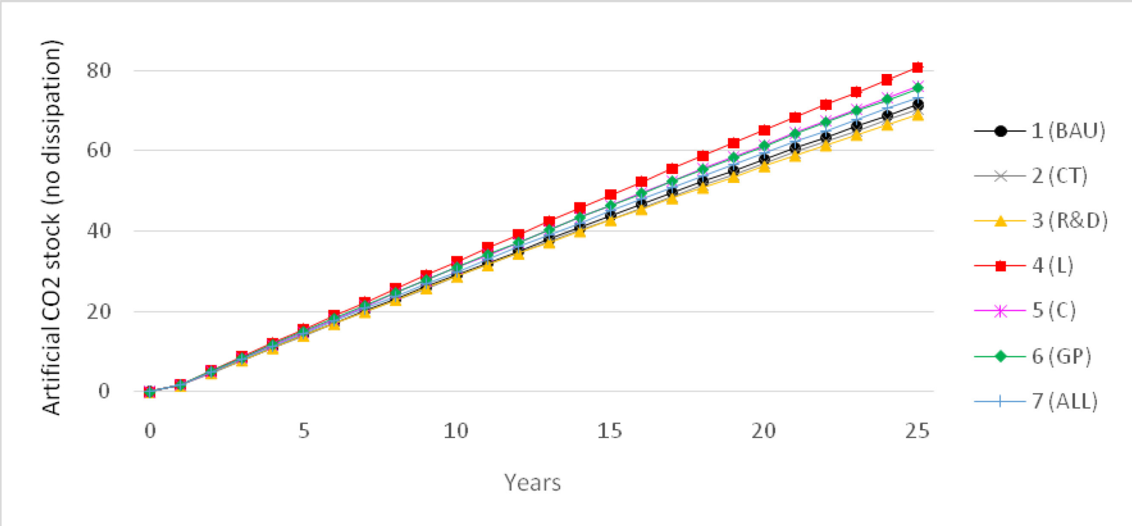
Source: Rengs et al. (2015)

Figure 9 shows the development of the stock of carbon emissions in relation to BAU for all given scenarios. The results are somewhat surprising. The only scenarios that are pushing carbon emissions down are given by the simple introduction of a carbon tax – Scenario 1 (CT) – and the double dividend policy with R&D subsidies – Scenario 3 (R&D). All other policies perform even worse than BAU. By far the dirtiest scenario in comparison to BAU is indicated by the labour tax reduction – Scenario 4 (L). An explanation for this case needs to compare the growth effect on GDP driven by higher purchasing power in Scenario 4 that outperforms the market selection on less carbon-intensive products. This aspect is again connected, as already mentioned, to the lending behaviour of firms in our model. Since we do not allow for too risky lending, green firm selection does no out-compete the general growth effect.

That a revenue neutral tax shift from labour to energy (or carbon) may result in even higher energy use or emissions, has already been discussed in the literature (Bayindir-Upmann and Raith, 2003). This paradox result depends on certain model parameters that lead to a positive GDP effect that compensates for the higher energy/emission efficiency brought about by the carbon tax.

Like the scenarios in Naqvi (2015) the scenarios in Rengs et al. (2015) underline the importance of technological change – in this framework explicitly modelled via R&D activities – for achieving a synergy between environmental, social and economic objectives.

Figure 9 **Carbon stock impact of policy scenarios**



Source: Rengs et al. (2015)

The Dynamic New Keynesian (DYNK) model

The DYNK model has been used for two different policy simulations, regarding revenue neutral CO_2 taxation. The political targets for Europe, formulated in roadmaps for GHG emission reduction prescribe significant reductions in resource use linked to domestic production (GHG emissions), as well as to domestic consumption (GHG footprint). The main instrument discussed in this context is the introduction of prices/taxes for GHG emissions and for the GHG footprint. At the same time, the problem of 'leakage' is identified in a scenario of a "go-it-alone" European climate policy. Higher costs for European producers due to these taxes may lead to relocation of energy-intensive production. This in turn may hurt growth of income and jobs in Europe while leaving GHG emissions unchanged or even higher on a global scale. In the end, the genuine source of leakage is consumer demand in Europe. Given this demand, producers outside Europe will increase their energy use, if European producers of energy-intensive goods are not competitive. One can think of two possible strategies to overcome leakage: (i) increasing energy efficiency more than proportionally, so that costs do not rise or (ii) taxing embodied emissions in order to reduce European demand for energy-intensive products. Alternative (i) may be achieved by additionally spurring technical change via using part of the tax revenues for directed technical change. In the following, we analyse the socio-economic impact of alternative (ii) and compare it with the results of 'classical green tax' reform, applying the DYNK model for the EU 27 economy.

Two different tax reform schemes have been analysed with the DYNK model for the EU 27 in order to understand the options for dealing with the challenges of absolute decoupling, price competitiveness of European manufacturing and leakage:

(i) the classical 'Green Tax Reform' where GHG emissions are taxed on an increasing scale and social security contributions (employers' and employees') are reduced simultaneously so that (ex post) public revenue neutrality is guaranteed (ii) an 'Environmental Fiscal Devaluation' where GHG emissions embodied in private consumption are taxed at the same rate and on the same increasing scale as in (i) above, and revenue neutrality is also achieved by the same rule for social security contributions as in (i). This tax reform can be seen as a special case of fiscal devaluation, i.e. a change in the tax system that mimics the price effects of a devaluation of the currency by rising taxes on consumption (higher prices of domestic consumption) and lowering taxes on labour (lower prices of exports). In the case of environmental fiscal devaluation consumption prices rise due to taxation of embodied emissions, and export prices decrease due to lower social security contribution. Note that in the concept of 'Environmental Fiscal Devaluation' all consumption goods are taxed irrespective of their origin (like in the case of the Danish fat tax), so that no inconsistency with international trade agreements arises.

The tax rates for GHG emissions have been determined in line with the EU Roadmap for a low-carbon economy, starting off with a tax rate of 25 €/t of CO_2 equivalent (in € of 2005) in 2015 and rising continuously to 250 €/t of CO_2 equivalent (in € of 2005).

Implementation in the case of 'Green Tax Reform' is straightforward, as the tax rates lead to higher effective input prices for energy in production and consumption. In the case of 'Environmental Fiscal Devaluation', the embodied emissions had in a first step to be quantified by simulating unitary consumption demand increases for all 59 commodities in the DYNK model. The results of these simulations yield a rough one-point-in-time estimate of domestic emission contents for each consumption category. From these results, the relationship between the outcome in terms of emissions and the shock in consumption demand can be calculated, which gives 'implicit coefficients' of embodied domestic emissions. Induced imports of each consumption category are also accounted for in monetary units as part of the simulation results. Hence, what is not directly included into the calculation of embodied emissions and resource use are all indirect effects in the rest of the world linked to European consumer demand. The correct way to deal with such effects would be a simulation with a MRIO (multi-regional input-output) model, which was beyond the scope of this research. Accounting for these indirect effects is approximated by taking the results for implicit coefficients of imported emissions of the EU 27 from a MRIO model, based on the WIOD database. The ex post revenue neutrality via lower social security contributions is implemented as an additional constraint in the public sector block of the DYNK model which guarantees that the social security contribution rate is endogenously determined in the model solution at a level consistent with ex post revenue neutrality.

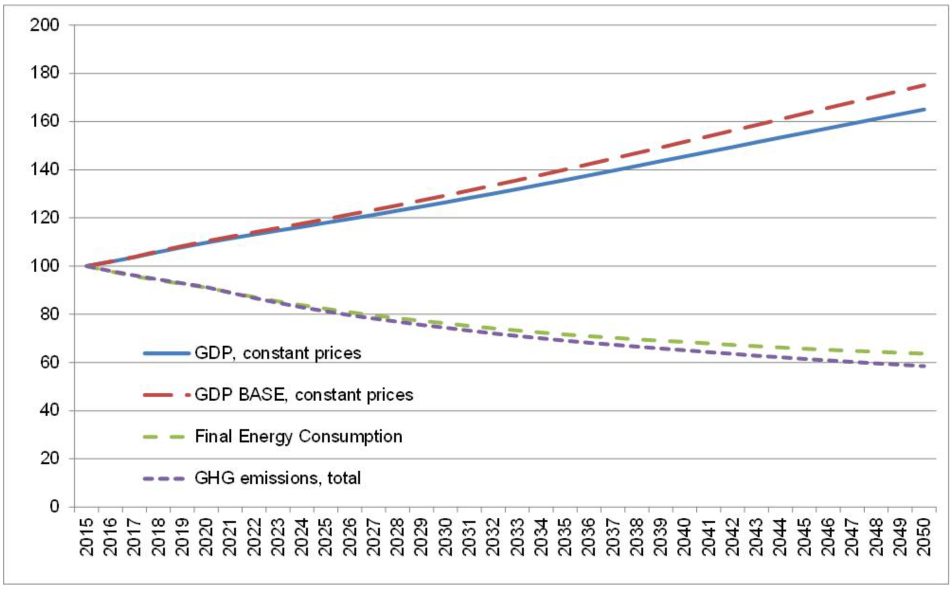
'Green Tax Reform' has different short- and long-run effects on the labour market, but a consistent negative impact (compared with the 'baseline') on GDP. This is due to price increases that in turn have a negative impact on exports as well as on household disposable income. The effective price of fossil energy rises due to CO_2 taxation; since fossil energy is not only a factor of production, but also a consumption good (fuels for cars and heating), the consumer price level increases more that the producer price level. This in turn has repercussions on the wage bargaining process, so that in the long-run, employees' gross wage rate increases more than in the 'baseline', offsetting a large part of the lower social security contributions until 2050.

Table 2 **Macroeconomic effects of "Green Tax Reform**

	2015	2020	2030	2050
GDP, const. prices	-0.03	-0.54	-2.20	-5.79
Private Consumption, const. prices	-0.33	-1.55	-4.92	-11.13
Capital formation, const. prices	0.00	-0.01	-0.04	-0.09
Exports, const. prices	-0.19	-1.12	-3.92	-9.64
Employment (persons)	0.31	0.25	-0.20	-0.84
Employment (hours)	0.31	0.26	-0.17	-0.80
Unemployment (persons)	-2.21	-2.01	2.09	16.93
Unemployment rate (% points)	-0.27	-0.22	0.18	0.80
GHG emissions, households	-5.35	-7.98	-11.78	-14.80
GHG emissions, production	-9.81	-17.41	-30.03	-43.04
GHG emissions, total	-8.56	-14.79	-25.04	-35.34
GHG emissions, Leakage	-0.07	0.30	2.31	11.14

Source: Kratena and Sommer (2014)

Figure 10 **Impact of "Green Tax Reform" on GDP, emissions and energy use**



Source: Kratena and Sommer (2014)

The labour market effect, driven by the change in relative prices between energy and resources on the one hand and labour on the other, is positive until 2030 (compared with the 'baseline'), turning negative thereafter due to the increasing negative output effect. It is, however, important to note that the annual difference in GDP growth to the 'baseline' is rather small, with only 0.15% p.a. (Figure 10). The main result of this scenario for the environment is that absolute decoupling of energy consumption and of GHG emissions from GDP is possible. This is not the case for DMC per capita for the material tax rate implemented in this scenario. This may, however, be the case for a higher tax on minerals than the one assumed here, based on the literature.

Comparing the results for energy consumption and GHG emissions with those from the impact analysis of the EU Roadmap for a low carbon economy, we note that in our model the reductions of energy use and emissions at the same CO_2 price level are considerably smaller. This is due to the fact that the EU Roadmap foresees several other instruments besides pricing of CO_2, like the support for renewables, and the widespread diffusion of other carbon-saving technologies like CCS (carbon capture and storage) and nuclear energy. These additional instruments are absent in our scenario of 'Green Tax Reform', only the share of renewables also doubles, induced by the CO_2 price hike.

The leakage in terms of GHG emissions amounts to 4% in 2050, but, as explained above, this estimate (which represents the lower bound of what the literature finds about GHG leakage) might be strongly biased downwards due to our resort to EU 27 technology in terms of embodied emissions and resource use.

The average employment effect of 0.33% is the result of very heterogeneous effects by industry, with job losses in the public sector (due to cuts in public expenditure in order to meet the deficit target) and high employment gains in the electricity sector (due to substitution towards labour inputs) as well as in some manufacturing and service sectors. The transport sector also loses jobs from the 'baseline' scenario.

'Environmental Fiscal Devaluation' increases both output (GDP) and employment in the short- as well as in the long-run compared with the 'baseline' scenario. The negative impact on consumption is smaller than in the case of 'Green Tax Reform', though the price effect on fossil fuels directly used by households (fuels for cars and for heating) is the same. An important positive impact on GDP in this scenario stems from the reduction of imports. The difference between the two schemes is explained by the differential impact on price competitiveness and exports. The changes in the price system lift exports above the 'baseline' until 2030. This in turn raises employment in addition to the positive effect of lower social security contributions, and also boosts disposable income. The macroeconomic effects clearly show the mechanism of fiscal devaluation: demand is shifted from domestic to foreign sources, leading to a positive net impact on GDP. The average growth rate of GDP is about 0.1% p.a. higher than in the 'baseline'.

While the scenario of 'Environmental Fiscal Devaluation' improves all environmental outcomes vis-à-vis the 'baseline', the desired absolute decoupling is not achieved (Figure 11).

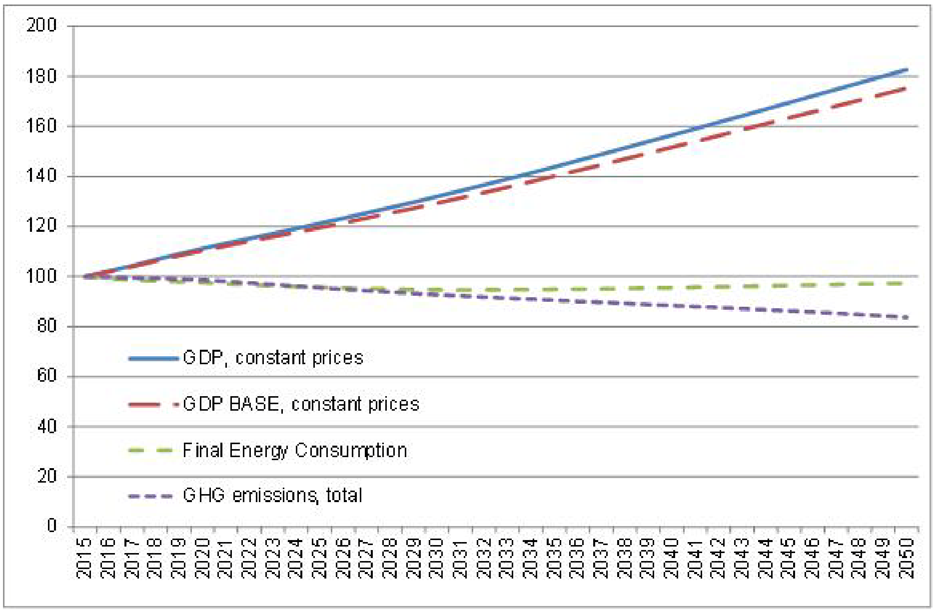
As all imports are reduced in this scenario, due to the taxation of the embodied environmental impact on consumption, also GHG emissions abroad decrease. 'Environmental Fiscal Devaluation' in Europe therefore reduces emissions and resource use on a global scale by more than within the EU 27, yielding a negative leakage effect. As has been explained above, our estimates of leakage are biased downwards by using the European technology as a proxy for the technology of EU imports.

Table 3 **Macroeconomic effects of "Environmental Fiscal Devaluation"**

	2015	2020	2030	2050
GDP, const. prices	0.34	1.11	2.39	4.62
Private Consumption, const. prices	0.02	-0.58	-1.94	-3.36
Capital formation, const. prices	0.00	0.00	0.00	-0.01
Exports, const. prices	0.32	0.92	1.28	-1.10
Employment (persons)	0.30	0.74	1.32	2.03
Employment (hours)	0.29	0.72	1.26	1.78
Unemployment (persons)	-2.18	-6.09	-13.93	-40.84
Unemployment rate (% points)	-0.27	-0.66	-1.21	-1.93
GHG emissions, households	-3.61	-7.19	-10.45	-10.16
GHG emissions, production	-0.42	-1.52	-3.82	-10.02
GHG emissions, total	-1.32	-3.10	-5.64	-10.05
GHG emissions, Leakage	-0.42	-1.12	-2.54	-4.78

Source: Kratena and Sommer (2014)

Figure 11 **Impact of "Environmental Fiscal Devaluation" on GDP, emissions and energy use**



Source: Kratena and Sommer (2014)

4. Conclusions

Macroeconomic modelling of policies aiming at the simultaneous fulfillment of environmental, social and economic objectives has the integration of several features into the modelling approach as a prerequisite. These features include an explicit treatment of the link between monetary aggregates and physical flows, an explicit representation of technical change and its relevance for the environment as well as a detailed treatment of the behavior of agents (households and firms). The latter issue has been dealt with in an agent-based macroeconomic model that allows for modelling behavioural changes brought about by policies and reinforced by social dynamics.

The integration of these features allows for dealing with a wider range of policy instruments and scenarios than in traditional economic assessment models, where price instruments dominate. That refers to instruments aiming at technical as well as behavioural change.

Two important conclusions can be drawn from the simulation results:

(i) important trade-offs and synergies exist between the different economic, social and environmental goals

(ii) simple policy scenarios mainly putting all the effort in one simple instrument (e.g. tax reform) are not likely to achieve an optimal result. A combination of instruments is most likely to achieve results satisfying the different economic, social and environmental goals. In this context, inducing technical change in the desired direction via policy instruments is especially relevant.

References

Bayindir-Upmann,T. , Raith, M.G., 2003. Should high-tax countries pursue revenue-neutral

Binswanger, M. (2001). Technological progress and sustainable development: what about the rebound effect? Ecological Economics, 36(1):119 _ 132.

Busl, C., Seymen, A. (2013), (Spillover) Effects of Labour Market Reforms in Germany and France, WWWforEurope Working Paper, (8), link to document.

Carroll, C.D., (1997), Buffer-stock saving and the life cycle/permanent income hypothesis, Quarterly Journal of Economics 112, 1-55.

Chen, Shu-Heng, Chang, Chia-Ling and Wen, Ming-Chang, (2014). Social networks and macroeconomic stability. Economics: The Open-Access, Open-Assessment E-Journal 8 (2014-16): 1-40.

Cincotti, S., Raberto, M. and Teglio, A. (2010). Credit money and macroeconomic instability in the agent-based model and simulator Eurace. Economics: The Open-Access, Open-Assessment E-Journal 4: 2010-2026.

Delli Gatti, D., Desiderio, S., Gaffeo, E., Cirillo, P. and Gallegati, M (2011). Macroeconomics from the Bottom-*up.* Springer, Berlin.

Dincer, I. (2000). Renewable energy and sustainable development: a crucial review. Renewable and Sustainable Energy Reviews, 4(2):157 _ 175.

Gilbert, N. (2007). Agent-Based Models – Quantitative Applications in the Social Sciences. Sage Publications, London.

Godley, W. and Lavoie, M. (2012). Monetary Economics. An integrated Approach to Credit, Money, Income, Production and Wealth, 2nd edition. London: Palgrave MacMillan.

Godley, W. and Lavoie, M., (2007). Monetary Economics: An Integrated Approach to Credit, Money, Income, Production and Wealth. Palgrave Macmillan, New York.

Herber, B. P. and Raga, J. T. (1995). An international carbon tax to combat global warming: An economic and political analysis of the european union proposal. American Journal of Economics and Sociology, 54(3):pp. 257_267.

Herring, H. and Roy, R. (2007). Technological innovation, energy efficient design and the rebound effect. Technovation, 27(4):194 _ 203.

Hope, C. W. (2011). The social cost of co2 from the page09 model. Economics Discussion Papers 2011-39, Kiel Institute for the World Economy.

Jackson, T. (2009). Prosperity without Growth: Economics for Finite Planet. Routledge.

Jackson, T., Drake, B., Victor, P., Kratena, K., Sommer, M. (2014), Literature review and model development, WWWforEurope Working Paper, (65), link to document.

Jorgenson DW, Goettle RJ, Wilcoxen PJ, Ho MS (2008) The economic costs of a market-based climate policy. DW Jorgenson Associates for Pew Center on Global Climate Change, Arlington.

Keen, S. (2014). Endogenous money and e_ective demand. Review of Keynesian Economics, 2(3):271 _ 291.

Khazzoom, J.D., 1989, Energy savings from more efficient appliances: a rejoinder, The Energy Journal, 10, 157-166.

Kratena, K., Sommer, M. (2014), Policy implications of resource constraints on the European economy, WWWforEurope Policy Brief, (6), link to document.

Lavoie, M. (2014a). A comment on "endogenous money and e_ective demand": a revolution or a step backwards? Review of Keynesian Economics, 2(3):321 _ 332.

Leibenstein, H. (1950). Bandwagon, snob, and Veblen effects in the theory of consumers' demand. The Quarterly Journal of Economics 64 (2): 183-207.

Lengnick, M. (2013). Agent-based macroeconomics: A baseline model. Journal of Economic Behavior & Organization 86 (C): 102-120.

Luengo-Prado, M.J. (2006), Durables, nondurables, down payments and consumption excesses, Journal of Monetary Economics, 53, 1509-1539.

Marron, D. B. and Toder, E. J. (2014). Tax policy issues in designing a carbon tax. American Economic Review, 104(5):563_68.

Meadows, D. L. and Club of Rome (1972). The Limits to Growth. Universe Books, New York.

Moore, B. J. (1988). The endogenous money supply. Journal of Post Keynesian Economics, 10(3):pp. 372_385.

Naqvi, A. (2015), Modeling Growth, Distribution, and the Environment in a Stock-Flow Consistent Framework, WWWforEurope Policy Paper, (18), link to document.

Nordhaus, W. D. (2011). Estimates of the social cost of carbon: Background and results from the rice-2011 model. NBER Working Papers 17540, National Bureau of Economic Research,Inc.

Rengs, B. and Wäckerle, M. (2014). A Computational Agent-Based Simulation of an Artificial Monetary Union for Dynamic Comparative Institutional Analysis. Proceedings of the 2014 IEEE Conference on Computational Intelligence for Financial Engineering & Economics (CIFEr): 427 – 434.

Rengs, B., Scholz-Wäckerle, M., Gazheli, A., Antal., M., van den Bergh, J. (2015), Testing innovation, employment and distributional impacts of climate policy packages in a macro-evolutionary systems stetting, WWWforEurope Working Papers, (83), link to document.

Rezai, A., Foley, D., and Taylor, L. (2012). Global warming and economic externalities. Economic Theory, 49(2):329_351.

Riccetti, L., Russo, A. and Gallegati, M. (2013). Unemployment Benefits and Financial Leverage in an Agent Based Macroeconomic Model. Economics: The Open-Access, Open-Assessment E-Journal 7 (2013-42): 1—44.

Seppecher, P. (2012). Flexibility of Wages and Macroeconomic Instability in an Agent-Based Computational Model with Endogenous Money. Macroeconomic Dynamics 16 (s2): 284-297.

Starr, R. M. (2003). Why is there money? endogenous derivation of 'money' as the most liquid asset: A class of examples. Economic Theory, 21(2/3):pp. 455_474.

Stern, N. (2007). The Economics of Climate Change: The Stern Review. Cambridge University Press.

Tahvonen, O. and Salo, S. (2001). Economic growth and transitions between renewable and nonrenewable energy resources. European Economic Review, 45(8):1379 _ 1398. 21

Tesfatsion, L. and Judd, K.L. (2006). Handbook of computational economics: Agent-based computational economics, vol. 2, North Holland, Amsterdam.

Tol, R. (2002). Estimates of the damage costs of climate change. part i: Benchmark estimates. Environmental & Resource Economics, 21(1):47_73.

Trainer, F. (1995). Can renewable energy sources sustain affluent society? Energy Policy, 23(12):1009 _ 1026.

Trigg, A.B. (2001). Veblen, Bourdieu and conspicuous consumption. Journal of Economic Issues 35: 99-115.

Varun, Prakash, R., and Bhat, I. K. (2009). Energy, economics and environmental impacts of renewable energy systems. Renewable and Sustainable Energy Reviews, 13(9):2716 _ 2721.

Veblen, Th., (2000) [1899]. Theorie der feinen Leute: Eine ökonomische Untersuchung der Institutionen. Fischer, Frankfurt.

Victor, P. A. (2012). Growth, degrowth and climate change: A scenario analysis. Ecological Economics, 84(C):206_212.

Vogel, J., Kratena, K., Hranyai; K. (2015), The Bias of Technological Change in Europe, WWWforEurope Working Paper, (98), link to document.

Yang, Z. and Nordhaus, W. D. (2006). Magnitude and direction of technological transfers for mitigating GHG emissions. Energy Economics, 28(5-6):730_741.

Project Information

Welfare, Wealth and Work for Europe

A European research consortium is working on the analytical foundations for a socio-ecological transition

Abstract

Europe needs change. The financial crisis has exposed long-neglected deficiencies in the present growth path, most visibly in the areas of unemployment and public debt. At the same time, Europe has to cope with new challenges, ranging from globalisation and demographic shifts to new technologies and ecological challenges. Under the title of Welfare, Wealth and Work for Europe – WWWforEurope – a European research consortium is laying the analytical foundation for a new development strategy that will enable a socio-ecological transition to high levels of employment, social inclusion, gender equity and environmental sustainability. The four-year research project within the 7th Framework Programme funded by the European Commission was launched in April 2012. The consortium brings together researchers from 34 scientific institutions in 12 European countries and is coordinated by the Austrian Institute of Economic Research (WIFO). The project coordinator is Karl Aiginger, director of WIFO.

For details on WWWforEurope see: www.foreurope.eu

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