EU Climate and Energy Policy Beyond 2020: Is a Single Target for GHG Reduction Sufficient?

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Abstract The immediate and long-term requirements of energy policy in Germany and the wider EU are widespread. In addition to meeting decarbonisation targets to mitigate climate change, energy policy must be designed in such a way that is socio-economically advantageous, delivering multi-policy objectives of energy security, a stable environment for energy system operation, affordable energy prices for consumers and industry, and an environment conducive to economic growth.

There has been much debate about the merits and weaknesses of alternative policy frameworks to deliver on emissions targets. Introduced in 2005, the EU emissions trading system (ETS) was designed to monetise the externalities associated with GHG emissions, with many citing the carbon price as providing the most efficient and cost-effective means of achieving a certain emissions target. By contrast, subsidies for renewable electricity generation and energy efficiency measures, when implemented alongside an emissions trading scheme, are often criticized for increasing the costs of emissions abatement and producing no additional environmental benefits. This chapter re-assesses the merits and weaknesses of this policy mix and explores the socio-economic impacts of alternative policy scenarios that

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achieve the same emissions target. We use E3ME, a global macro-econometric model, to show that environmental regulation and subsidies for energy efficiency and renewable investment at European level, when implemented alongside a carbon price, lead to improved long-term environmental and socio-economic outcomes compared to when a carbon price is the sole policy instrument.

1 Introduction

1.1 Theoretical Background

With the Paris Agreement (UNFCCC 2015) now ratified, the decision to limit global emissions to a level that is consistent with a 2°C target has been taken. Leaving aside the issue of the US's participation in the Paris Agreement, the main decision that remains at global level is how far to pursue the objective of limiting climate change to 1.5°C above pre-industrial levels.

At national level (and regional in the case of the EU), however, there are still important decisions to be made. In the medium term, there is the question of how the current Paris pledges, known as NDCs (Nationally Determined Contributions) can be scaled up in ambition to be consistent with the 2°C target. More immediately, policy makers must decide upon a policy mix that will help their territories comply with the pledges that they have made.

Economists have played an important role in advising policy makers. Much of the advice has been drawn from neoclassical economic theory, which underpins the current mainstream. The main modelling tools that have been used by economists, a combination of Computable General Equilibrium (CGE) (Dixon and Jorgensen 2012) and energy systems optimisation models (Loulou et al. 2005), are based on this strand of economic theory.

These models consistently suggest that the most efficient way of reducing greenhouse gas emissions in line with the specified targets is to apply either a tax on emissions at the rate required to meet the targets or an emission trading scheme in which the carbon price is determined by the market[1] (Böhringer and Rosendahl 2011; Fankenhauser et al. 2010; Meran and Wittmann 2012). This carbon price should be applied to all emitters equally with no exemptions. If it is not possible to price all greenhouse gas emissions, then at least energy CO_2 emissions should be covered. If there are any existing subsidies on fossil fuels, these should be removed immediately due to their market distorting effect.

However, this result comes directly from the assumptions that are used in the models. The models are optimisation tools; by placing a constraint directly on the output that is to be manipulated (i.e. greenhouse gas emissions), there is minimum disruption to the rest of the economy.

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[1] As the models typically do not cover uncertainty well, a carbon tax and emissions trading scheme may have the same properties in modelling terms.

This in itself is not problematic; all models are based on assumptions and almost by definition the results from the models must reflect the underlying assumptions. However, especially given the wide range of literature and policy analyses (see examples in Dixon and Jorgensen 2012) that has been developed from these models, it is important to dig further into the structure and assumptions of the models. The policy recommendations that arise from them can only be accepted if the assumptions are correct.

Perhaps the most important assumption is what economists refer to as 'perfect knowledge'. In order to produce optimal decisions, agents must be fully aware of all their options, and the costs and benefits of each one. Further assumptions include fully optimising, 'rational' behaviour by individuals to maximise their welfare and firms to maximise profits, and the existence of markets that operate without constraint.

There are legitimate questions to be asked about how realistic any of these assumptions are, but arguably the most important relates to real-world limitations in the degree of knowledge that agents have when making economic decisions. Recently, some economists have developed new theories based on knowledge limitations (Goldberg and Frydman 2007) but the treatment of knowledge gaps has always been an important feature of the whole Keynesian school of economics. Even prior to the Great Depression and Keynes' more famous works, *A Treatise on Probability* (Keynes 1921) laid out the foundations for his later theory. Keynes realised that fundamental uncertainty (now sometimes referred to as 'unknown unknowns') hindered economic decision making and led to individuals building up savings reserves to protect against future stocks. As the money that was saved rather than spent did not lead to demand for goods (and the labour associated with producing those goods), the economy tended to operate below capacity.

Several key economic properties follow from the relaxation of this single assumption of perfect knowledge. Most notably, the level of production is determined by the balance between expenditure and savings (i.e. aggregate demand) rather than purely supply-side constraints on the maximum that an economy can produce. Other important outcomes include:

- If the level of demand is not high enough, it will not be possible to provide jobs for all the available workers, leading to involuntary unemployment.
- 'Perfect' competition is unlikely; gaps in knowledge lead to branding and differentiated products that can charge a price premium.
- Income inequality is a likely outcome as firms and individuals can exploit knowledge gaps for their own benefit.
- Firms may underinvest, particularly in research and development, as they cannot be certain that they will be rewarded for their efforts.

There are many more, but these features are all prominent in the real world and present challenges to policy makers across a range of government departments. They are also recognised as important issues in the current post-Keynesian school of economics (King 2015; Lavoie 2015), which has developed the original ideas of Keynes further.

The modelling that we carry out later in this chapter uses an approach that has been developed from post-Keynesian economics. We test whether, with some of these key assumptions relaxed, it still holds that a single carbon pricing instrument is the optimal policy approach. Before that, however, we summarise the current EU policy.

1.2 EU Policy

There are numerous climate-related policies at European level and many more at national level. However, three main policies cut across most sectors in the European economy:

- An aggregate target for greenhouse gas (GHG) emission reduction, which is supported by the European Emission Trading System (ETS) in the power sector, heavy industry and intra-EU aviation.
- A target for the share of final energy consumption that should come from renewable sources.
- A target for improvements to energy efficiency (measured as reductions in energy consumption), relative to a baseline projection.

These three targets formed the '20-20-20' targets for 2020, meaning a 20% reduction in GHG emissions compared to 1990 levels, a 20% renewable energy share and a 20% improvement in energy efficiency. The targets that were set in 2014 for 2030 include a 40% reduction in emissions, a 27% renewable share and a 30% improvement to energy efficiency.

Even though carbon pricing plays a central role in EU policy, the approach of having three targets rather than a single GHG reduction target (backed by a price on emissions) has been criticised heavily by neoclassical economists, see e.g. Böhringer et al. (2009), for being inefficient. European policy makers justify the range of policies on several different factors, some of which are political but others relating to the real-world validity of the economic assumptions discussed above.

In the case of renewables, European policy has the aim of developing key technologies so that they can contribute to emissions reductions around the world, up to and beyond 2030. The current solar revolution is likely to be at least in part due to policies in certain European countries that increased adoption, leading to more efficient production and lower prices for everyone else. The recognised limitation is that, without specific support, 2030 targets could be met in Europe by, for example, switching from coal to natural gas in the power sector, but without the necessary technologies to make further emission reductions.

In the case of energy efficiency, it is widely recognised by the European Commission and others that households face non-price impediments.[2] A lack of direct

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[2] See e.g. European Commission web pages, https://ec.europa.eu/energy/en/topics/energy-efficiency

knowledge is a key issue (e.g. what to buy and how to install it) but access to credit and principal agent problems with landlords not wanting to make investments that benefit their tenants are also important. By setting targets for energy efficiency, the EU and national governments are setting ways to tackle these issues that cannot be addressed with carbon pricing alone. The IEA (IEA 2014) lays out clearly some of the potential benefits of improving energy efficiency.

Clearly there is strong interaction between these policies, which present additional challenges to policy makers. For example, it seems very likely that if the 2020 energy efficiency target is met then the GHG reduction target will be met easily. Alongside the recession in Europe, policy interaction has been cited as a reason for having very low ETS prices in Europe; if renewables and energy efficiency do all the work to reduce emissions then a carbon price is not so important. It is recognised, however, that a low carbon price does not provide non-power sector companies (where emission reduction measures are typically more expensive) the necessary incentives to invest in low-carbon future technologies.

Recent work has discussed the need for policy makers to consider a comprehensive policy mix to effectively manage and encourage sustainability transitions (Rogge and Reichardt 2016); and the advantages of complementing carbon pricing with additional targets (Lehmann and Gawel 2013; del Rio 2017; Lehmann et al. 2019). Grubb et al. (2014) provides a clear outline of how technologies require different types of policy support at the various stages of their development.

1.3 Structure of This Chapter

The modelling in this chapter builds on previous work by Sijm et al. (2014). It brings in more recent data to reflect changing economic fortunes in Europe and the recent falls in solar prices. The current version of the post-Keynesian macro-econometric E3ME model (see below), linked to a set of bottom-up energy technologies models (FTT), is used to assess scenarios in which the different targets are met. The modelling does not include assumptions about the optimality of different policies but instead simulates the policies one-by-one and assesses them on their own merits.

The complex and interdependent nature of the energy-economy interactions requires a whole-system modelling approach. Due to the inherent uncertainty about technology costs and future energy requirements, no method will yield a certain outcome, but there is scope to assess the potential environmental and economic impact for a given set of scenarios based on best estimates of future technology costs and characteristics.

The following section summarises the modelling approach that was used and the scenarios that were assessed. We then present the results before discussing in more detail in the last section the benefits of different policy combinations.

2 Quantitative Analysis

2.1 Model Characteristics

2.1.1 The E3ME Model

The E3ME model (Energy-Environment-Economy Macro-Econometric model) is a computer-based tool that has been constructed by international teams led by Cambridge Econometrics. The model is econometric in design and is capable of addressing issues that link developments and policies in the areas of energy, the environment and the economy. The essential purpose of the model is to provide a framework for policy evaluation, particularly policies aimed at achieving sustainable energy use over the long term. However, the econometric specification that the model uses also allows for an assessment of short-term transition effects. The current version of E3ME covers 59 world regions, although in this analysis we focus solely on the EU. The model integrates energy demand and emissions with the economy; fuel demand is determined by prices and economic activity, with feedback through the energy supply sectors. Energy combustion results in greenhouse gas emissions. An extensive description of the model is provided in Cambridge Econometrics (2014), with further information at the model website www.e3me.com.

In terms of basic accounting structure, purpose and sectoral and regional coverage, there are many similarities between E3ME and CGE models, such as GTAP (Hertel 1999) and GEM-E3 (E3MLab, National Technical University of Athens 2017). However, the modelling approaches differ substantially in their treatment of behavioural relationships and the structure of markets. As discussed above, CGE analyses pursue an optimisation approach and typically assume purely rational behaviour of agents with perfect knowledge. Price adjustments provide for equilibria in all markets, including the labour market. In contrast, E3ME is an econometric model which predicts agents' behaviour on the basis of historical data sets. Thus, E3ME does not assume optimal behaviour. Prices are set by a mark-up principle and wage rates are determined by the wage-bargaining process between employers and employees.

These differences have important implications for the possible model results. In CGE models, all resources are fully utilised, meaning the economy is always operating at full capacity. Therefore, it is not possible to raise output or employment by government interventions. In E3ME, there are existing market disequilibria and unused capital and labour resources, which may allow for regulation to increase investment, output and employment. Thus, if an economy is not operating at close to capacity, E3ME may provide a more realistic assessment of policy performance as it does not depend on the rigid assumptions of CGE models.

The major drawback of the E3ME approach is that it relies on the quality of time-series data sets (Jansen and Klaassen 2000; Bosetti et al. 2009; Cambridge Econometrics 2014). Moreover, this approach rests on the assumption that past behaviour can be employed to predict future trends, even under different policy regimes, i.e. the

Lucas Critique (Lucas 1976). Although it has now been recognised that all models are subject to the Lucas Critique (Haldane and Turrell 2017), uncertainty around the results from macro-econometric models must be considered especially carefully when making substantial policy changes.

2.1.2 The FTT Family of Models

The E3ME model is linked to three bottom-up technology models that form the FTT (Future Technology Transformations) family of tools. This level of technology detail is critical to understanding the processes that drive the development and adoption of new technologies, which is required to meet long-term carbon reduction targets.

FTT:Power is a simulation model of technology diffusion in the electricity sector globally and is explained in detail in Mercure (2012). As opposed to most other models (see, e.g., Messner and Strubegger (1995) for the MESSAGE model and Seebregts et al. (2001) for the MARKAL model), it does not solve a cost-optimisation problem in order to model investor decisions and the composition of the electricity sector. FTT:Power is composed of a decision-making model for electricity sector investors at the firm level, evaluating decisions made by a diverse distribution of investors influenced by cost and policy considerations. It uses pairwise comparisons of options at the investor level using a stochastic description of component costs, based on 24 technologies in 59 E3ME regions. It includes cost dynamics such as learning-by-doing and natural resource cost-supply curves (Mercure and Salas 2012), as well as a dynamic model of non-renewable energy commodity price dynamics (Mercure and Salas 2013).

FTT:Transport works on a similar basis but is applied to passenger cars. The model includes 25 different types of vehicle (cars and motorcycles) based on size class and power train. Individuals do not automatically purchase the lowest-cost vehicle but instead make decisions based on their individual characteristics and existing choice of vehicle. In the same way as in FTT:Power, it takes time for new technologies to diffuse, even if they become cost-effective for consumers. The FTT: Heat model also works on a similar basis and covers heating technologies within residential properties. New technologies (e.g. heat pumps) take time to diffuse due to household characteristics and limitations in expertise in installation.

The FTT models have been fully integrated to the E3ME model with two-way feedbacks between each of the E3 modules of E3ME (Cambridge Econometrics 2014). The results presented in the next section therefore show the interaction between the different models.

2.2 *Scenarios*

We apply the combined modelling framework to assess five scenarios (one baseline and four policy scenarios). The scenarios are chosen with reference to the EU climate and energy policy package for 2030. All meet an ambitious 49% cut in GHG emissions from 1990 levels:

- A baseline where the current trajectories for the EU ETS cap and current EU policy are maintained (*BASE*)
- A scenario where an economy-wide carbon tax achieves the 49% emissions reduction (*CP)*
- A scenario where the 27% renewables target is met, coupled with an economy-wide carbon tax, which together achieve the 49% emissions reduction (*RES)*
- A scenario where a 30% energy efficiency improvement target is met, coupled with an economy-wide carbon tax, which together achieve the 49% emissions reduction (*EE)*
- A scenario where the 27% renewables target and 30% energy efficiency improvement targets are met, coupled with an economy-wide carbon tax, which together achieve the 49% emissions reduction (*RES&EE)*

This section introduces the basic assumptions underlying all the scenarios and specifies the characteristics and rationales of the baseline and policy scenarios.

2.2.1 Baseline Scenario

The baseline scenario (*BASE*) represents the business-as-usual case in which existing 2020 GHG and RES-E policies, as well as other policies related to reducing energy consumption or improving energy efficiency, are maintained but not tightened. The EU region has been calibrated to the reference scenario of the ‘PRIMES projections’, published by DG Energy (European Commission 2016). The publication includes full details of the policies that are included in the projections.

All non-EU regions have been calibrated to the current policies scenario of the IEA in its World Energy Outlook report (IEA 2016). Effectively this means that the rest of the world does not advance climate policy and would not meet the NDC targets that were pledged as part of the Paris Agreement. Although there are some feedbacks from countries outside the EU in the scenario through trade competitiveness and technology spillovers, the choice of baseline for the rest of the world does not affect our conclusions.

2.2.2 Common Basic Scenario Assumptions and Input Variables

In each policy scenario, a carbon tax is applied without discrimination across all sectors of the economy. There is no differentiation between the carbon price for ETS and non-ETS sectors. Carbon price revenues from the electricity sector, and non-ETS sectors,[3] are recycled through lump-sum allocations to households, which are treated as increases in wealth.

In all scenarios, RES-E subsidies are in place (but with different subsidy levels). In the *BASE*, *CP*, & *EE* scenarios, the already existing RES-E subsidy levels are represented. Subsidies are technology-neutral, uniform across EU Member States, and paid in addition to the wholesale electricity price. Feed-in-Tariffs (FiTs) are defined as a percentage of the difference between the average levelised cost (LCOE) of RES-E generation and the current electricity price. Due to the model set-up with inertia related to technology adoption, the percentage is larger than the actual relative difference between the LCOE and the electricity price. Subsidies are funded through carbon price revenues.[4]

2.2.3 Policy Scenarios

In the *CP* scenario, a carbon price is applied across all sectors of the economy, and increased from *BASE* ETS prices, to achieve a more ambitious GHG target in 2030. A reduction of 49% of GHG emissions from 1990 levels has been chosen as an ambitious target for 2030, surpassing the EU's Paris Agreement commitment; this ambition reflects recent improvements in renewable power generation technology costs, and a revised interim target for a trajectory to 80–95% GHG reductions by 2050.

In the *RES* scenario, the revised Renewable Energy Directive target of 27% renewables in the final energy consumption in the EU by 2030 is met.[5] Policies are introduced in the three areas targeted by EC policy: power generation (RES-E), transport (RES-T), and heating & cooling (RES-H&C). In power generation, capital investment subsidies are increased by 50% and FiTs are increased by 10% of the difference to the electricity strike price. It is assumed that there is some development in a combination of demand side management, grid interconnectors and electricity storage to allow a larger share of intermittent renewables while retaining grid stability.

Investor discount rates for investment in solar and wind power are reduced to encourage investment, to capture effects of policy instruments like guarantees and subsidised capital. In transport, a fuel tax levy on fossil fuels (equivalent to the economy wide carbon tax) and purchase subsidies on electric vehicles (EVs) are introduced. EV subsidies start at €3000 in 2018 and increase linearly to €4000 in 2030 (2017 prices). In heating, coal technology in households is increasingly regulated from 2018, and capital subsidies of 50% are introduced for heat pump and solar thermal heating systems.

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[3] Non power generation ETS sectors are allocated for free on a lump sum basis.

[4] Where subsidies are greater than carbon price revenues, the lump-sum payment to households becomes a lump-sum levy.

[5] The RES—T Share calculation following the ILUC amendment of the RES Directive is used.

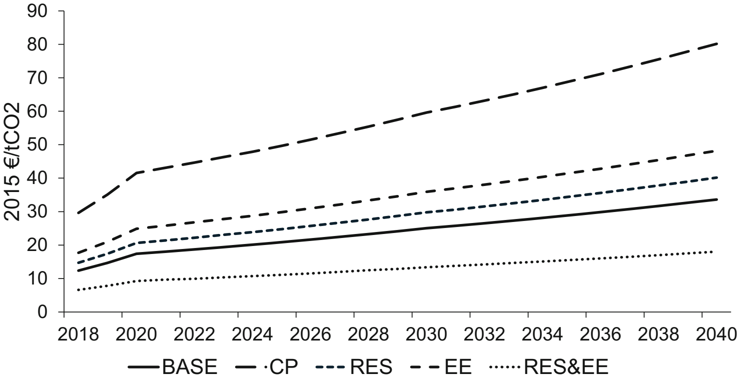

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Fig. 1 EU Carbon Price, 2018–2040

In the *EE* Scenario, the updated Energy Efficiency Directive target of 30% gains is met. The scenario uses detailed data from PRIMES scenarios to introduce exogenous changes in energy used by households and the tertiary sector.

In the final scenario, *RES&EE,* both the 27% renewables and 30% energy efficiency targets are met. Given the significant reduction of electricity consumption in the *EE* scenario, to achieve the 27% renewables target, we must assume that there are further developments in energy storage and demand side management to maintain grid stability.

The carbon price is adjusted in each policy scenario so that the 49% emissions reduction target is achieved. Figure 1 shows the carbon price trajectories under *BASE* and the four policy scenarios.

2.3 Model Results

2.3.1 Introduction

This section presents the key results from the chapter. We start by showing the two most important findings, that the single carbon price does not produce the best outcome either in terms of reducing long-term emissions or maximising levels of economic production. The following sections present some of the more detailed results from the modelling exercise.

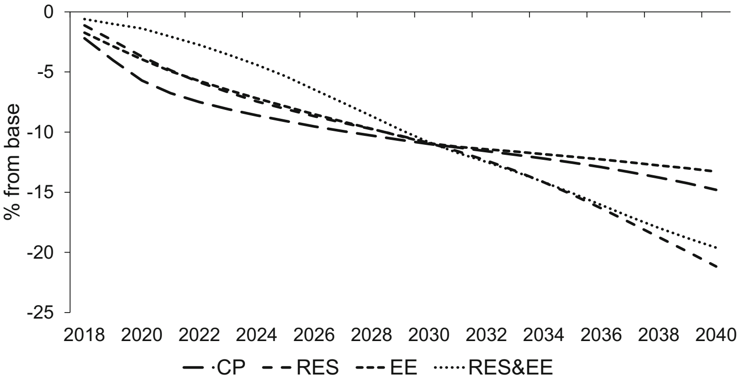

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Fig. 2 EU CO_2 Emission Levels, 2018–2040. Notes: Figure shows % reduction in emissions from baseline. In 2030 an 11% reduction compared to baseline is equal to a 49% reduction compared to 1990 levels

2.3.2 Results for CO_2 Emissions

Figure 2 shows the impacts of the policies on CO_2 emissions, compared to the baseline case. In all four policy scenarios the 2030 emissions targets are met (emissions 11% below baseline is equivalent to 49% below 1990 levels once non-CO_2 emissions are accounted for).

The different policies show different trajectories in reducing emissions up to 2030. The carbon price (CP) has the most immediate effect, mainly by incentivising a switch from coal to gas use in power generation. Renewables (RES) have a slower reduction in emissions because the technologies required to meet the renewables target continue to be developed throughout the projection period. In the energy efficiency scenario (EE), the rate of progress depends on how the energy efficiency programmes are implemented (here we have assumed a linear path). The slowest reduction in emissions is in the case with both energy efficiency and renewables policy (RES&EE). This may seem counter-intuitive but this scenario also has the lowest carbon price and, as noted above, the carbon price offers the quickest emissions reductions.

In general, however, these differences are relatively minor and could be smoothed out by advancing energy efficiency programmes earlier in the period. More important are the impacts after 2030, for which we can see that emissions continue to fall much faster in the scenarios with targets for renewables deployment (RES, RES&EE), even though the carbon price in these scenarios is less than half the rate in the CP scenario. The difference, around 6% of emissions by 2040 (and growing), is substantial.

The message from the modelling is quite clear, that long-term decarbonisation is dependent on the development and diffusion of low-carbon technologies. Policies

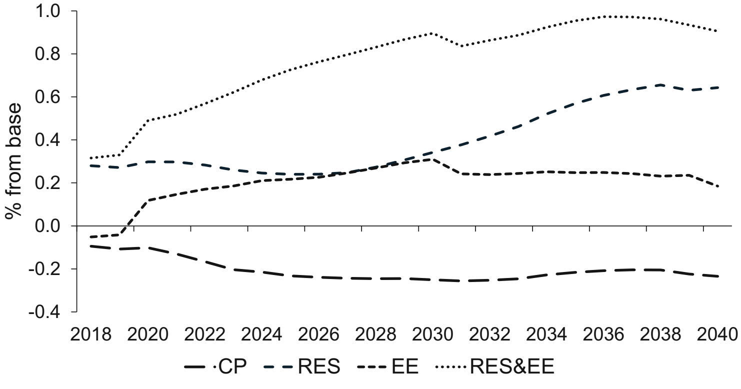

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Fig. 3 EU GDP Impacts, 2018–2040

that support these technologies will lead to much lower economic costs further down the line.

2.3.3 Results for GDP

Figure 3 presents the impacts on GDP in each scenario, as % difference from baseline. In these scenarios the GDP impacts result from two main factors:

- Changes to investment led by borrowing, which can provide a short-term stimulus to the economy.
- Changes in the trade balance, particularly the import bill for fossil fuels.

The scenarios with higher renewables and increased energy efficiency both include substantial short-term investment (the blip in the EE and RES&EE lines on the chart are when the energy efficiency investment ends in 2030). The carbon price in the CP scenario does not lead to a very large increase in investment on its own. Moreover, both renewables and energy efficiency investments lead to reduced imports of fuel to the EU, particularly for gas, whereas the carbon price on its own could lead to a higher import bill if the main effect is to replace coal with gas.

We therefore see in the results that the carbon price on its own (CP scenario) leads to the worst outcome for the European economy. The energy efficiency policy (EE scenario) leads to a small but stable increase in GDP while the renewables targets boost short-term activity, albeit while increasing debt levels in the economy (RES, RES&EE scenarios).

Table 1 Macroeconomic impacts, 2030, % from baseline

	CP	RES	EE	RES&EE
GDP	−0.3	0.3	0.3	0.9
Employment	−0.1	0.1	0.0	0.3
Consumption	−0.6	0.3	0.1	0.9
Investment	−0.1	0.4	0.3	1.0
Exports	−0.2	0.0	0.0	0.1
Imports	−0.5	−0.2	−0.5	−0.1
Prices	0.9	−0.1	−0.2	−1.1

Table 2 Sectoral impacts, 2030, % from baseline

	CP	RES	EE	RES&EE
Primary	−0.2	0.2	0.2	0.6
Manufacturing	−0.4	0.4	0.0	0.8
Utilities	−2.1	0.8	−3.5	−0.9
Construction	−0.2	0.3	0.6	1.1
Bus. Services	−0.4	0.4	0.2	1.0
Public Services	−0.2	0.1	0.1	0.3

The pattern of GDP results across EU Member States is very consistent, with the same characteristics found in nearly all countries. The only exceptions are in Latvia and Lithuania, where changes in trade of refined fuels between the countries impacts trade balances and GDP differently, but with little knock-on effect to employment.

2.3.4 Other Economic Impacts

Table 1 presents the impacts on the main macroeconomic indicators in 2030. The impacts on employment are modest overall and follow the pattern of results for GDP. Impacts on investment and trade follow the patterns described above. Although imports fall in all scenarios there is a difference in the composition of the change; in the CP scenario there is a general fall in imports due to lower domestic activity while in the other scenarios it is mainly lower fuel imports (with some other imports increasing). In the context of energy security, the RES and EE policies therefore produce a better outcome than the CP scenario.

One big difference between the scenarios is the impact on prices. The RES scenario shows a small fall in prices, which is partly due to renewables becoming more cost competitive by 2030 and partly due to continued government support which keep down renewable costs (financed by carbon tax revenues which impact on the amounts returned to households).

Table 2 presents a summary of the results at sectoral level. In most cases the results for sectoral production follow the patterns that we have seen in the GDP results.

The biggest differences between scenarios are in the construction and utilities sectors. The construction sector benefits substantially in the EE and RES&EE scenarios because of the large installation programmes required. Construction also makes a (smaller) contribution to installing renewables but sees little impact in the CP scenario.

The utilities sector can be summarised as gaining in the RES and RES&EE scenarios due to electrification (including in transport) but losing out in the CP and EE scenarios, where measures are put in place to reduce demand.

3 Discussion

The E3ME results differ to those from typical optimization modelling approaches, not only in the order of preference for the policies, but in finding potential positive economic impacts. To understand the outcomes better we must look deeper into the modelling approach.

First, there is the availability of spare capacity in the economy. Much of the economic benefit in the energy efficiency and renewables scenarios comes about from a redistribution of spending from imports of fuel to domestically produced goods. Such a shift in spending patterns can only lead to higher output if there is available capacity to produce more, otherwise we would expect prices to increase and crowding out of existing production.

Similarly, if higher investment levels boost the economy overall, there must be available capacity in the economy (particularly the construction sector) to produce the goods, otherwise there will again be crowding out of production. Fortunately, data from Eurostat on the manufacturing sector suggest that firms typically operate at around 80% capacity; quantitative information about the construction sector is more difficult to assess but surveys also suggest that most firms are not operating at capacity. However, it should be noted that if firms did reach capacity then it would be much more difficult to see positive results overall.

A closer look at the results for investment also highlights the importance of available capacity in financial markets, i.e. allowing for an endogenous stock of money in the economy. Or, to put another way, if firms are able to increase borrowing to fund investment in renewables, the net impact depends on whether this results automatically in lower investment in other sectors (or increased savings elsewhere). In standard optimization approaches, the stock of available money is fixed (a condition to solve the model) but E3ME allows for additional debt to be taken on and the supply of money to increase (Pollitt and Mercure 2017). This is more in tune with how central banks believe the system to operate in reality (McLeay et al. 2014).

The other key outcome in the results stems from the FTT submodels and, in particular, the path dependency of technological progress. In the real world, technologies take time to diffuse, for example due to gaps in knowledge or a lack of available infrastructure. The FTT modelling framework reflects the time it takes for technologies to become established in the marketplace. However, once established, technologies can continue to capture market share, even without further policy support. The current 'solar revolution' that was kick-started by policies in Germany and other European countries provides a good example of such a mechanism.

4 Conclusions

Current EU climate policy is based on three targets: one which sets the level of emissions reduction, one which sets a minimum share for renewable energy and one which sets a target for energy efficiency. This policy approach has met some resistance from mainstream economists who claim that the optimal way to reduce emissions is to have a single emissions reduction target and use market-based measures to get there.

There are two fundamental differences between the positions set out by European policy makers and mainstream economists. First, whether the world we live in is 'optimal' or 'first-best' in which all firms and individuals are aware of the technological options available to them and minimize their costs accordingly, and in which markets operate freely with prices adjusting to market clearing levels. Second, the nature of technological development itself, in particular whether the pace and direction of technology development is something that happens 'outside the system', or which can be influenced by policy decisions.

The aim of the modelling exercise presented in this chapter was to use a model that does not rely on optimizing assumptions to test whether the EU was right to set a combination of climate and energy targets for 2020 and 2030, rather than relying on a single emissions reduction target and price-based mechanisms. The E3ME model, a tool based on empirical estimates of human behavior was used to assess four scenarios with combinations of policies.

The model results show that a carbon price alone does not appear to be the best way to limit long-term emission reductions, because it does not lead to the rapid development and deployment of the necessary technologies. The results also show that a carbon tax alone would not lead to the best outcome for GDP in Europe. Other policies can assist in both influencing behavior and promoting technology development.

In summary, the modelling results give a clear message that we do not live in an optimal world and any policy recommendations based on the assumption of optimizing behavior should be taken with extreme caution. Current EU policy appears to be well targeted at addressing some of the most important issues around decarbonization and, at least for now, all three targets are needed.

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