



Case study – technical analysis on capacity constraints and macroeconomic performance

*Technical Study on the Macroeconomics of
Climate and Energy Policies*



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Part I Introduction

Introduction to this report

This report has been prepared as part of a wider project designed to improve the understanding and macroeconomic modelling of energy and climate policies. Key topics in the project have included¹:

- the way in which technological development, and the role of policy in stimulating such development, is represented in theory and empirical modelling
- the role of finance as a facilitator or constraint on investment, and its representation in empirical modelling
- the relationship between energy trends and macroeconomic performance
- the resilience of the EU economy to energy supply shocks

The present report examines another important issue in understanding and modelling the macroeconomic impact of energy climate policies, namely the role that capacity constraints could play in influencing the outcomes of a future scenario in which investment is higher.

Macroeconomics as a discipline is concerned fundamentally with the interaction between supply and demand across an economy. Most macroeconomic models, including the ones used to assess climate and energy policy in the EU, incorporate representations of both supply and demand but different modelling approaches place different levels of emphasis on the two factors.

These differences in treatment of supply and demand influence the results from all kinds of modelling exercises, but they become particularly apparent when the models are used to assess climate and energy policy. The reason is that promoting a clean energy transition typically involves quite large reallocation of resources (to satisfy changes in demand):

- over time, usually with more up-front investment costs
- across sectors, with construction and engineering sectors usually benefitting
- between geographical regions, with fossil fuel producers and exporters losing out

The modelling assumptions about resource scarcity or mobility and how sectors can increase their supply to meet higher demands in a particular place at a particular point in time are of critical importance to determining the final outcomes of the assessment. If supply can expand to accommodate the increase in demand without significant increases in costs, then positive outcomes are possible (economic activity may be higher). However, if supply is not able to increase, or only at higher marginal cost, the net result of the shift in demand will be to raise prices (or raise the prices of some products and lower the prices of others), and production in other parts of the economy will be reduced. This difference is the principal reason why different modelling approaches have consistently reported qualitatively different macroeconomic results (i.e. positive or negative) when analysing the potential effects of climate and energy policy (e.g. European Commission 2013, 2015, 2016).

'Crowding out', which is the degree to which higher production in one sector leads directly to lower production in other sectors, has thus been identified as a key area of interest in the assessment of climate and energy policy, whether model-based or

¹ Copies of reports are available at <https://ec.europa.eu/energy/en/data-analysis/energy-modelling/macro-economic-modelling>.

otherwise. In this report we refer to supply limitations as 'capacity constraints', as the term 'crowding out' has become associated with a particular meaning in economics (see below). Throughout this report we identify three areas where capacity constraints are important:

- labour markets
- financial capital markets
- product markets

While model results for macroeconomic indicators such as GDP are the result of the interaction of all three markets, each has its own specific characteristics that are helpful to consider in isolation. Furthermore, the treatment in the modelling varies across the different markets.

Structure of this report

The remaining section of this chapter lays out the terminology that we use throughout this report. The next chapter reviews the results of previous studies for evidence of capacity constraints at the macro level affecting economic performance. The following chapters describe how constraints are implemented in the standard modelling approaches, including in the E3ME and GEM-E3-FIT macroeconomic models, the two models used in the context of this project. A set of sample simulations are presented to illustrate the key properties of the different modelling approaches (including recent developments to the E3ME model). The final chapter offers conclusions from the analysis and some concrete recommendations for how to interpret the results from the models.

Definitions

In this report we refer to 'capacity constraints' as limitations on the amount that an economy, or a sector of an economy, can produce (or 'supply') in a given period of time. It is important to make the distinction between 'supply' (the level of production actually achieved, and the associated resources used) and 'potential supply' (the maximum level of production that could be achieved, and the maximum available resources that could be used, based on capacity). The implication is that, while it may be possible to increase production in an economy, any attempt (for example, by policy) to increase production beyond capacity, e.g. potential supply, will lead to displacement of production elsewhere, typically through price effects.

For example, if, through a stimulus package, 100 jobs are created in the public sector, the direct result at the whole-economy level could lie between one of two outcomes:

- 100 people move from unemployment to employment in the public sector
- 100 additional people are employed in the public sector, but lack of spare labour drives up wages as a result and employment decreases by 100 in other sectors

The second outcome is often described as labour market 'crowding out', on the basis that the activities of the public sector have left less space for the private sector to operate. In fact, traditionally, the term 'crowding out' has been used by economists to describe one particular example of capacity constraints, when an increase in *public sector* activity leads to a reduction in *private sector* activity. As the analysis in this report considers a broader range of scenarios (e.g. competition for resources between different parts of the private sector) we generally avoid using the term.

Another term that is sometimes used is 'crowding in', which is closely linked to 'multiplier' effects. Crowding in occurs when a shock to production in one sector

(caused, say, by an increase in debt-financed government spending) does not displace spending and production elsewhere but instead encourages it. This could be due to supply-chain effects, income multipliers, the accelerator effect on private investment, or some other economic mechanism. The distinction between crowding out and crowding in is one of supply and demand; while crowding out occurs due to limits on potential supply, crowding in and multiplier effects occur due to boosts in demand that lead to further demand. As we explore in this report, the key question is whether the level of production is determined primarily by constraints on supply or the level of demand.

Some specific definitions relate to the three markets considered in this report:

- Labour markets: The potential supply of labour is determined by working age population multiplied by labour market 'participation rates', and is measured by the number of people available to work. Labour market demand is represented by the number of people employed, with the difference between the available supply of labour and demand being the unemployment rate. (Models that treat labour market participation rates as endogenous allow the potential supply of labour for a given working-age population to expand in response to higher employment). The price in the labour market is the wage rate, which in the macro-sectoral models considered here is usually set by sector. These sector wage rates represent the average across the different skill levels and occupations of workers in each sector.
- Product markets: Potential supply is usually unobservable in product markets but we do know the actual level of supply and demand from national accounting statistics. A broad indication of spare capacity may be reported in business survey indicators of capacity utilisation, but these are typically insufficiently detailed by sector and/or insufficiently related to the national accounts indicator to be used explicitly in empirical modelling; however, they can be useful as a broad guide to the state of capacity utilisation when reviewing history or assessing the current state of the cycle. The prices in these markets are represented by the prices of the products.
- Financial capital markets: The product in financial capital markets is 'money' or 'finance' (or 'liquidity'). In the CGE tradition, when financial capital is distinguished, the key concept is the allocation of *saving*, defined as income less consumption, for investment. In the Keynesian tradition, when financial capital is distinguished, the key concept is the availability of money with which to make purchases; saving emerges as an outcome of the level of macroeconomic activity. Prices in capital markets are usually represented by rates of interest (or, in a more complete treatment, by a cost of capital that also takes account of the cost of raising equity): different types of organisation and different types of investment will typically have to pay different rates of interest.

The final set of definitions describes the models themselves. Three different approaches are considered:

- 'Input-output models' are tools that can be used for multiplier analysis. Their main advantages are simplicity and a modest set of data requirements, but the approach does not consider capacity constraints. We therefore use the approach in this report primarily as a benchmark with which to compare the results of other approaches.
- 'Computable General Equilibrium (CGE) models' are the most commonly applied tools to estimate policy impacts across the whole economy. They are derived from neoclassical economic theory and have a focus on the determination of a market-clearing set of prices; 'spare capacity' (in the sense of resources that are involuntarily unemployed at prevailing prices) exists only

where market imperfections prevent prices from clearing the market. Outside of these cases, greater demand for a resource results in higher prices. The GEM-E3-FIT model was originally a CGE model, although it has been developed substantially beyond a standard CGE framework².

- 'Macro-econometric models' are derived from post-Keynesian economics. Compared with CGE models they typically have much more of a demand-side focus and place more emphasis on quantity than price adjustments to reconcile mismatches in demand and supply. E3ME is an example of a macro-econometric model. The term 'macro-econometric' was given to these models because they typically rely heavily on econometric methods based on time series data to estimate parameters, but here our focus is on their emphasis on the implementation of post-Keynesian theory. Nowadays some CGE models also use econometric methods to estimate parameters, but to maintain the distinction in theoretical underpinnings, we reserve the term 'macro-econometric' for models that come from the Keynesian rather than CGE tradition.

The theoretical underpinnings of the models are described briefly in Part II.

² GEM-E3-FIT has been adapted to provide a better representation of important real-world phenomena. Notably, the treatment of the labour market has been modified to allow for involuntary unemployment and the treatment of the financial system has been changed to allow borrowing over time. See Karkatsoulis et al (2014; 2016a; 2016b) for further details.

Part II Review of the available literature and data

Introduction

This chapter reviews previous studies that have assessed whether capacity limitations impede economic growth. Following the structure of this report, we aim to distinguish labour, product and financial capital markets in each case, but not all studies make this distinction.

It should be noted from the outset that the body of previous relevant literature is quite limited, which is perhaps surprising given the importance of the topic. However, in part this is due to the difficulty in providing hard evidence about the real-world impact of capacity constraints, i.e. it is not possible to develop a definitive counter-factual case.

One way of developing a counter-factual case is of course to carry out a modelling exercise, but then the results reflect the assumptions inherent to the model. These are the assumptions that we are aiming to assess in this exercise, and so we do not include model-based exercises in this review unless they provide insights beyond the assumptions which characterise the model.

What follows is an overview of the theoretical background to alternative macroeconomic modelling approaches and a brief discussion of existing literature on capacity constraints in labour, product and financial capital markets. Particular attention is paid to how these constraints could impact modelling choices and results.

Theoretical background

Although the aim of this report is not to go into the details of different economic theories it is important to recognise that the differences between the models reflect the theories on which the models are built.

CGE models are based on neoclassical macroeconomic theory. One of the attractions of the theory is that the macroeconomic properties of the model reflect the microeconomic assumptions for the behaviour of individuals, although this requires an assumption that each decision maker has detailed knowledge of their available options so that they can optimise their decisions. The formulation of CGE models was presented by Walras (1954) and the system of equations within the model determines the complete set of prices in all parts of the economy that balance supply and demand (the equilibrium). As these prices include those of labour and physical capital, the equilibrium ensures that no resources are involuntarily left unemployed: all resources that owners are willing to supply at the prevailing prices are employed and there is therefore no distinction between supply and potential supply (i.e. all available capacity is used). If this property is considered unrealistic (for example, in the case of the labour market when unemployment rates are high), a special treatment is applied to account for the departure from the market-clearing equilibrium. Contemporary applied CGE models often incorporate a treatment of the *labour market* that allows for involuntary unemployment, representing theories such as search and matching, efficiency wages, wage bargaining and skills mismatching. Boeters and Sayard (2013) offer a detailed review of the different implementations in a CGE framework.

With regard to *production*, CGE models typically assume that producers choose the optimal combination of inputs, given their prices, and operate with technology that exhibits constant returns to scale when considering a period over which production inputs (especially physical capital) can be increased; in the short term (during which

capital cannot be increased) production exhibits decreasing returns to scale, and so a higher level of production is offered only if prices are higher.

With regard to *financial capital*, the treatment in CGE models is motivated by the need to impose a macroeconomic closure rule to assure that the saving-investment identity is satisfied. The role of interest rates is to clear the market for saving (higher rates encourage more saving (by curbing consumption spending) and curb investment) and financial assets are not necessarily identified explicitly. More recent models offer a fuller representation of financial assets to allow national economies to invest more than their domestic saving in any given period by borrowing saving from the rest of the world and then repaying the loan later. Most of the recent implementations of the financial sector in CGE models are based on Bourguignon et al (1989), further extended by Fargeix et al (1990) and Capros and Karadeloglou (1993). GEM-E3-FIT includes an extensive representation of financial assets and flows of funds and varies the interest rates faced by borrowers (industries) according to their debt to income ratio.

Most standard macroeconomic textbooks give a description of the theory that underlies CGE models and the Handbook of CGE modelling (Dixon and Jorgensen, 2012) provides many examples of CGE models and their application.

Macro-econometric models are based on post-Keynesian economic theory. The starting point is that decisions are made under conditions of uncertainty (Keynes, 1921) and therefore it is not possible to make decisions that are optimal; instead the models attempt to simulate actual behaviour, based on historical relationships that are usually derived from econometric equations.

This is a critical difference from CGE models. In the latter, the assumption of optimising behaviour is seen as making the model robust to structural changes under which a macro-econometric approach might become mis-specified (because parameters estimated over a historical period before the structural change may not be valid after a future structural change). In the post-Keynesian view, the assumption of optimising behaviour is too unrealistic to be a helpful route to avoiding mis-specification; the possibility of mis-specification has to be considered case by case (by asking whether the scenario in question is likely to represent a structural break that invalidates the historically-estimated parameters).

This departure from assumptions about optimising behaviour underpins the model characteristics that contrast with CGE models, notably that prices do not tend to levels that assure equilibrium in all markets. As a result, there is no guarantee that all available resources are used and supply need not match potential supply. The level of demand becomes much more important and there is the possibility for unused capacity (resources that are involuntarily unemployed) to exist in the economy.

Supply constraints are explicitly recognised in the *labour market*, and tighter labour markets are associated with higher wage inflation. In *production*, short-term constraints on supply are implemented by some sort of representation of capacity utilisation. In E3ME, this is incorporated through the concept of 'normal output' (see below). With regard to *financial capital*, the treatment is motivated by the need to explain the availability of money to support the spending that drives outcomes. Money is created by commercial banks when they identify a profitable lending opportunity: there is no other constraint on the supply of bank finance and higher levels of lending to one sector does not necessarily mean lower lending to others. In early Keynesian models, including earlier versions of E3ME, the treatment of money was implicit: if households and firms chose to spend, it was assumed that bank finance would follow. More recently, motivated in part by the financial crisis, financial assets have been explicitly identified and the willingness of banks to take on risk, reflected in the premium charged over the interest charged on risk-free loans, has

been distinguished from the willingness of households and firms to invest (E3ME, forthcoming).

An introduction to post-Keynesian economics is provided in (King, 2015) and (Lavoie, 2015) provides a recent textbook. Aside from E3ME, the best-known macro-econometric model is GINFORS (Lutz et al, 2010)³.

Evidence of capacity constraints in labour markets

Capacity constraints in labour markets are the easiest to observe and this explains why they are not usually seen as requiring discussion. Therefore the amount of literature on the topic is relatively limited. It is accepted that the size of the labour force places a maximum constraint on the level of employment, and that wage rates may be bid up as that constraint is approached; this is regarded as self-evident and not requiring justification.

However, there are some subtleties in estimates of the supply of labour that models should seek to account for. These are:

- variations in labour market participation rates
- possible endogenous policy responses
- matching people to jobs

Each of these is discussed in turn below.

Variations in labour market participation rates

Both CGE and macro-econometric models include provision for the size of the labour force to vary, although the rationale is slightly different in the two modelling approaches. In traditional CGE models, the decision on whether to work depends on a trade-off in utility between work and leisure time and individuals choose to work if the wage they receive is sufficiently high to offset the value to them of the loss of leisure time. In macro-econometric models the reasons for joining or leaving the labour force may be non-financial, for example workers may cease to be part of the labour force if they are in long-term unemployment (due, say, to a deterioration in their employability).

Rates of labour market participation vary due to many factors, but notably the demographic structure of the working age population (e.g. older people are less likely to seek work, and female participation rates have typically been lower in a number of countries). But for any given demographic group, the data typically suggest that the participation rates in Europe vary in response to pressure of demand in the labour market. The econometric parameters that are used in the E3ME model support this hypothesis (see Table II.1): they show the percentage response in the size of the labour force in response to a 1% change in each of production, wage rates and unemployment rates. Stronger demand would be reflected directly in higher output and indirectly in higher wages and lower unemployment, all of which act to increase the size of the labour force (through higher participation). This issue has also been widely discussed in the US, where participation rates fell substantially in the aftermath of the financial crisis (Hall, 2015).

³ The authors describe GINFORS as 'neo-Keynesian' rather than post-Keynesian, although in practical modelling terms the differences are subtle.

Table II.1: Responses in the size of the labour force to a shock of 1% in selected drivers (in %)

	Short-Term	Long-Term
Production levels	0.48	0.52
Wage rates	0.51	0.49
Unemployment rates	-0.13	-0.18

Source: E3ME database.

Note: The responses shown are the results for the entire EU28 labour force, formed by aggregating E3ME's results across the various demographic groups and countries.

There are many factors that potentially influence labour market participation rates, and mixed evidence on the power of these factors to explain short and long-run unemployment. There is robust evidence to suggest that the level and duration of unemployment insurance has a significant negative impact on labour market participation rates and several studies have found that high labour taxes increase unemployment (Bassanini, 2006). Some economists have sought to explain long-run declines in labour market participation with the rise of labour market institutions that have been shown to have negative impacts on labour market participation. However, in most cases, these institutions had existed before labour market participation started trending downwards in the middle of the 20th century. Other economists have sought to explore how the nexus of labour market institutions and exogenous macroeconomic shocks might better explain trends in labour market participation (Nickel, 2005). There are robust examples of the effects of macroeconomic shocks and changes in real demand on labour market participation rates. Nickel's empirical analysis of unemployment patterns in OECD countries from the 1960s to the 1990s found that approximately half of broad movements in unemployment could be explained by shifts in labour market institutions and the other half by demand weakness in times of economic recession. From the perspective of capacity constraints, this matters because the more scope there is for labour market participation to increase when the labour market is tight, the less binding is labour supply as a short-term constraint on capacity.

Possible endogenous policy responses

Macroeconomic models usually hold as fixed all policies except the ones that are being tested. However, in reality policies are set depending on the current political context, including the state of the economy. Although policy could be expected to address an economy operating well below capacity more generally, the most closely watched indicator is the unemployment rate and therefore it is particularly relevant to labour markets. In the past, many countries operated policies designed to promote 'full employment' (however defined) and reductions in unemployment remain an aspiration in most countries.

There is plenty of evidence that policy makers are reactive and modellers engaged in forecasting exercises may present misleading results if future changes in policy are not accounted for (see e.g. the recent debate in the UK; Financial Times, 2017). However, when assessing climate and energy policy impacts, the assumptions that are adopted either hold all other policies fixed or ensure that government fiscal balances do not change between scenarios⁴. This is an intentional choice that makes it much

⁴ This is referred to as either 'revenue', 'fiscal' or 'budget' neutrality.

easier to interpret the model results. With regard specifically to *monetary policy*, the reaction of the central bank to above or below-target inflation can be treated as part of the economic system that is being modelled⁵: in that case, a capacity constraint that threatens higher inflation in the face of higher spending will take the form of an increase in the policy interest rate rather than (if the policy is effective) an increase in wage and price inflation and an associated loss of trade competitiveness. Insofar as this leads to higher interest rates throughout the economy, the policy response will act to curb interest-rate sensitive spending (such as investment spending and household spending on durables), but the cause in this case is not a shortage of *financial capital* (despite the rise in the 'price' of such capital) but a shortage of *productive capacity* (leading to the threat of higher inflation and prompting the policy response).

Matching people to jobs

While full employment is something of a rarity, there may still be important labour market capacity constraints. The reason for this is that not every person can do every job, which economists refer to as a lack of 'labour mobility'. There are two principal reasons why the matching between people and jobs may not take place:

- geographical constraints: the jobs are created in one area but the available workers are in another part of the country and are not willing to relocate
- skills constraints: the available unemployed workforce does not have the necessary skills to fill the available positions

Although labour mobility issues arise generally and are by no means limited to climate and energy policy, they are particularly relevant to any transition that is expected to lead to new kinds of jobs replacing existing jobs (European Commission, 2011). The extraction of fossil fuels and many of the intensive users of fuels are highly location specific and require specific skills that will be different from the new jobs created. Mismatches between the supply and demand for labour could not only lead to worse socio-economic outcomes but could threaten the development of the technologies necessary to meet climate targets (CEDEFOP, 2010).

There is limited evidence about how much of a constraint skills mismatches will be as an economy adapts to a more stringent climate and energy policy, but Jagger et al (2013) find that supporting policy will likely be required. The potential bottlenecks in skills are likely to occur in specific niche sectors which are difficult to scale up to the macro level. Some particular examples, including a lack of nuclear engineers (Telegraph, 2014), are often cited, but the policy recommendations are usually for a boost to the population with more general STEM (Science, Technology, Engineering, and Mathematics) skills (European Commission, 2011; CEDEFOP, 2010). Stroud et al (2014) cite the green transition as an opportunity to retrain workers in areas that have suffered from industrial decline.

It should be noted that macroeconomic models typically do not address skills-related issues in great detail (European Commission, 2011). The most advanced treatment is the one developed by the OECD but even this has quite strong limitations due to both data availability and (like all macro models) the lack of disaggregation required to identify skills bottlenecks (see Section 2.3 of CEDEFOP and OECD, 2015). E3ME does not distinguish labour by skill type, and GEM-E3-FIT has two categories: skilled and unskilled.

⁵ By implementing, for example, a Taylor rule, as has been introduced in E3ME.

Summary

In summary, of the three markets that we are considering in this report, the labour market is the one about which there is the greatest consensus regarding capacity constraints. The literature is quite clear that capacity constraints exist. While there are some differences in opinion about how the size of the labour force changes in response to wider economic and policy developments, these differences are small and unlikely to account for much of the differences in model outcomes.

There is a broad consensus that skills issues may place additional capacity constraints on a labour market that is adapting structurally to ambitious climate or energy policy. It is noted that the macroeconomic models do not have the required detail to address the issue effectively and therefore a separate, more micro assessment of capacity constraints due to limited labour substitutability is required. Hence, there could be scenarios in which macroeconomic models overestimate the potential supply of useful labour because they do not take account of the impact of rapid structural change on labour supply mismatches. Similarly, rapid structural change typically implies shifts in demand that have important geographical differences, both within and across countries; this is especially significant for decarbonisation policies due to the geographical specificity of fossil fuel production. Again, macroeconomic models typically lack the regional detail to capture this effectively; cross-country population movements are identified, but in Europe language barriers make this less likely to be an effective route for re-employment of workers displaced from fossil-fuel activities.

Evidence of capacity constraints in product markets

At macro level, the concept of an 'output gap' is an important issue for economists, including those based in central banks, because it informs judgement about when the policy interest rate needs to be raised. As described below, there have been many attempts to measure the output gap, using a range of different methods, but one important point to note from the literature is that all these papers take it as given that there is some degree of unused capacity in the economy, i.e. the output gap is not assumed to be equal to zero.

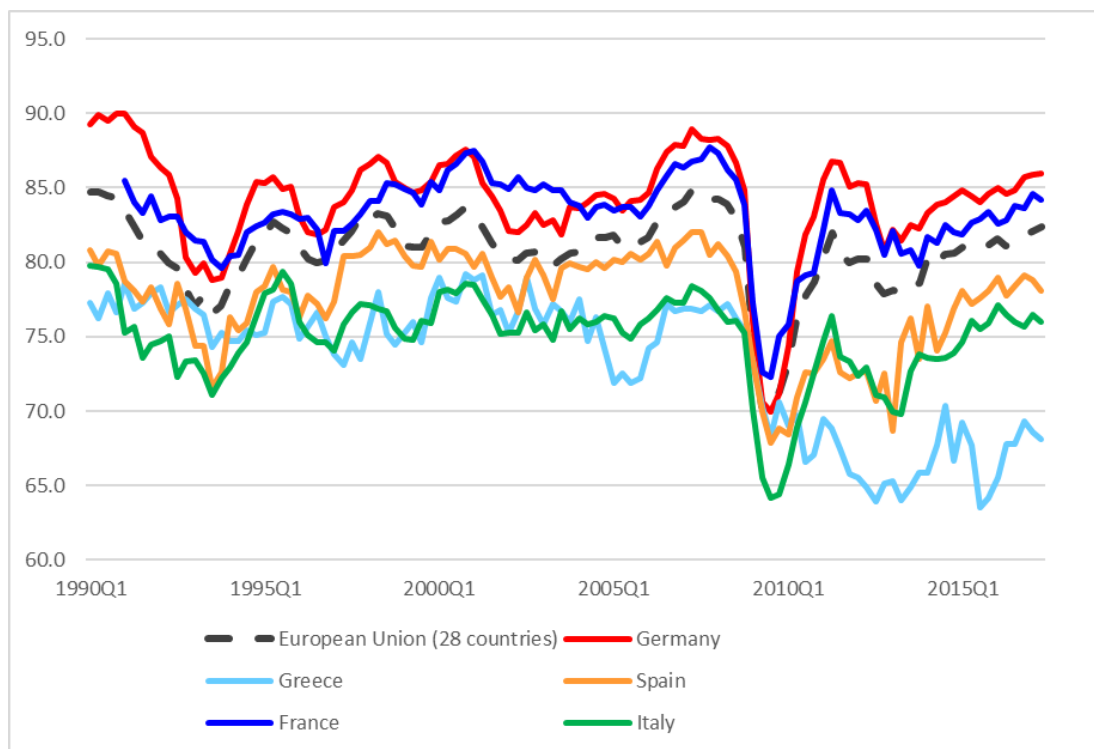
The figures published by Eurostat (see Table II.2) suggest that manufacturing was operating at around 82% of capacity at the start of 2017. Figure II.1 shows how the rates change over time for the EU28 and selected Member States. Although rates of capacity utilisation vary in line with the economic cycle, they remain remarkably stable over time. Apart from Greece, which remains well below its historical rate, capacity rates in most EU countries are now in line with long-run averages.

Table II.2: Rates of capacity utilisation in manufacturing, % (2017q1)

Region	Capacity used	Region	Capacity used
Euro area (19)	82.1	Latvia	73.3
EU28	81.8	Lithuania	76.3
Belgium	80.5	Luxembourg	81.2
Bulgaria	73.5	Hungary	80.3
Czech Republic	84.4	Malta	79.4
Denmark	79.2	Netherlands	81.3
Germany	85.3	Austria	84.8
Estonia	71.3	Poland	78.7
Ireland	:	Portugal	80.0
Greece	69.0	Romania	76.9
Spain	77.7	Slovenia	84.7
France	84.1	Slovakia	86.6
Croatia	71.4	Finland	80.8
Italy	76.5	Sweden	83.0
Cyprus	56.1	United Kingdom	81.7

Sources: Eurostat, ref teibs070.

Figure II.1: Rates of capacity utilisation in manufacturing (%)



Sources: Eurostat, ref teibs070

Table II.3: Construction firms reporting production constraints, EU28 (Feb 2017)

Constraint	% of firms reporting
None	36.1
Insufficient demand	30.6
Weather conditions	20.2
Shortage of labour	10.8
Shortage of material and/or equipment	1.1
Other	11.5
Financial constraints	14.3

Sources: Eurostat, ref ei_bsbu_m_r2

Although there is no equivalent measure for the construction sector, there is a Eurostat survey that asks about constraints that the sector faces. Results of the survey are available at Member State level, with the most recent EU results shown in Table II.3. Even with the current upswing in economic activity, nearly two thirds of firms reported that their output levels were not constrained at all and the most common constraint on production was 'insufficient demand'. Apart from the weather (the survey was carried out in winter), the next most commonly cited factor was financial constraints. Taken together with insufficient demand, the impression given is that the sector is still recovering from the aftermath of the financial crisis.

Taken together, the data from Eurostat suggest that the sectors that would be most affected by climate and energy policy do have some spare capacity. A similar result has been found for the US (see review in Morin and Stevens, 2004). The key question is whether this spare capacity is likely to be maintained over time up to 2030 or 2050, which is usually the time horizon in current climate policy scenarios. The relationships

Box II.I: Can firms produce at 100% capacity?

This review has identified several different definitions of 'capacity' and also found that survey data can be unreliable if the respondents use inconsistent definitions or misunderstand the questions being asked. This leads to the question of whether firms would ever be able to produce at 100% capacity. Figure II.1 shows that manufacturing firms in aggregate have not got above 90% capacity in any quarter since 1990.

It is perhaps better not to consider capacity in a sector as an absolute constraint but more the point at which measures must be taken that would increase prices. For example, if staff work overtime or additional equipment is hired on a short-term basis this will increase potential production but the additional production would come at a higher cost and would therefore push up prices.

Empirically, this would mean interpreting capacity utilisation of 80-85% in EU manufacturing as a rate at which firms expect to operate, with any movement outside this range (in either direction) having influence on firm behaviour and price setting. The further firms and sectors move from this band, the larger the changes in behaviour and prices are likely to be. [maybe they can only do so in case of changes in policies: for instance allowing factories to operate at night time]

In most cases, we would not expect climate or energy policy to change firm behaviour. In the short run, any stimulus from policy would increase rates of capacity utilisation and therefore prices. In the longer term, firms would likely move to increase capacity in line with their expectations of higher output.

over time shown in Figure II.1 suggest that they could be, although it is important how these results are interpreted (see Box II.1). The modelling that fed into the recent Impact Assessment of the Energy Efficiency Directive (European Commission, 2017) imposed a 15% cut-off on the absolute increase in production compared with the reference case in any year (with a rapid increase in investment over a five-year period) but still allowed prices to increase in E3ME through the capacity equations.

The rest of this section focuses where possible on spare capacity at the *sectoral* level, as this is what is most relevant to the macro-sectoral economic models used to assess policy impacts. It should be noted, however, that there may be aggregation bias in measuring capacity this way, as decisions are made at firm level and competition between local firms (in different sectors) may affect these decisions (Driver, 2000).

When attempting to quantify the output gap, there are some variations in definition used (Morin and Stevens, 2004, 2005). For example, while absolute technical capacity in a firm may be to run all machinery for 24 hours a day, the cost of doing so may be so prohibitive that a firm is unlikely ever to do so; or the capacity is made available only if prices rise, meaning that there is an endogenous link from demand to capacity (ibid, also Perry, 1973). In the surveys that are typically used, it is also unclear whether equipment under maintenance should be counted as part of capacity or not, or even how labour capacity is accounted for (since a firm may be able to ease a capacity constraint fairly easily by increasing overtime working or by hiring additional workers). Furthermore, there are challenges in sectors that have almost zero variable costs and near infinite capacity; these include some of the new knowledge-based sectors (e.g. web search) but the issue is less relevant for the sectors that could be expected to grow quickly under climate and energy policy scenarios.

Although now very dated, Klein et al (1973) discuss many of the key issues relating to measuring capacity at both macro and sectoral level. One notable point raised in the paper is that industries can share capacity (e.g. if a plant can produce two different goods but not at the same time), so there could be some double counting. The authors also discuss how measures of capacity can be fed into econometric equations for price formation, capital formation and international trade.

The methodologies used to measure capacity or the output gap broadly fall into one of, or a combination of, three categories:

- econometric analysis
- economic production function approaches
- survey-based data

Various different econometric approaches have been used. Dergiades and Tsoulfidis (2007) provide an example of an advanced approach based on an SVAR (structural vector autoregression) and apply it to 14 countries in the EU. They compare their results to those published by the European Commission, which are based on a production function methodology (Denis et al, 2002; most recent publication in Table II.2). While they report some differences in results, they do not appear to be qualitatively different from the EU figures, suggesting robustness in results.

The production function method is also used by the US Congressional Budget Office, the IMF and the OECD. It matches output against measures of the available capital stock, labour, energy and technology. Holland (2012) discusses the approach more generally and notes one advantage over the survey-based approach, that the production function method accounts for new firms as well as the existing firms that surveys are sent to. However, as noted above and in Driver (2000), the approach cannot account for firm-level interaction.

Nickell (2005) provides a summary of survey-based methods, with a focus on the UK. The paper notes a wide range of different projections of capacity and describes some of the key issues already discussed in this review, including the different definitions used and how they are interpreted by survey respondents. The author also raises the sensitivity of results to the treatment of overtime in labour calculations, again relating to what is defined as 'capacity' (i.e. what is the maximum length of time people can or should work).

We found very little information in the literature that links measures of economic capacity to climate and energy policy. This could be because the output gap literature focuses on cyclical variations, whereas analysis of climate and energy policy typically examines long-term trends, or because the predominant use of CGE models (which assume no involuntarily unemployed resources) for quantitative analysis renders the issue redundant. Alternatively, it could be because historically climate and energy policy has had lower prominence, or because the economic impacts of climate policy are typically small at macro level. The only clear linkages that we found lie in the competitiveness and carbon leakage debate, where it is suggested that long-term investment decisions (and therefore capacity) may be impacted by current and future policy (e.g. Meunier and Ponsard, 2014). If policy deterred investment by energy-intensive sectors, future production capabilities would be reduced, which would have important implications for the sectors involved. However, these sectors do not contribute a large share of total economic production and so the impact economy-wide capacity would be limited.

Summary

In summary, the empirical literature provides a clear consensus that firms and sectors do not typically produce at 100% capacity. Ways of measuring capacity vary from study to study and it is frequently noted that there are issues with the definitions used and interpretation of these definitions in surveys. Quantitative estimates of capacity utilisation in both the EU and the US suggest that manufacturing sectors are using around 80% of available capacity at any given time, with variations that depend on the state of the economic cycle; although there is no comparable figure for construction, the Eurostat survey results suggest a similar pattern.

From a modelling perspective, if taken literally, this finding suggests that firms could increase production by up to 25% in the short term before hitting absolute constraints (compared to the 15% limit imposed on the E3ME model in European Commission, 2016). However, it may be better to think of this less in absolute terms and more that production can increase towards what firms report as capacity, but this may be accompanied by price increases as firms have to absorb additional labour and material costs when producing extra units of output. Finally, it should be noted that in the medium to long run firms can ease capacity pressures by increasing investment.

Evidence of capacity constraints in financial markets⁶

The relevance of potential constraints in financial markets can be summed up in the following question: does an increase in investment in one sector lead to an equivalent reduction in investment in other sectors? Or can investment in a sector increase (if not without limit, at least within the scale proposed in a scenario) without offsetting reductions elsewhere? While such an effect could arise as the result of capacity constraints in either product markets (e.g. construction) or labour markets, here we focus on limits to the capacity to *finance* investment in new products. In this section we discuss first evidence relating to the quite narrow topic of limits on the supply of money, before assessing the evidence of how this affects the wider economy.

Exogenous versus endogenous money

There are two leading theories about the supply of money. Under the theory of *exogenous money*, the supply of money is controlled by the central bank. This is the representation presented by Walras in his original description of CGE modelling in the 19th century. Under these conditions an increase in investment in one sector draws on the fixed stock of money and so displaces either investment elsewhere or consumption spending⁷.

In contrast, under the theory of *endogenous money*, the money supply is represented primarily by the stock of bank deposits which commercial banks can create on demand when they provide loans to firms and individuals. The central point of the theory is that banks do not need to gather savings to lend out. Nor is their capacity to create deposits limited by the supply of central bank money through a 'money multiplier' process, since the central bank provides money to commercial banks on demand (at the policy rate of interest that it sets, typically to target inflation). Every time a bank advances a loan, it creates both an asset for itself in the form of the loan on its balance sheet, and an asset for the borrower in the form of the bank deposit created, thereby increasing the money supply. Under these conditions the supply of money at macro level is only limited by the willingness of the banks to lend and the entrepreneurs to borrow at the interest rate charged by the banks.

Coggan (2012) describes how the banking system has worked from the times of using tokens as money, through to gold coins, paper money and, most recently, electronic money. While the money supply was closer to being exogenous in earlier times, it could also be argued that money has been endogenous ever since its inception (ibid). In modern times the most conclusive proof that the money supply is endogenous has been provided by the Bank of England (McLeay et al, 2014), which sets out clearly the money creation process.

The evidence in the literature strongly supports the view that the money supply is endogenous (see discussion in Pollitt and Mercure, 2017; review in Anger and Barker, 2015; or Chapters 12-14 of Keen, 2011). This implies that it is important to model the lending behaviour of banks explicitly, because the availability of funds for investment is not limited to a fixed stock of money controlled by the central bank.

⁶ This section provides a brief introduction to the topic in terms of capacity constraints. CS4 of this project considers the representation of finance in macroeconomic models more generally.

⁷ Even in a world with a fixed money supply, in principle a higher velocity of circulation could allow a higher level of spending, but the emphasis in CGE modelling is on matching the supply of saving to the demand represented by investment rather than the level of activity that the fixed quantity of money could support.

Effects of increased lending on the wider economy

Keen (2011, Chapter 13; 2014) presents strong evidence that higher levels of borrowing lead to stronger rates of economic growth, based on the principle that debt finance feeds directly into aggregate demand. The findings show a strong correlation and a compelling story, but without evidence of causality. This lack of evidence of causality is a consistent theme throughout the discussion, which is summed up by Pollin et al (2014) in their description of a US green growth programme, one of the few assessments of climate and energy policy that addresses the issue head on:

If an amount in the range of 6.5 percent of new investment in the United States were to flow into clean energy sectors, it does not mean that funds to support other areas of investment would face more difficulties getting supported... the rise in clean energy investments will be matched to a significant degree by declining levels of investment in the conventional energy areas. Pollin et al (2014), page 243.

The authors express a clear view that they do not believe there will be financial displacement effects, but note that in any case a low carbon future will be associated with less investment in fossil fuel sectors. In other words, the reason why clean energy investment displaces other investment is not competition for finance but the consequence of shifts in the size and composition of energy demand. The authors also note that the current share of investment in GDP (19%) is lower than the US's long-term average (22%), and that the additional energy investment would not be enough to increase the investment share above the average. Overall, we were not able to find many examples in the literature of assessments of how increased borrowing in one part of the private sector affects borrowing rates in other parts of the private sector. However, there are some assessments of whether higher *public sector* borrowing and investment leads to lower private sector investment.

The issue of public borrowing and debt levels peaked following the financial crisis as countries moved from fiscal stimulus to austerity. The paper by Reinhard and Rogan (2010) appeared to show that when national debts increased beyond 80% of GDP interest rates were pushed up, displacing borrowing elsewhere in the economy. However, later revisions to the calculations showed that there was no clear relationship. Japan is often cited as a country that has had both high public debt levels and near-zero interest rates for a long time. Another study from Germany (Czarnitzki and Fier, 2002) found evidence of 'crowding in', as targeted subsidies for innovation led to further increased private investment.

Looking outside the field of climate and energy policy, there are several relevant papers that focus on large investment programmes, such as the US ARRA following the financial crisis and the Marshall Plan following the Second World War (Council of Economic Advisers, 2010; Bivens, 2011; De Long and Eichengreen, 2011). The findings of these papers emphasise that the experience was one of crowding in and initial stimulus leading to further production, but it is important to note that both programmes took place at times when there was subdued demand for borrowing from the rest of the economy.

In some instances, there may be displacement effects over time, and this could be relevant to modelling climate and energy policy. An example was the car scrappage schemes that followed the financial crisis (Mian and Sufi, 2010), which showed that higher investment when the scheme was in place was followed by a period when fewer people needed new cars. The message is clear that the presentation of modelling results should not focus on years where there are particular stimulus effects but should cover the entire lifetime of the asset (to allow comparison between scenarios which differ in the extent to which capital substitutes for current spending)

More generally, in this discussion of borrowing, it is important to note the distinction between borrowing to create new assets and borrowing to purchase existing assets. Borrowing to create new assets will lead to higher rates of production and employment, while borrowing to purchase existing assets is simply a transfer of wealth. Higher rates of borrowing to purchase existing assets is not relevant to climate and energy policy but this type of borrowing could lead to displacement effects. For example, if increased borrowing pushes asset prices higher there is an inflationary effect on firms, who may use up credit lines just to secure premises (Chakraborty et al, 2014). Similarly, if an over-powerful financial sector attracts the most skilled workers then labour market capacity constraints could limit growth in other economic sectors (Kneer, 2013; Law and Singh, 2014; Cecchetti and Kharroubi, 2015, Cournède et al, 2015). In the aftermath of the financial crisis, several papers note that a large financial sector can limit growth elsewhere (e.g. Tori and Onaran, 2015).

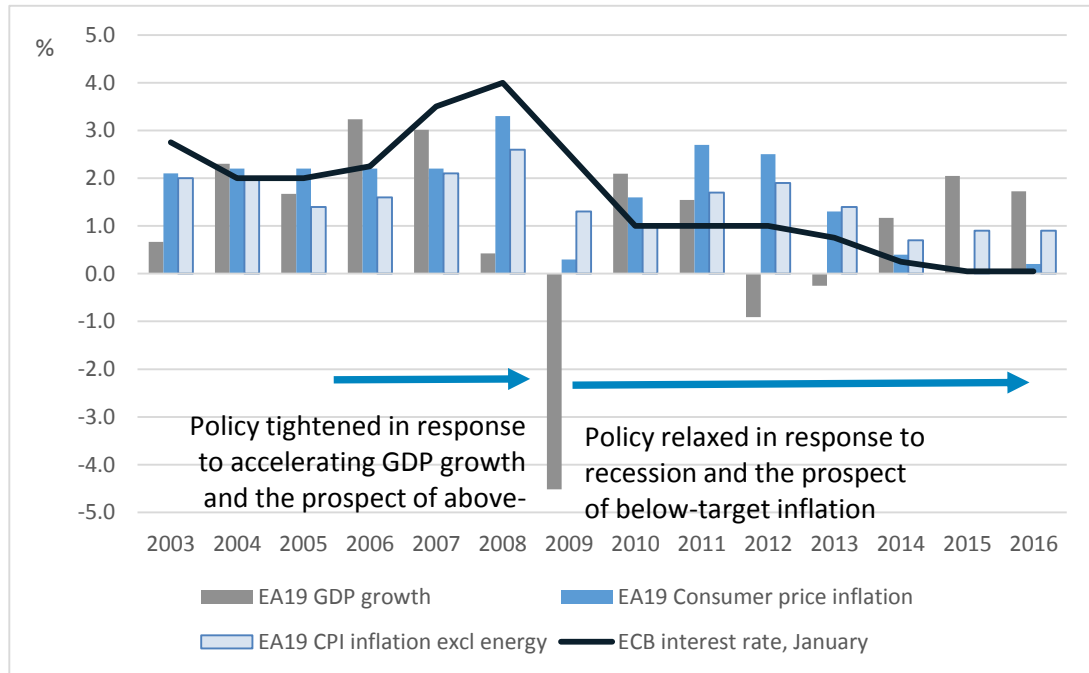
Evidence from the 2006-08 upswing

We conclude this literature review section with a brief review of data from the 2006-08 upswing to assess whether and how capacity constraints, and particularly financial constraints, can be observed to have had an impact on investment in that period.

Figure II.2 shows the outcomes for Euro Area 19 GDP growth and consumer price inflation in the period leading up to the upswing and in the subsequent crisis. It also shows the policy interest rate set by the ECB in response to macroeconomic conditions. The interest rate increases and subsequent cuts were not pursued as aggressively by the ECB as, for example, by the Federal Reserve (rates were raised more sharply and cut more sharply in the US), but the responses to prospective inflationary pressure are clear.

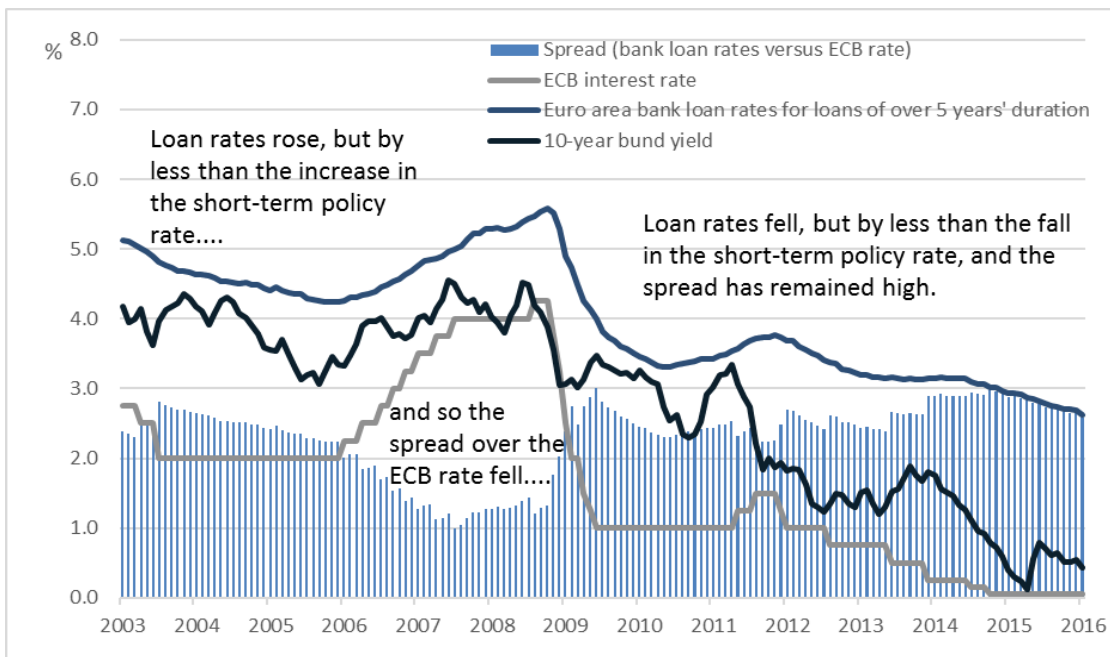
Figure II.3 shows the impact on an average measure of commercial bank loan rates for the euro area. The longest loan maturity available for the whole period is 'over five years' duration'. For the financing of investment, our interest is typically in loans of a longer duration, but we can infer what is likely to have happened to those rates from data that are available for a shorter, more recent period, on loan maturities of over ten years and from data on commercial bond yields in the US. Long rates typically move by less than short rates because expectations of future short rates do not rise and fall in line with the current short rate. The longer the loan maturity, the less the response of long rates to short rates. This is reflected in the 'risk-free' German 10-year bund rate, also shown in the figure.

Figure II.2: ECB monetary policy responses to macroeconomic conditions, 2003-2016



Source: Eurostat.

Figure II.3: How commercial bank loan rates responded to the changes in the ECB rate

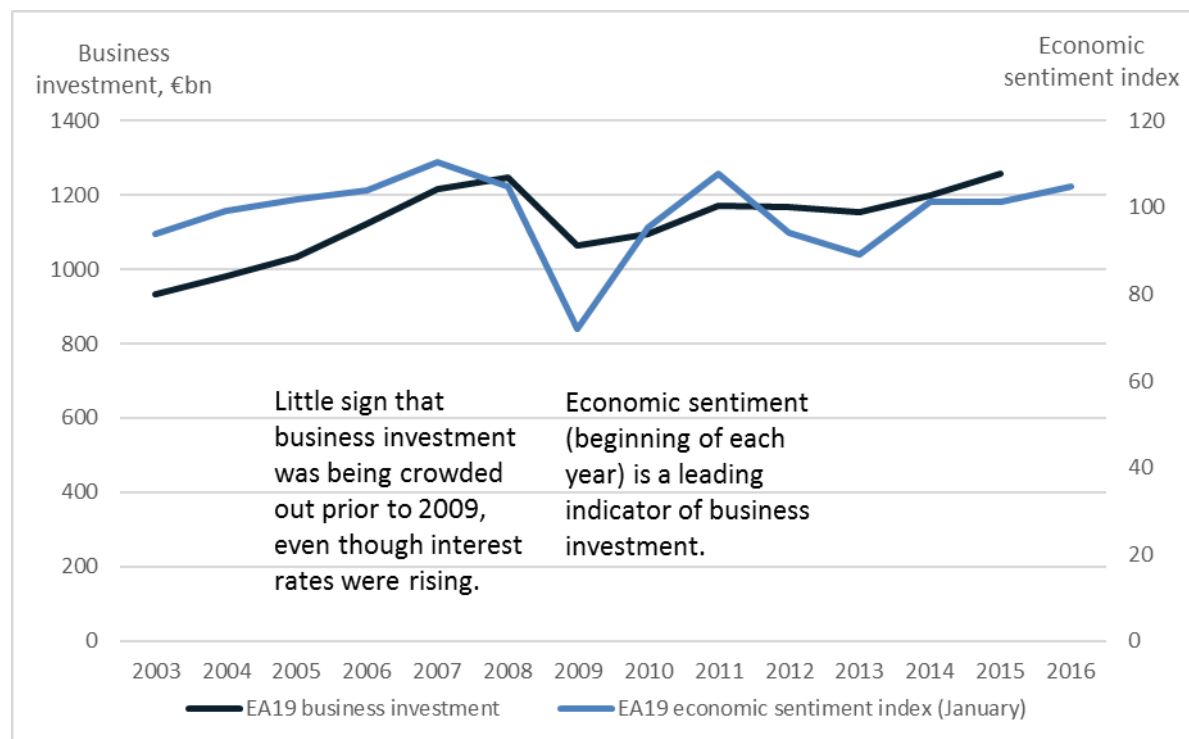


Source: ECB.

Figure II.3 shows that the spread between longer maturity commercial bank loans and the ECB policy rate narrowed during the 2006-08 upswing: commercial bank loan rates increased, but only by 1-1.25 pp. In the subsequent period, commercial bank loan rates fell back from their late-2008 peak but the reduction was much less marked than the downward trend in the policy rate.

Figure II.4 shows the trend in business investment, together with an economic sentiment indicator. Business investment continued to grow into 2008, although at a slower rate, and then fell sharply when GDP growth collapsed. Of course, what would have happened to business investment if interest rates had not risen and fallen over this period is not observable: possibly investment would have grown still more strongly in the upswing and would have fallen back even further in the slump. But what is striking is that economic sentiment (measured in January of each year) is a leading indicator of business investment. In other words, business expectations of future economic activity seem to be more closely related to the outturn for business investment than the change in interest rates that was driven by the change in the policy rate (in turn, responding to the impact of capacity constraints on consumer

Figure II.4: Business investment and economic sentiment



price inflation).

Source: Eurostat.

The conclusions that we draw from this review of the experience of the 2006-08 upswing are as follows. This was a period of acceleration of investment during a period of strong economic growth: it represents the most recent period when we might have expected to see investment curbed by a shortage of saving. What we observe is:

- the mechanism by which capacity constraints could lead to inflationary pressure and hence to a tightening of monetary policy and changes in the cost

of finance for long-term investment was dampened because changes in the rate charged on long-term borrowing rose by much less than the policy rate

- changes in business investment were driven more by business expectations of the state of the economy than by changes in interest rates
- the spread between the policy rate and the cost of finance for long-term borrowing remained relatively high following the crisis, a period when we might have expected to see a surplus of savings (augmented by quantitative easing) encourage investment

Prima facie, therefore, there is little sign that the mechanisms by which investment could be curbed by a shortage of saving during the upswing, or crowded back in during a surplus of saving in the post-crisis period, were operating with much impact. Rather, the availability of finance seems to have operated *pro-cyclically*, as banks lent with confidence during the upswing and then reined in lending when confidence collapsed.

There is, however, an important caveat to these results. We observe a measure of interest rates reported by banks, but we do not observe any rationing by banks that may have occurred. In other words, the supply of financial capital by banks may not be fully reflected by the reported interest rate, but since banks' willingness to lend is influenced strongly by economic sentiment, it is likely that rationing during the post-crisis period reinforced the pro-cyclical character of lending.

Summary

The different theoretical traditions (from Walras and from Keynes) give rise to different predictions about the impact of a greater demand for finance for investment and there remains no consensus among economists about this. The Walrasian tradition treats the supply of money as set exogenously by the central bank, so that an increased demand from one sector of the economy can only be met by reduced demand from elsewhere, mediated through higher interest rates. The Keynesian tradition treats the supply of money as determined by the decisions of banks, which reflect their confidence in the state of the economy. In that tradition, finance availability may be increasing even as the central bank raises interest rates, or declining even as the central bank cuts interest rates, as the experience of the 2008 crisis suggests.

Overall conclusions from the literature and data

Many climate and energy policies seek to boost investment and replace energy with capital or labour inputs in production. The result could be a mild economic stimulus, led by the firms that manufacture and install/construct the necessary equipment and plants. However, this stimulus would not be realised if there were capacity constraints that prevent the economy from expanding production.

The question about how these constraints may restrict the economy is not specific to climate and energy policy. Relatively few studies have assessed climate and energy policy explicitly in this regard, perhaps because at macro level the impacts of climate and energy policy tend to be quite small. By linking the more general findings though, we can make some tentative conclusions:

- The available number of workers is a very real constraint on the economy. The jobs created by climate and energy policy are unlikely to exceed the number of unemployed people (i.e. reach full employment) at any one time, but there could be bottlenecks due to skills, geographical location and the ability to match workers to suitable jobs.

- Firms in key sectors (mainly construction and parts of manufacturing) appear to maintain a degree of spare capacity that would allow production to expand in response to climate and energy policy. Exactly how much depends on the interpretation of the survey responses; clear early warnings of future policy would allow firms to invest in additional capacity, further reducing constraints.
- Financial constraints are the most difficult to assess. Firms with high debt levels may have difficulty borrowing, which would reduce the effectiveness of climate and energy policy. However, there is no evidence to suggest that additional borrowing in the energy sector would lead to reduced borrowing and investment in other sectors.

Part III Model-Based Scenarios

This chapter illustrates differences between the modelling approaches in their treatment of potential capacity constraints by simulating selected stylised scenarios.

Introduction to the test scenario

The impacts of supply constraints are tested in the usual way, by comparing a scenario to a reference case under different conditions. The reference case is the EU Reference Scenario 2016 (European Commission, 2016b), and so the scenario tests the extent to which capacity constraints affect departures from that reference case, not the feasibility of the reference case itself.

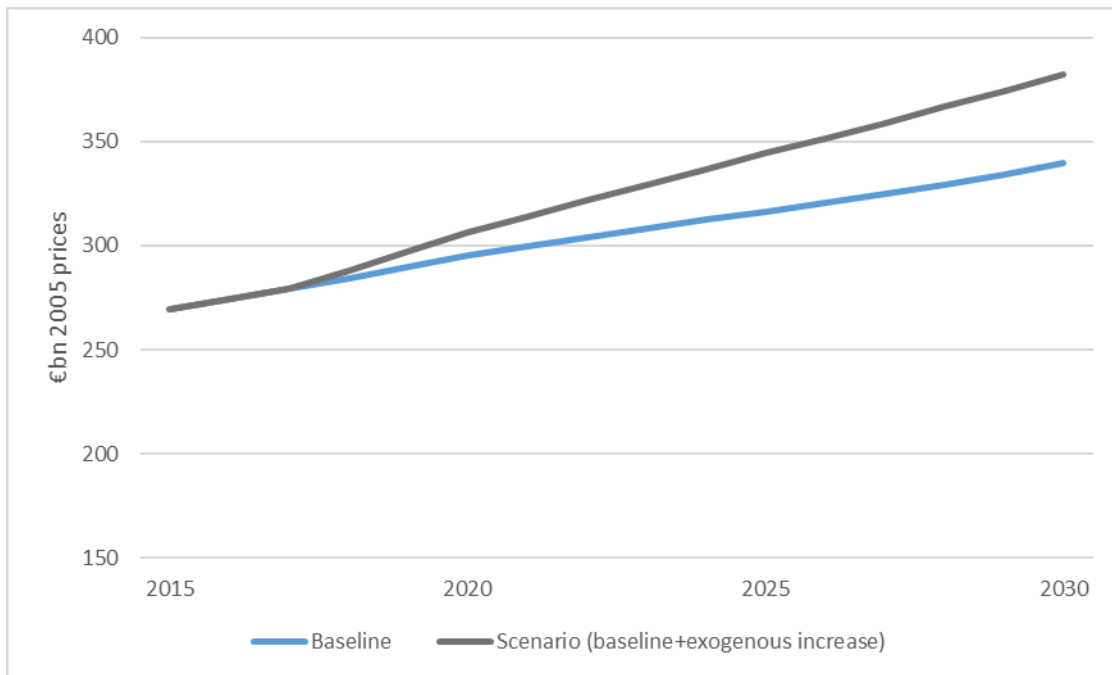
A simple scenario has been designed to test the treatment of the possible effects of supply constraints. The scenario considers a case where there is an increase in the demand for energy efficient equipment (represented as part of the electrical equipment sector) in Europe from other countries, i.e. there is an increase in exports of electrical equipment. A stimulus from exports has been chosen in order to isolate the influence of supply capacity constraints from other mechanisms in the models that would complicate interpretation of the results⁸. The increase in exports is equal to 1% of output in the sector in 2018, increasing by a further percentage point each year up to 2030. So, in 2030 output in electrical equipment in Europe is 13% higher than in the reference case.

This scenario is tested under a range of different degrees of supply constraints and using three different modelling approaches. We start with a simple input-output approach with no supply constraints; this provides a benchmark to which other results are compared. We then run the E3ME and GEM-E3 macroeconomic models, with various constraints imposed, to test the importance of these constraints.

Figure III.1 shows the levels of output in the electrical equipment sector in the reference and the test scenarios.

⁸ For example, a scenario in which EU investment in energy efficiency equipment was higher would have consequences for the costs and prices of the investing sectors.

Figure III.1: Manufacture of Electrical Equipment, sector output



Developments to the E3ME model

The E3ME model is usually regarded as a demand-driven model, but it does include supply constraints:

- labour markets – labour market participation rates are endogenous but there is a limited population that can supply labour; wage rates increase as labour market capacity (i.e. full employment) is reached
- product markets – the model includes an implicit measure of capacity through its 'normal output' equations that inform pricing and investment decisions (see below)
- financial markets – there is no constraint on the 'maximum supply of money'⁹,

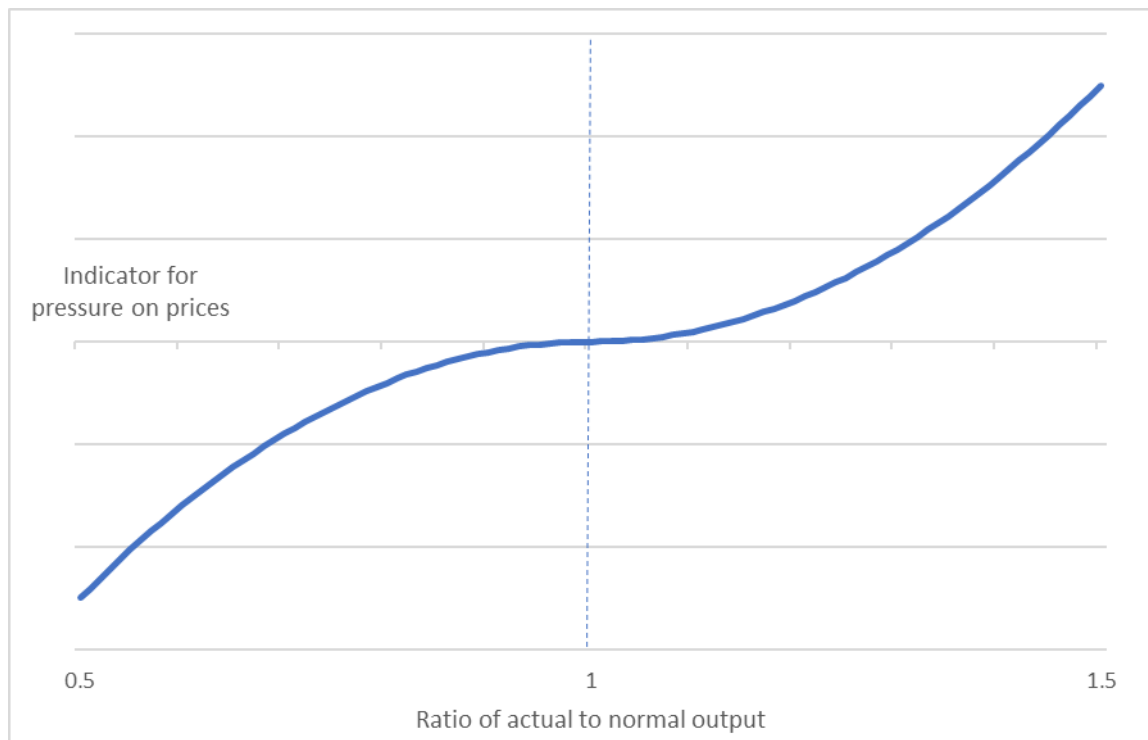
As part of this project, the equations in E3ME that determine capacity in product markets have been revised to include non-linear responses. In the previous version of the model, the impact on prices of a rising level of capacity utilisation was linear: moving, say, from 90% to 95% capacity utilisation had the same effect as moving from 95% to 100%. But it seems very likely that the response is non-linear: the price response to a unit increase in capacity utilisation increases as higher levels of capacity are reached. A further description of the new equations is provided in Part V. The

⁹ As a separate development, financial constraints reflecting endogenous money creation have also been introduced into E3ME. The interest rate charged by banks varies in response to macroeconomic conditions because the policy rate set by the central bank is raised when inflation accelerates, and other rates are influenced by this, and because banks are more willing to bear risk when they expect the economy to grow strongly. This is described in more detail in the separate project report *Representing finance constraints in a post-Keynesian macro-sectoral model*.

equations are econometrically estimated with the level of capacity being proxied by a rolling average of previous years' output. The further that actual output increases above this implicit normal capacity, the more companies increase prices (at an accelerating rate, see Figure III.2).

The new equations are used in all the scenarios that were assessed, except the one that tests capacity in product markets (where instead it is assumed that actual production levels may not increase at all). The equations have been incorporated into the standard version of E3ME (Cambridge Econometrics, 2014), which is used in this exercise.

Figure III.2: Functional form for non-linear response of prices to the ratio of actual to normal output



Source: E3ME.

Results from the input-output analysis

Method and results

Type I and Type II output multipliers¹⁰ were calculated from Eurostat's latest EU27 input-output table in the usual way. The GVA multipliers for the electrical equipment sector are provided in Table III.1.

¹⁰ A Type I multiplier shows the economy-wide impact on a given indicator of a demand shock that produces a one unit increase in a given industry's own indicator, summing together the unit shock itself with the impact through the supply chain ('indirect effects'). A Type II multiplier includes not only the supply-chain impacts but also the impact of the spending out of the additional wage income ('induced effects'). In Table III.1, the GVA multipliers show that a boost to the output of electrical

Table III.1: GVA multiplier values for the electrical equipment sector, EU28¹¹

	Multiplier
Type I value	2.38
Type II value	3.75

Source: Cambridge Econometrics

Table III.2 provides the implied increase in EU28 GVA in our scenario.

Table III.2: Increase in EU28 output and GVA in the test scenario, IO method

	Initial shock to elec equip output	Initial shock to elec equip GVA	Type I output impact	Type II output impact	Type I GVA impact	Type II GVA impact	Type I GVA impact	Type II GVA impact
	€2005bn	€2005bn	€2005bn	€2005bn	€2005bn	€2005bn	% EU28 GVA	% EU28 GVA
2018	3.6	1.2	7.0	12.1	2.8	4.5	0.02%	0.04%
2019	7.2	2.4	13.9	24.2	5.6	8.9	0.05%	0.07%
2020	10.7	3.5	20.8	36.1	8.4	13.2	0.07%	0.11%
2021	14.2	4.7	27.6	47.8	11.1	17.5	0.09%	0.14%
2022	17.6	5.8	34.2	59.4	13.8	21.7	0.11%	0.17%
2023	21.0	6.9	40.9	71.0	16.4	25.9	0.13%	0.21%
2024	24.5	8.1	47.5	82.5	19.1	30.2	0.15%	0.24%
2025	27.9	9.2	54.2	94.1	21.8	34.4	0.17%	0.27%
2026	31.3	10.3	60.8	105.5	24.4	38.5	0.19%	0.29%
2027	34.7	11.4	67.4	117.0	27.1	42.7	0.20%	0.32%
2028	38.1	12.5	74.0	128.5	29.7	46.9	0.22%	0.35%
2029	41.5	13.6	80.6	139.9	32.3	51.0	0.24%	0.37%
2030	44.9	14.7	87.2	151.4	35.0	55.2	0.25%	0.40%

Source: Cambridge Econometrics

Note: Static input-output multipliers have no time dimension. The figures shown in the table represent the long-run impact of the initial shock that begins in the years shown.

equipment that produces a €1 increase in the industry's GVA leads to a €2.38 increase in economy-wide GVA (including the initial €1 increase in electrical equipment) through supply-chain effects. When induced effects are included, the impact on economy-wide output rises to €3.75.

¹¹ Based on EU27 input-output table.

Interpretation of the results

The results in Table III.2 show that, for the scale of increase in electrical equipment GVA in 2030 brought about by the assumed shock to the industry's exports, the impact (including both supply-chain and induced household spending effects, and ignoring any lag in transmission through the economy) is 0.4%. This provides the benchmark against which the E3ME and GEM-E3-FIT model results can be compared. Although multiplier analysis does not include either price effects or supply constraints, which would reduce the impacts, it also misses some of the endogenous linkages in the E3ME model that could lead to *higher* levels of output. Most notably, higher levels of output may lead to increased expectations of future demand and therefore additional investment. There may also be a small feedback through trade in the global model (e.g. if the EU demands more Chinese equipment then China may in turn demand more capital goods from Europe). However, comparison with the modelling results that follow shows that the lack of any constraints in the simple input-output approach yields a larger economy-wide impact than in any of the scenarios that use models that incorporate feedback from prices and other constraining factors.

Results from the E3ME analysis

Introduction

In this section, five different scenarios are assessed. These include a reference, a central scenario including an exogenous increase in EU exports and four sensitivities exploring the economic impact of that scenario under particular alternative capacity-constraint assumptions.

The four sensitivities explore how the macroeconomic impact of the scenario changes relative to the PRIMES reference when

- the labour market is at full capacity (i.e. there is no scope for employment to increase across the EU) (S2)
- the financial market has no spare capacity (and therefore all required investment crowds out existing investment rather than adding to the total stock of investment in the economy) (S3)
- the labour and financial markets are at full capacity (i.e. there is no scope for either employment or investment to increase across the EU) (S4)

Descriptions of the scenarios are shown in Table III.3 below.

Table III.3: Scenario descriptions (E3ME analysis)

Scenario	Description
Reference	PRIMES Reference Scenario 2016
S1 'No capacity constraints' ¹²	An exogenous increase in EU external exports of the Manufacture of Electrical Equipment sector (NACE Rev.2 2), equivalent to 1% of sector output from 2018 to 2030 with the share increasing by 1% pa each year (by 2030 the exogenous increase in export is equal to 13% of industry output)
S2 Full labour market capacity constraints	As S1, but no net increase in employment compared to the reference (but allowing for shifts in employment between sectors)
S3 Full investment capacity constraints	As S1, but no net increase in investment compared to the reference (but allowing for shifts in investment between sectors)
S4 Full labour market and investment capacity constraints	As S1, but no net increase in employment and investment compared to the reference (but allowing for shifts in employment and investment between sectors)

Macroeconomic impacts

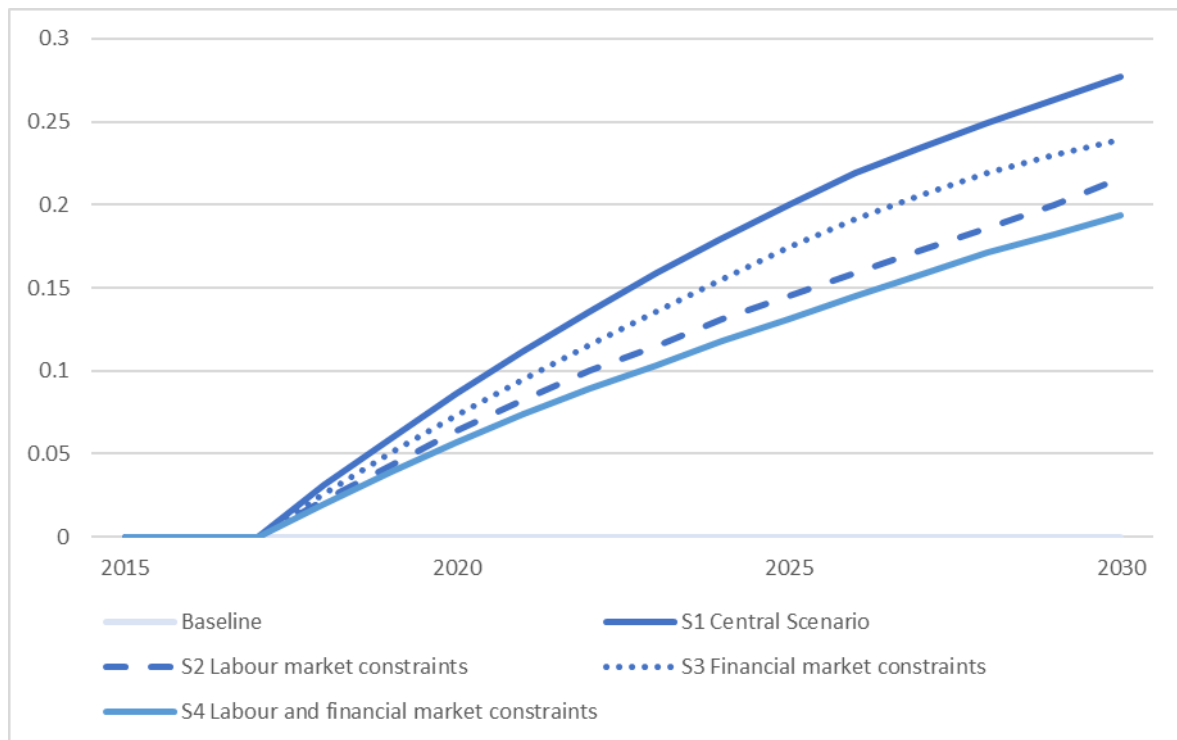
Figure III.3 shows the GDP impact in each scenario. GDP increases in all scenarios. As might be expected, the impact is largest with no crowding out, while the financial market constraints have the smallest impact on GDP outcomes, narrowing the impact of the scenario to 0.24% by 2030 from 0.28% in the central scenario. However, in the

¹² Strictly speaking, this means 'none of the additional constraints that are introduced in S2-S5'. As noted above, E3ME includes a 'normal output' effect that leads to higher prices as actual output rises, and this effect has been made non-linear (and so stronger) in the present modelling. E3ME also includes a wage equation which leads to higher wages when unemployment is low.

test scenario (in which exports are boosted) only limited additional investment is required (i.e. much of the additional production can be made with only modest investment in new equipment and plants); a typical decarbonisation scenario is investment-intensive, in which case financial market constraints may bite more strongly.

Full crowding out of employment (which minimises the role of induced effects within the model from additional wages earned in the European economy) depresses the impact further, to just under 0.22% by 2030. When both investment and labour market constraints happen together (S4), the GDP impact is reduced to 0.19%. Full crowding out in the product market (S5) shows no increase in GDP against the reference, as by definition no increase in economic activity (and therefore output) is possible under this constraint.

Figure III.3 E3ME scenario impacts on EU28 GDP, percentage difference compared to reference



Source: E3ME, Cambridge Econometrics.

Macroeconomic results in the 'no capacity constraints' scenario (S1)

In the 'no capacity constraints'¹³ scenario, GDP is 0.28% higher in 2030 than in the reference. The initial shock of an increase in exports drives a number of impacts which contribute to the overall impact. Increased exports require additional domestic output, driven by both an increase in productivity of the workforce within the Manufacture of Electrical Equipment sector, but also an increase in employment in the sector; total

¹³ Not strictly 'no constraints', since E3ME includes the non-linear treatment of responses in relation to normal output and wage increases in response to lower unemployment.

employment increases by 0.1%. Note that employment increases not just in the Electrical Equipment sector, but also in sectors that form the supply chain to this sector (as demand for inputs to the sector increase), hence incorporating Type I multiplier effects.

The higher productivity and employment lead to increases in consumer expenditure (which is 0.1% higher across the economy as a whole in S1 than in the reference), giving Type II multiplier effects as well. In addition, both the initial increase in exports (through increased demand for imported intermediate products) and increased consumer demand drive an increase in imports (of 0.8%), although this is substantially less than the increase in exports (1.5%, driven by the initial exogenous shock and supply chain effects), resulting in an improvement in the balance of payments. The additional economic activity requires additional capital, which is realised through additional investment across the economy; total investment is 0.2% higher in S1 than in the reference.

Macroeconomic results with full labour market constraints (S2)

With full labour market constraints (and therefore no increase in total employment), the increase in GDP in the scenario is limited to 0.2% versus the reference. While consumer expenditure impacts are reduced (to zero), the balance of trade impacts are similar to S1 (a 0.8% increase in imports and a 1.5% increase in exports), demonstrating that the impacts on trade are driven primarily by supply chain effects rather than changes to consumer expenditure. The smaller increase in consumer expenditure requires a smaller increase in investment, of only 0.14%.

Macroeconomic results with full financial market constraints (S3)

When all additional investment is crowded out (and therefore the total increase in investment is zero), GDP impacts are somewhere between those seen in S1 and S2 (0.24%). Employment increases modestly (less than 0.1%), suggesting that the increase in investment in S1 is driving at least part of the increase in employment seen in that scenario. Consumer spending increases by 0.1% versus the reference, boosted by the additional employment in the supply chain, and driving further induced positive impacts on employment.

Macroeconomic results with full labour and financial market constraints (S4)

With both labour and financial market constraints, GDP impacts are reduced further to 0.19%. The reductions in GDP in S4 compared to the no crowding out scenario (S1) are slightly less than the sum of reductions in S2 (labour market constraints only) and S3 (financial market constraints only) compared to S1. These differences can be explained by lower levels of product imports in S4 when both constraints exist, compared to when each constraint applies independently in S2 and S3 (i.e. there is some interaction through prices).

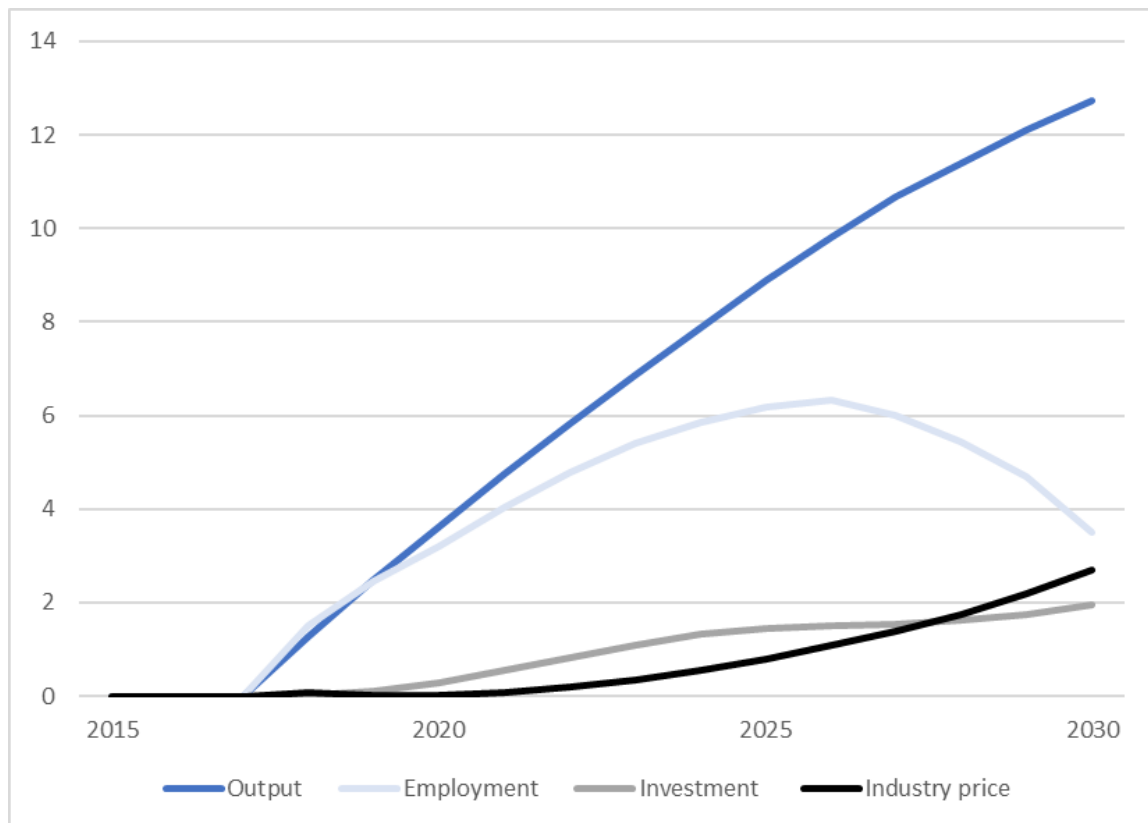
Sectoral impacts across the scenarios

The largest impact is, unsurprisingly, seen in the Manufacture of Electrical Equipment sector. Figure III.4 shows the change in this sector in the unconstrained scenario S1. Output in the sector is more than 12% higher in S1 than in the reference by 2030, a gap which grows over time, but at a declining rate. As the additional economic activity in the scenario moves the economy closer to capacity constraints, increasing investment is required to generate the additional GDP, while industry prices increase more rapidly as individual sectors move closer to supply constraints. Employment is initially boosted due to increased output, but in the long run, wages rise in these sectors due to the limitations on the rate at which employment can be expanded,

driving a substitution away from labour towards other factors of production; it is this which leads to a reduction in the initial positive employment impacts after 2025.

While scenarios S2, S3 and S4 constrain employment and investment growth at a whole-economy level, within the Manufacture of Electrical Equipment sector the scenarios do not show substantial differences; the macroeconomic differences between them reflect the extent to which the additional economic activity in this sector is displacing activity elsewhere in the economy in those scenarios.

Figure III.4 E3ME S1 impacts on the Manufacture of Electrical Equipment sector



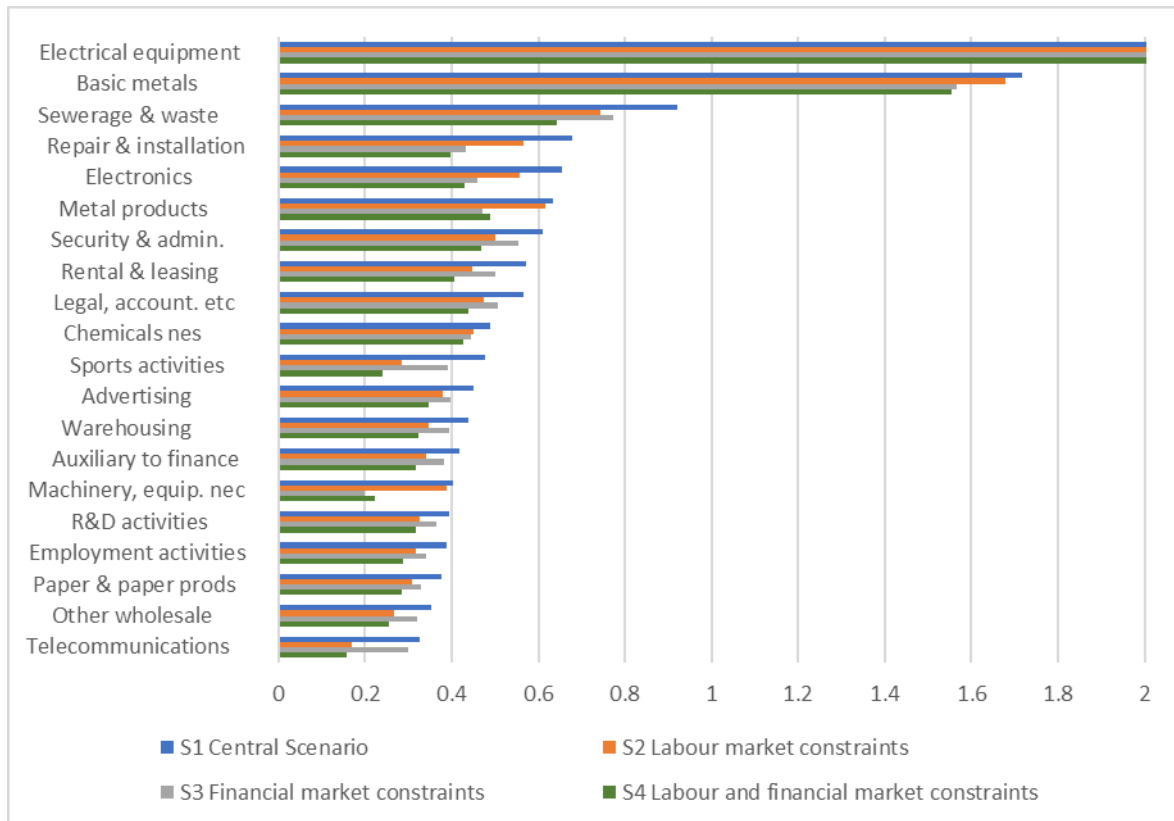
Source: E3ME, Cambridge Econometrics.

The impacts on other sectors are highly dependent upon their linkages to the Manufacture of Electrical Equipment sector. Figure III.5 shows the impacts of the different scenarios among those sectors which show the largest percentage difference from reference (in terms of output) in S1.

The sectors which show the most substantial increases in the scenarios are those which are part of the supply chain (either up- or down-stream, such as basic metals) or provide services to the sector (such as sewerage & waste). In S1, S2, S3 and S4 output increases in almost every sector of the economy. However, in S2 (where labour market constraints prevent increases in total employment), the sectors which are most labour-intensive see larger output falls (relative to S1) than those sectors which are less labour-intensive (such as manufacturing). When financial markets are constrained (S3), the more capital-intensive sectors (such as metal products and machinery, equipment, n.e.c.) lose out to a greater extent in comparison to S1 than those which are less dependent on capital investment. The impacts in S4, where there are both labour and financial market constraints, are mixed. In most sectors output

impacts are lowest in S4 as expected. In some sectors (such as metals and machinery), the results of S4 lie between results of S2 and S3. For these sectors, there are bigger reductions in their imports due to the additional constraints.

Figure III.5 E3ME output differences from reference case in sectors most impacted in the

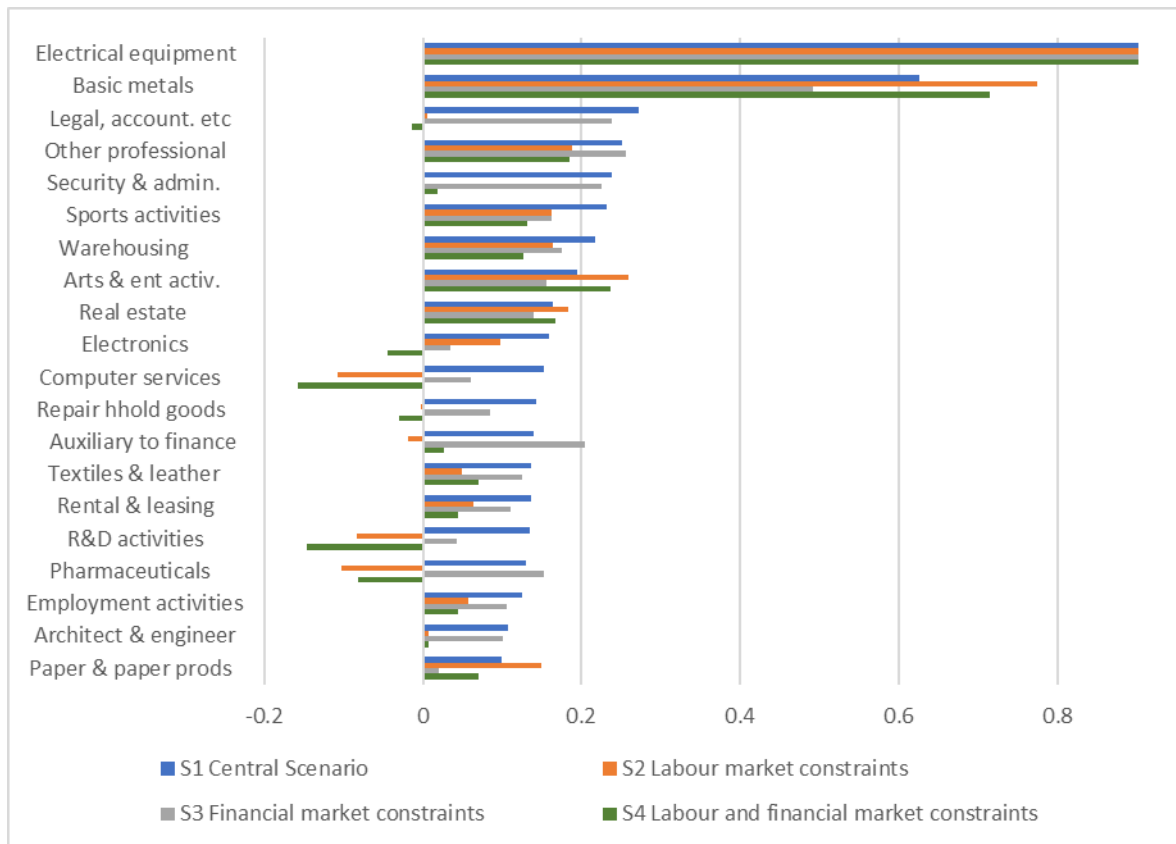


Source: E3ME, Cambridge Econometrics.

Note: Manufacture of electrical equipment is more than 12% above the baseline in all three scenarios, beyond the scale shown in this chart.

The employment picture is more mixed; while the percentage difference from the reference is smaller in terms of employment than output, the scenarios also have a much more diverse impact on employment outcomes by sector. The difference is most stark when labour markets are constrained (S2), because in that case total employment has to remain as in the reference, a number of sectors which see more than a 0.1% difference from reference in S1 in 2030 have lower employment in S2 than in the reference by the same period, including computer services and R&D activities. Employment in the electrical equipment supply chain (such as basic metals and other wholesale) is higher in S2 than in the unconstrained scenario, however. When finance is constrained (S3), those sectors which are most dependent upon investment perform more poorly than in S1 – most notably R&D activities and computing services. In S4, employment results broadly follow the same patterns as in S2 but are smaller in magnitude due to the additional financial market constraints. Figure III.6 shows the employment impacts of the different scenarios amongst those sectors which show the largest percentage differences from reference in S1.

Figure III.6 Employment differences from reference case in sectors most impacted in the



Source: E3ME, Cambridge Econometrics.

Note: Manufacture of electrical equipment is more than 3.5% above the baseline in all four scenarios, beyond the scale shown in this chart.

Sensitivity scenarios – doubling the initial shocks

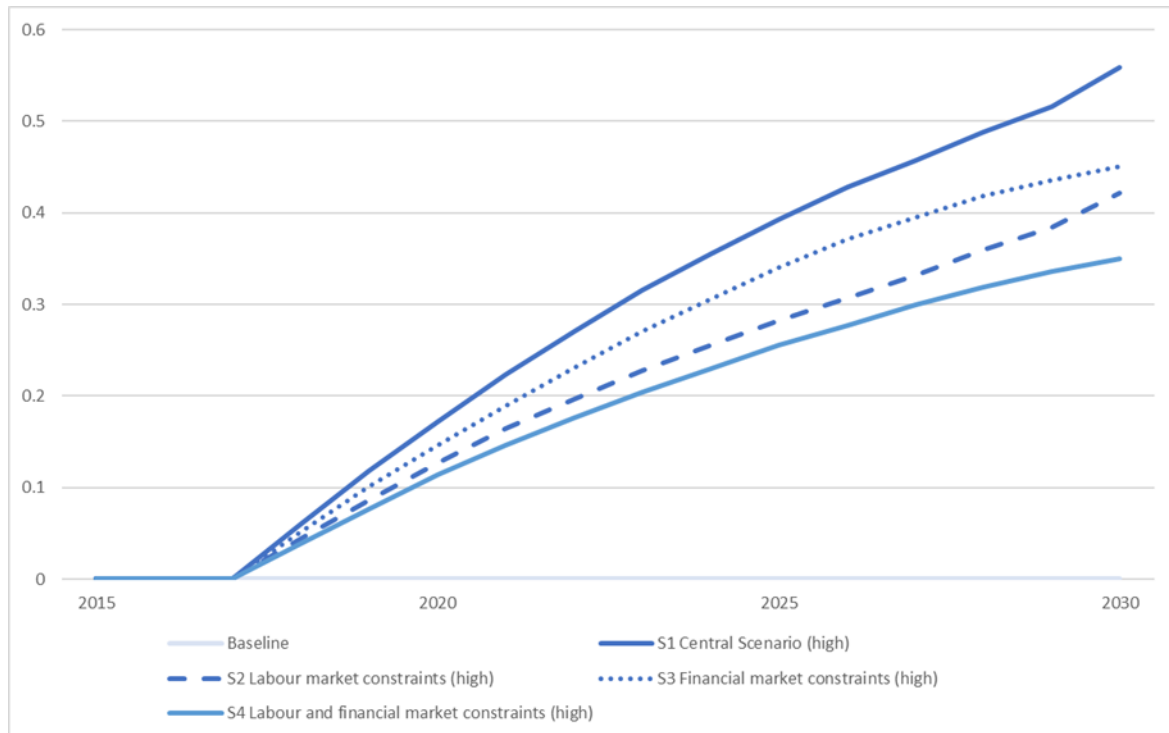
A set of sensitivity scenarios was assessed in which the exogenous increase in exports of electrical equipment is doubled to 2% of the sector's output from 2018 to 2030, with the share increasing by 2% pa each year (by 2030 the exogenous increase in export is equal to 26% of industry output). This is close to the maximum increase that can be assessed in E3ME before the model solution becomes unstable.

The GDP impacts are roughly double the size of the main scenarios, as shown in Figure III.7. One notable difference is the increasing rates of positive GDP impacts toward 2030 in the no crowding out scenario (S1) and labour market constraints scenario (S2). The pick-up in GDP impacts comes from real effects of higher investments that offset higher price effects. In the scenarios where we have financial market constraints, we do not see the same accelerations in the GDP results.

This phenomenon highlights an important issue to consider when the capacity constraints are applied at sectoral level. When capacity limits are approached in one sector, there will be an increase in investment (possibly financed by borrowing) which leads to *increases* in activity in other sectors. There is therefore crowding in, rather than crowding out of activity. The nature of the impact depends on the sector in question; here it is electrical equipment which contributes to investment goods but in

a relatively limited way. If the sector was construction, then higher prices (due to capacity constraints) would feed back to the prices of investment goods, increasing the cost of capital and leading to reductions in investment made by other sectors.

Figure III.7: E3ME sensitivities scenario impacts on EU28 GDP, percentage difference compared to reference

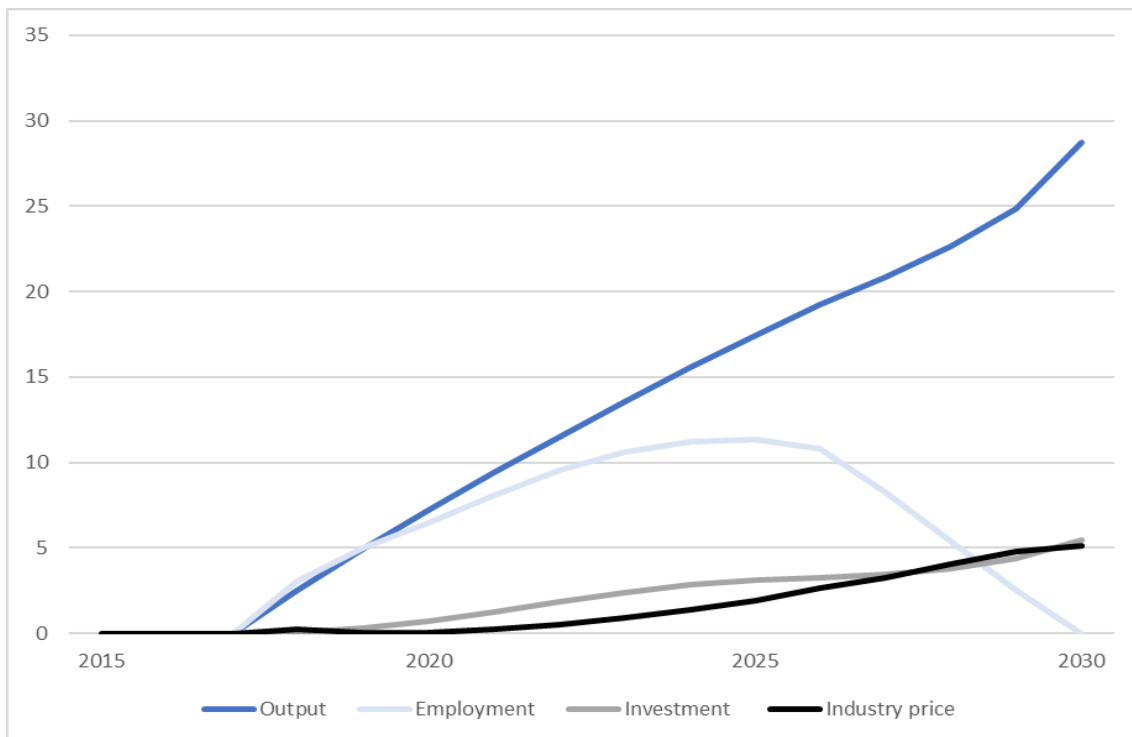


Source: E3ME, Cambridge Econometrics.

Results for Manufacture of Electrical Equipment sector from the unconstrained scenario with higher export shocks are given in Figure III.8. Overall, we see a faster acceleration in the Electrical Equipment sector output as a result of this substitution between labour and capital in the long run.

Besides, in a similar way to the main scenarios, the impacts for the sector do not vary by much under the different constraints. Instead when the constraints are imposed the changes are in other sectors. Compared to the main S1, employment increases quickly initially and then falls more rapidly as wages increase faster than in the main scenario (due to tighter labour markets). The sector's investment continues to increase in the sensitivity scenario compared to the main scenario where investment slows down towards 2030.

Figure III.8: E3ME sensitivity (S_1) impacts on the Manufacture of Electrical Equipment sector, percentage difference compared to reference



Source: E3ME, Cambridge Econometrics.

Multipliers from the E3ME analysis

Output multipliers calculated from the main E3ME analysis are shown in Table III.4. The multipliers calculated from the model are broader than the IO analysis as the model captures not only Type I and Type II multipliers but also output feedbacks from the price and investment effects from the shocks; on the other hand, the (static) IO multipliers are long-run impacts, whereas in E3ME the impact of any given shock may be spread over a number of years.

The results show that E3ME multipliers in the 'no constraints' scenario become smaller over time, starting from 3 in 2018 and ending up at 2.38 in 2030. Although this scenario begins with 'no constraints', over time the continued increases in output move the economy closer to capacity, and so the multipliers decline over time. The multipliers become smaller when financial market and labour market constraints are imposed. The labour market constraints have a bigger impact on limiting the size of multipliers compared to the financial market constraints.

Table III.4: Output multipliers from the main E3ME analysis (EU28)

	Exogenous shocks m euro (2005) 1% of electrical equipment output (grow at 1%pa)	Total changes in output from baseline m euro (2005)				E3ME Multipliers multipliers			
		S1 'No cons'	S2 Labour market cons	S3 Financial market cons	S4 Labour and financial market cons	S1 'No cons'	S2 Labour market cons	S3 Financial market cons	S4 Labour & financial market cons
2018	2913	8739	6925	7481	6196	3.00	2.38	2.57	2.13
2019	5930	18408	14835	15959	13509	3.10	2.50	2.69	2.28
2020	9055	27684	22660	23971	20547	3.06	2.50	2.65	2.27
2021	12254	36378	29568	31434	26759	2.97	2.41	2.57	2.18
2022	15547	44382	35886	38397	32425	2.85	2.31	2.47	2.09
2023	18938	52385	42154	45414	38108	2.77	2.23	2.40	2.01
2024	22431	60299	48582	52591	44092	2.69	2.17	2.34	1.97
2025	26027	68569	55177	60089	50348	2.63	2.12	2.31	1.93
2026	29688	76869	62036	67665	56853	2.59	2.09	2.28	1.92
2027	33449	84837	69328	75083	63726	2.54	2.07	2.24	1.91
2028	37314	92352	76318	81952	70182	2.47	2.05	2.20	1.88
2029	41285	100140	83736	88535	76655	2.43	2.03	2.14	1.86
2030	45365	107885	91401	94625	82843	2.38	2.01	2.09	1.83

Source: E3ME, Cambridge Econometrics.

Note: The output multiplier is the increase in economy-wide gross output divided by the shock to electrical equipment gross output in each year. Because of dynamic effects in E3ME, the impact on economy-wide gross output in any given year includes the lagged impact from previous years.

Results from the GEM-E3-FIT analysis

Introduction

The same base case scenario was prepared in GEM-E3-FIT as in E3ME (the corresponding sector in GEM-E3-FIT for 'Manufacture of Electrical Equipment' is the sector 'other equipment goods'). In the closed accounting of the CGE framework it is necessary to identify which are the drivers for the increase of EU exports; here¹⁴ this was achieved by reducing the duty rates imposed by non-EU countries on EU

¹⁴ It should be noted that many alternatives could have been considered (each one with different impacts on activity variables). By way of example we mention a few: i) increase in duties that the EU imposes on competing products, ii) Increase in EU subsidies for equipment goods, iii) exogenous increase in technical progress, iv) changes in the consumption patterns/preferences of non-EU countries.

equipment goods such that EU exports of equipment goods increased above the Reference projection by about €7bn (2010 prices) in 2020 rising to €48bn in 2030. Table III.6 presents what the imposed increase in production represents as % of the EU28 GDP (the direct impact on GDP in 2030 is 0.28%).

Table III.5: Direct impact on GDP of simulated increase in production

	2020	2025	2030
GDP (bn €)	14748	15798	16911
Imposed increase in production (bn €)	10	29	48
as % of GDP	0.07%	0.18%	0.28%

Four alternative scenarios which vary the conditions under which the increase in equipment exports occurs were then developed in GEM-E3-FIT, labelled here with the same name as the corresponding scenarios in E3ME.

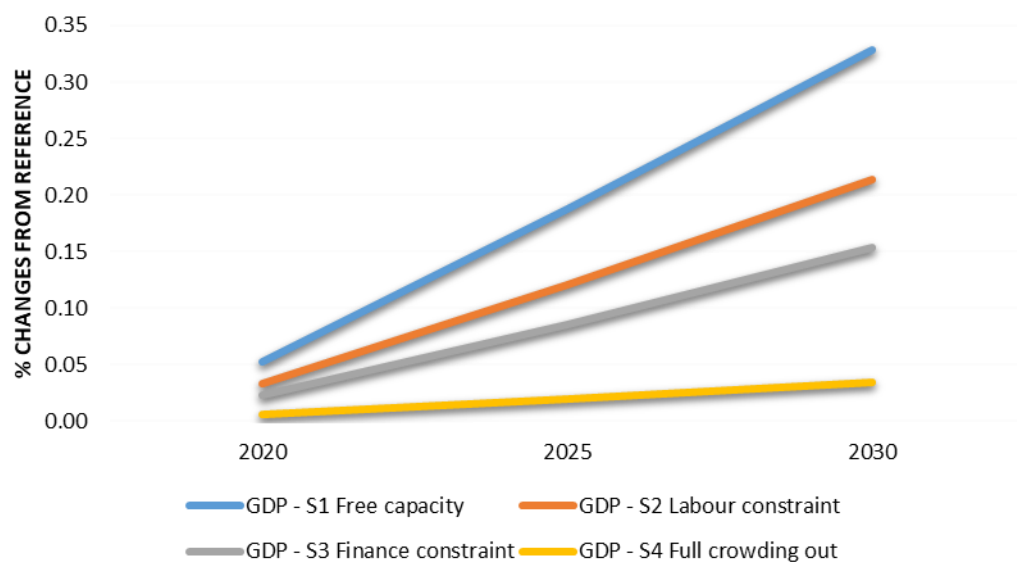
Table III.6: Scenario descriptions (GEM-E3-FIT analysis)

Scenario	Description
Reference	PRIMES Reference Scenario 2016
S1 No capacity constraints	An increase in EU external exports of 'other equipment goods' brought about by a reduction in duty rates imposed by non-EU countries on EU exports. Equivalent to €10bn (2010 prices) in 2020 rising to €48bn in 2030 (similar magnitude to the E3ME scenario).
S2 Labour market capacity constraints	As S1, but no access to additional labour compared to the Reference scenario. Expected to lead to increased wage rates in EU countries and consequent impacts on household incomes and consumption (positive) and trade competitiveness (negative).
S3 Investment capacity constraints (country)	As S1, but no access to additional financial resources for each MS compared with the reference. Expected to lead to a higher cost of capital, crowding out investment in other sectors.
S4 Full labour market and investment capacity constraints	As S1, but no net increase in employment and investment compared to the reference (but allowing for shifts in employment and investment between sectors)

Macroeconomic impacts

As expected in all the scenarios EU28 GDP increases above the reference scenario as all scenarios entail a net income inflow. Depending on resource availability the impact on GDP may vary. In the no capacity constraints scenario (S1) GDP increases in 2030 by 0.33% from reference scenario. As noted earlier in the GEM-E3-FIT reference scenario the additional €48 bn in 2030 represents a 0.28% boost (i.e. without any feedback from the rest of the economy the economy would grow by 0.28%), and so the multiplier impact accounts for a further 0.05% of GDP. The S4 scenario, where complete crowding out is assumed (labour and capital are relocated from other sectors to be used in the other equipment goods sector), GDP increases from reference in 2030 by 0.03%. The financing constraint is more constraining for GDP growth than the labour constraint. This effect can be attributed to two factors: i) the cumulative effect that a lower investment path has on future production capacity, and ii) the increase in output requires additional financing (either for purchasing physical capital and/or hiring new employees).

Figure III.9: Impacts on GDP for the different scenarios



Source: GEM-E3-FIT.

Macroeconomic results in the unconstrained scenario (S1)

Table III.7 shows macroeconomic results for S1, where agents have sufficient labour and capital resources to meet the increased demand for their products. GDP increases by 0.33%. The increase in exports prompts an increase in investment to increase production capacity. Private consumption increases due to the income associated with higher economic activity.

Table III.7: Results of the S1 (no capacity constraints) scenario

% change from reference	2020	2025	2030
Gross Domestic Product	0.05	0.19	0.33
Investment	0.05	0.18	0.31
Private Consumption	0.05	0.16	0.27
Exports	0.15	0.53	0.96
Imports	0.06	0.22	0.38
Average Wage rate (€/hour)	0	0	0
Unit Cost of capital	0	0	0

Source: GEM-E3-FIT

Wages and the unit cost of capital remain unchanged from the reference by assumption.

Macroeconomic results with labour market constraints (S2)

Table III.8 shows the results for S2. GDP increases in 2030 by 0.21% above the reference, less than the increase under S1. Wage rates increase above the reference level as a result of the additional demand for labour. This has a positive effect on households' disposable income (so that the boost to consumption is similar to that in S1) and a negative effect on competitiveness, so that the net boost to exports is less than in S1.

Table III.8: Results of the S2 (labour market constraints) scenario

% change from reference	2020	2025	2030
Gross Domestic Product	0.03	0.12	0.21
Investment	0.05	0.16	0.29
Private Consumption	0.03	0.12	0.20
Exports	0.09	0.34	0.63
Imports	0.07	0.25	0.44
Average Wage rate (€/hour)	0.04	0.15	0.26
Unit Cost of capital	0.0	0.0	0.0

Source: GEM-E3-FIT

Macroeconomic results with financial market constraints (S3)

Table III.9 shows the results in the case where access to financial resources is constrained. The increase in GDP above the reference scenario is 0.15%, the lowest increase of S1-S3. Overall investment remains similar to the reference levels due to the crowding out effect and the trade balance deteriorates due to the increase in unit capital costs. Higher production costs reduce real household disposable income and trade competitiveness deteriorates.

Table III.9: Results of the S3 (financial market constraints) scenario

% change from reference	2020	2025	2030
Gross Domestic Product	0.02	0.09	0.15
Investment	0.01	0.03	0.05
Private Consumption	0.02	0.08	0.14
Exports	0.10	0.36	0.66
Imports	0.06	0.20	0.35
Average Wage rate (€/hour)	0.00	0.00	0.00
Unit Cost of capital	0.0	0.1	0.2

Source: GEM-E3-FIT.

Macroeconomic results with labour and financial market constraints (S4)

Table III.10 shows the results in the case where there is a complete crowding out and additional capacity needs to draw resources from other economic activities. The increase in GDP above the reference scenario is marginal 0.03%, the lowest increase of all cases examined. Changes are mainly driven through the multiplier effects.

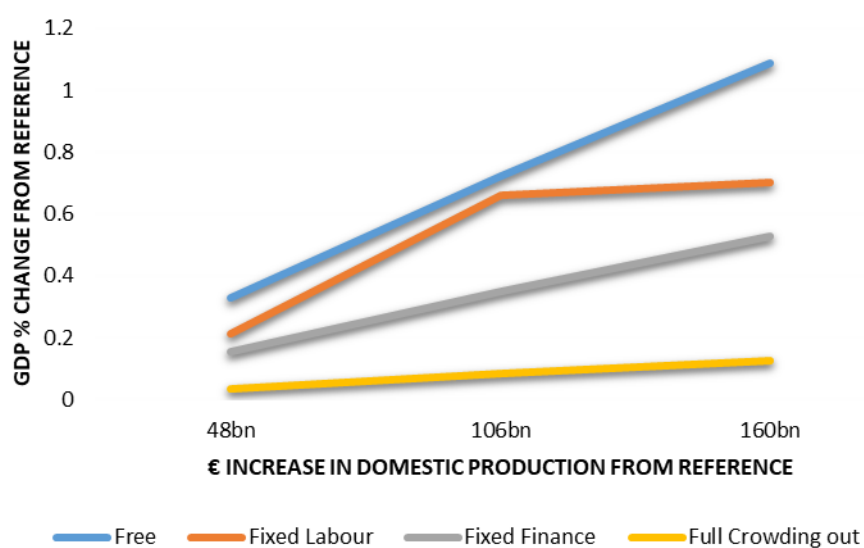
Table III.10: Results of the S4 (financial and labour market constraints) scenario

% change from reference	2020	2025	2030
Gross Domestic Product	0.01	0.02	0.03
Investment	0.00	0.01	0.02
Private Consumption	0.01	0.04	0.06
Exports	0.05	0.18	0.32
Imports	0.06	0.23	0.41
Average Wage rate (€/hour)	0.03	0.12	0.21
Unit Cost of capital	0.03	0.1	0.2

Macroeconomic results of sensitivity scenarios – doubling the initial shocks

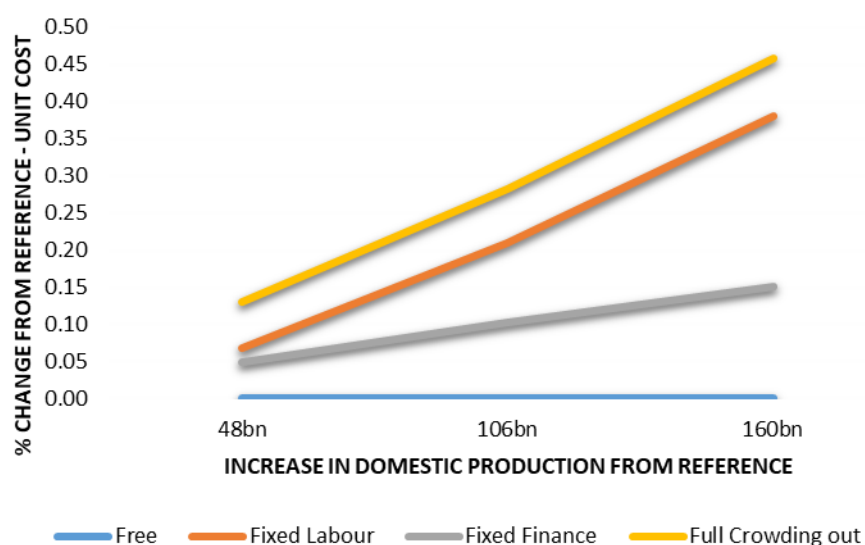
In order to better illustrate the impacts of capacity constraints additional simulations were performed where the increase in demand for equipment goods is doubled by 2030. Figure III.10 presents the impact on GDP of the different scenarios. In the case with fixed labour supply GDP benefits reduces as the level of production increases indicating that the labour force acts as a natural upper capacity constraint.

Figure III.10: Impacts on GDP from alternative increases in demand for equipment goods (2030)



Source: GEM-E3-FIT.

Figure III.11: Impacts on unit production costs of equipment goods (2030)



Source: GEM-E3-FIT.

Multipliers from the GEM-E3-FIT analysis

The implicit multipliers (the increase in total production divided by the increase in production of the equipment goods sector) from the GEM-E3-FIT simulations are presented in Table 12. The multipliers as expected diminish over time but also across variants. In the highly constraining case where the additional production in equipment goods is supported from financing and employment reallocated from the other economic sectors the multiplier is below 1 meaning that production in other sectors is mostly reduced as crowding out effects prevail.

Table III.11: GEM-E3-FIT multipliers (EU28)

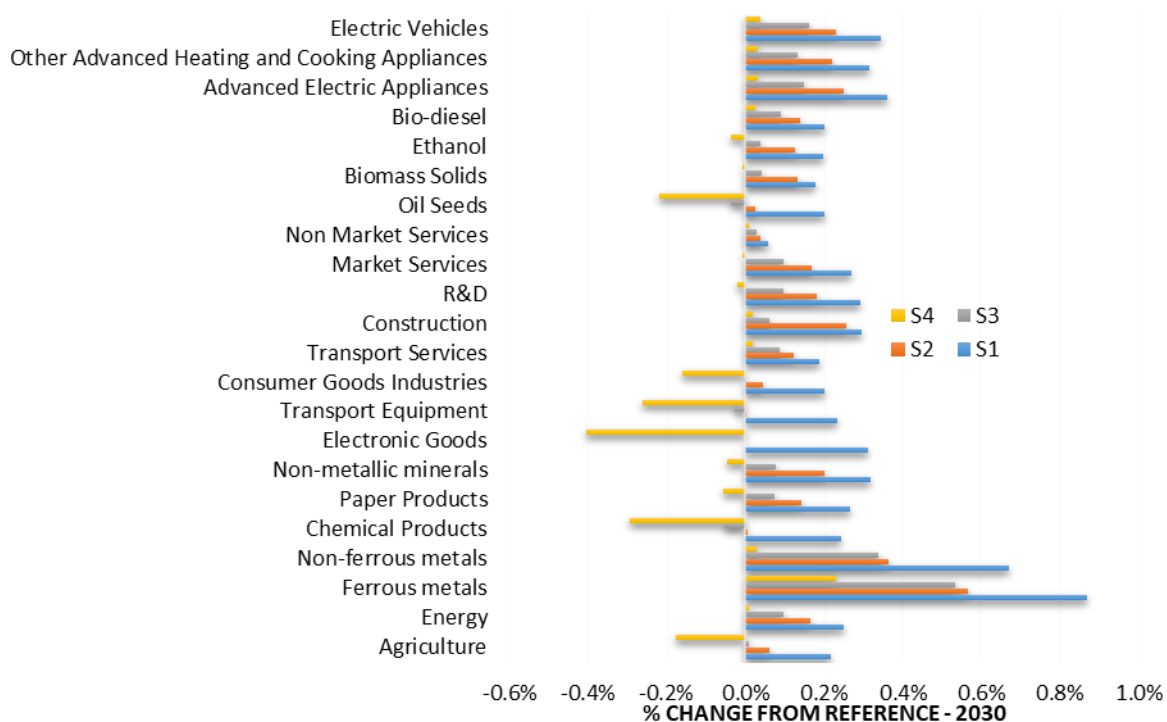
	S1	S2	S3	S4	Increase in Output from Reference (bn €)
2020	3.31	2.39	1.71	0.55	6.58
2025	3.20	2.33	1.69	0.53	25.28
2030	3.08	2.28	1.67	0.52	47.92

Source: GEM-E3-FIT.

Sectoral impacts across the scenarios

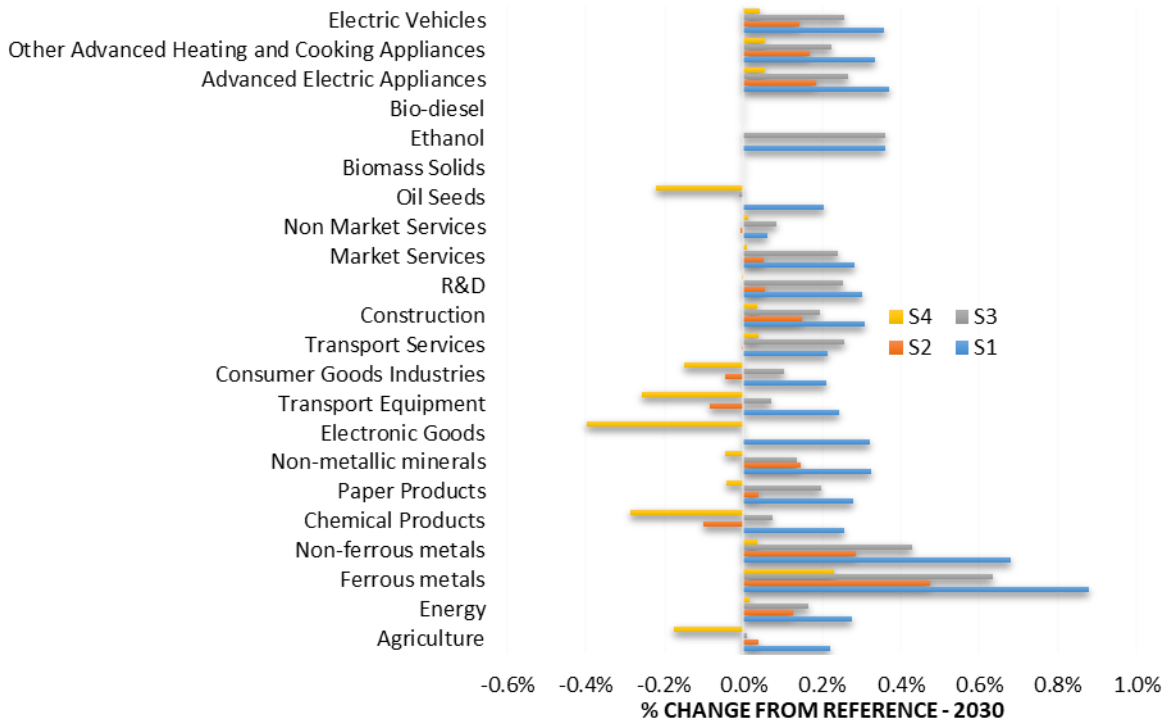
At the sectoral level, apart from the equipment manufacturing sector itself, the sectors that provide intermediate inputs to equipment manufacturing see the largest increases. The increase in household income and higher demand for capital goods also increase production throughout the economy, but to a lesser extent. The sectoral employment impacts largely follow the impact on production, and so the metal industry benefits most. Figure III.12 and Figure III.13 present the sectoral impacts of the different scenarios examined.

Figure III.12: GEM-E3-FIT sectoral output differences from reference case in the scenarios



Source: GEM-E3-FIT.

Figure III.13: GEM-E3-FIT sectoral employment differences from reference case in the scenarios



Source: GEM-E3-FIT

Conclusions from the model-based scenarios

Multipliers

The output multipliers in the input-output analysis are the largest: an output Type II multiplier of 3.37. This reflects the fact that the result is entirely demand-driven, there are no constraints on expansion of capacity, and there are no feedback effects (including the impact of changes in prices). The multipliers in the unconstrained case for E3ME and GEM-E3-FIT in the first year are similar in magnitude (3.0 and 3.31 respectively), but they decline over time as the boost to output is sustained, reflecting the operation of feedback effects, the change in the structure of the economy over time and the increasing productivity that the static input-output analysis ignores. While, in principle, a stimulus to investment in the models could add to demand and boost output in a way that the static input-output analysis does not capture, in practice the scenarios show that this effect is not large enough to outweigh the impact of the constraints that the models incorporate.

The multipliers in the GEM-E3-FIT results are larger than in the E3ME results. In previous analysis of decarbonisation scenarios, E3ME has generally given more positive results for GDP than has GEM-E3-FIT. In this section we seek to understand why, in the present analysis, the opposite result has been found.

The analysis here suggests that the difference is mainly explained by the underlying assumptions for the availability of spare capacity and finance for investment. The default setting for E3ME is 'no constraints', meaning that there is available finance and spare capacity for output, employment and investment to expand in response to a stimulus to demand. The default setting in GEM-E3-FIT is for the prices of resources

to rise in response to a stimulus to demand; depending on the user's choice, this is likely to involve more crowding out of spending than in E3ME's default case. Hence, a simple comparison between E3ME and GEM-E3-FIT decarbonisation scenarios is likely to compare an S1 type of world in E3ME with an S2 or S3 type of world in GEM-E3-FIT. So, one reason why the higher GEM-E3-FIT multipliers in this report may come as a surprise may simply be that here we are making the underlying assumptions about the state of the world for each model more comparable.

A second finding is that the scale of the multiplier effects can depend on what kind of intervention (initial assumption) is specified, and the models differ somewhat in the importance of different kinds of interventions. In the scenarios presented here, in E3ME the additional demand is imposed on the model as an exogenous boost to exports (in effect, an unexplained improvement in EU export competitiveness or reduction in barriers to imports elsewhere). In GEM-E3-FIT an assumption was made that duties are reduced in non-EU countries, and in this model the removal of taxes (distortions) increases resource allocation efficiency and hence acts to the benefit to the economy. If the same increase for EU exports had been implemented through an exogenous increase in technical progress in GEM-E3-FIT, the multiplier effect would be even larger because productivity would be directly increased. In previous analysis of decarbonisation scenarios using the two models, the driver for changing the demand was additional financing available to the economic agents so that they can undertake their investment plans, which does not (in GEM-E3-FIT) improve resource efficiency but does (in E3ME) improve embodied technological progress.

A third reason why E3ME multipliers may be lower than expected is that the results shown here embody the new, non-linear treatment of 'normal output', which gives a stronger response of prices to capacity constraints.

A fourth reason for the lower E3ME / higher GEM-E3-FIT multipliers is that the attempt made here to make the scenarios comparable in the two models can only go so far with models that come out of different theoretical traditions. To make GEM-E3-FIT represent an 'unconstrained' world, an intervention is made to prevent prices from rising (capital and labour prices are fixed – supply is unlimited at this level of prices). In E3ME, the relationship between capacity (represented by the 'normal output' indicator) and current output is modelled, so that the corresponding 'unconstrained' scenario in E3ME actually involves some increases in prices as demand is stepped up. Similarly, to make E3ME represent a 'constrained' scenario for labour or capital, an intervention is made to impose 100% crowding out (no net additional jobs, or no net additional investment). In GEM-E3-FIT, the constrained scenarios involve allowing increased demand to raise prices, with corresponding adjustments to supply and demand, rather than an imposed limit on resource availability. The consequence is that an unconstrained scenario in GEM-E3-FIT is more expansionary than in E3ME (which allows prices to rise, albeit in practice less rapidly than in a constrained scenario in GEM-E3-FIT), and a constrained scenario is more constrained in E3ME than in GEM-E3-FIT (which allows more adjustment in response to price changes).

The ranking of the impact of the various constraints is also different between the models. In E3ME, financial constraints (constrained investment) has less of an impact than labour constraints, whereas in GEM-E3-FIT the reverse is the case. The difference is most pronounced by the financial constraint case. The most likely explanation for this is differences in assumptions with regard to the role played by capital in facilitating expansion of production. In GEM-E3-FIT constraining investment directly constrains supply because more capital is needed to facilitate any increase in production (particularly if the opportunities for substituting labour for capital are modest). In E3ME, sectors are assumed to be operating below capacity and so can increase output until capacity constraints are reached: the effect of constraining

investment is to prevent accelerator effects from further stimulating demand. In contrast, in the constrained labour case, increases in wage rates in E3ME feed through to consumer prices and to trade competitiveness, a much more direct route of impact than is the case for constrained investment / higher capital costs.

Conclusions for future modelling

The modelling has introduced a better treatment of product market constraints in E3ME through the inclusion of a non-linear response to high levels of output (in relation to 'normal' output). The scale of that non-linear response continues to be estimated econometrically.

The analysis has explored different kinds of constraints (financial and labour market) in detail and shown how they are treated in E3ME and GEM-E3-FIT and the scale of impact. The nature of the constraint has a significant effect on the economy-wide consequences of an intervention that boosts demand.

For assessment of climate and energy policies, it is therefore essential to consider whether the models are assuming that particular constraints are in operation, and whether those assumptions are appropriate for the policy that is being examined. In past model comparisons, the different assumptions about constraints have typically been summed up as 'with or without crowding out'. The analysis here points to the need to be explicit about the nature of the constraints that could apply, and to ensure that comparative model analysis compares like with like by, as far as possible, basing the scenarios on common assumptions about those constraints.

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Part V Appendices

Appendix A Testing the New Capacity Constraints in E3ME

Introduction

As part of the model development undertaken for this study, the way in which the 'normal output' (i.e. capacity) equations are estimated within E3ME has been improved. Normal output is now calculated within the modelling framework, following a non-linear path, as opposed to the previous linear relationship. Hence, actual output growth can now be more severely limited by the existence of supply constraints at times of rapid growth – for example if some sectors show a large impact of an ambitious climate policy.

Normal output features in several of the model's other econometric equations. Most obviously, as capacity is reached, prices increase – both for products and for labour (i.e. wage rates). These price effects would be expected to have a negative impact on total production and GDP. Not all the effects are negative, however, as producing at or near capacity hitting constraints could also lead to higher investment (in additional capacity) which would boost output and GDP.

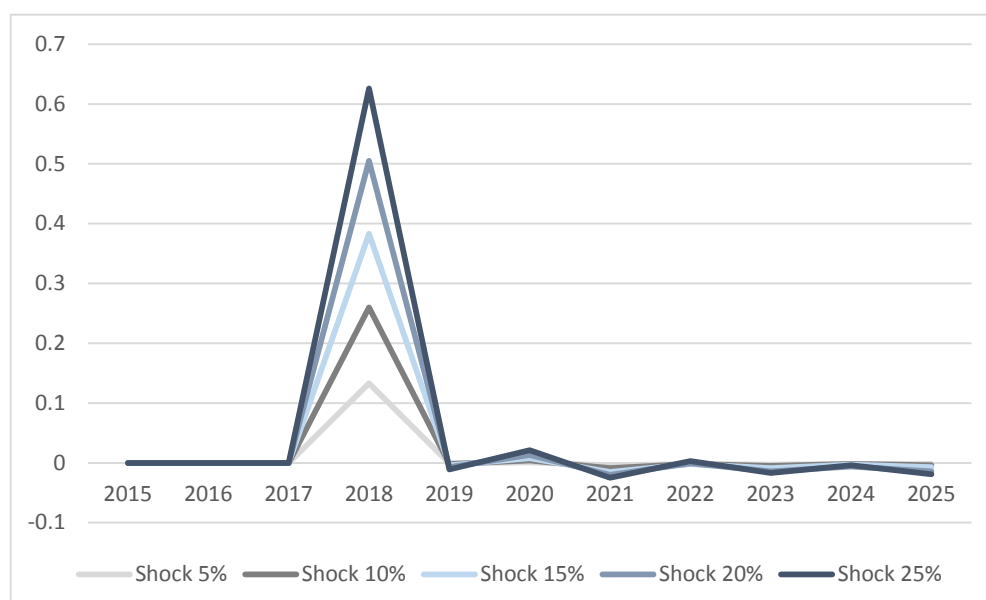
In this appendix, we assess the impact of this change in treatment on the economic results obtained from the model. To do this, a number of scenarios were set up, to mimic different severities of shocks to the same Electrical Equipment sector that was shocked in the main report. In each Member State, exogenous increases of increasing size in extra-EU exports of electrical equipment were introduced in a single year (2018) (equivalent to 5%, 10%, 15%, 20% and 25% of baseline sectoral output).

The shocks were introduced to a baseline in both the old (with linear normal output) and new (with non-linear normal output) model versions, and the macroeconomic impacts compared across the two versions. The results, which generally confirm that the new specification reflects capacity constraints more than the old specification, are set out below.

New normal output specification

In all cases, there is a sharp spike in output in 2018, reflecting the shock that we entered to the model. There is very little persistent effect from this one-off shock that ends immediately after 2018.

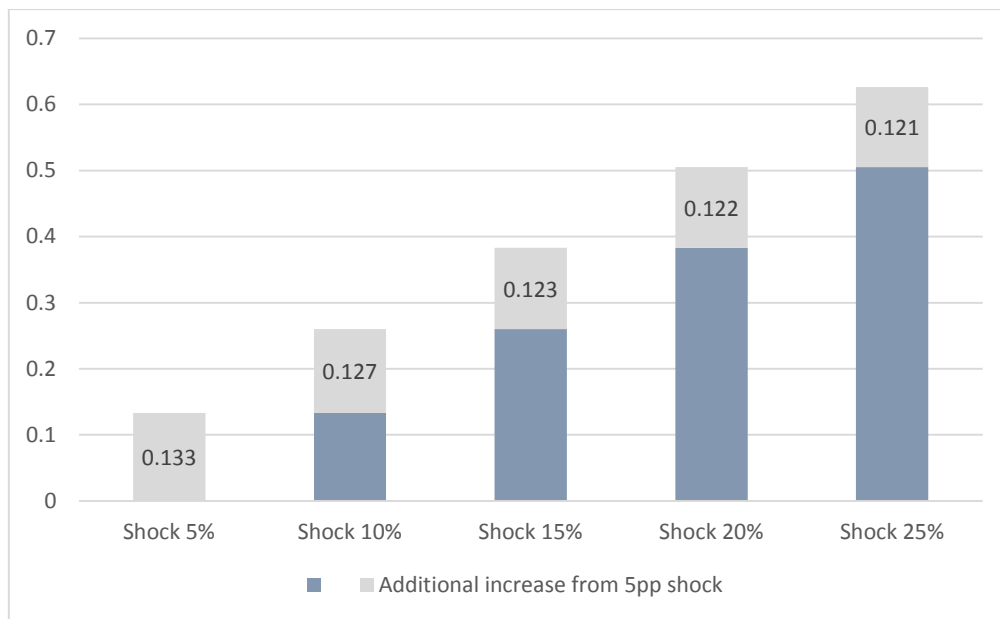
Figure A.1: EU28 GDP impacts with increasing scale of shock to exports in 2018, % difference from baseline



Source: E3ME, Cambridge Econometrics.

As the scale of the impact is increased (from 5% of total sectoral output), there are diminishing marginal impacts on GDP (i.e. the total GDP impact a 5% sectoral output shock relative to baseline (i.e. 0% shock) is greater than the GDP impact of a 10% shock as compared to a 5% shock, which is greater than a 15% shock compared against a 10% shock, etc.). This is consistent with capacity constraints acting to restrict the additional growth that the economy can accommodate.

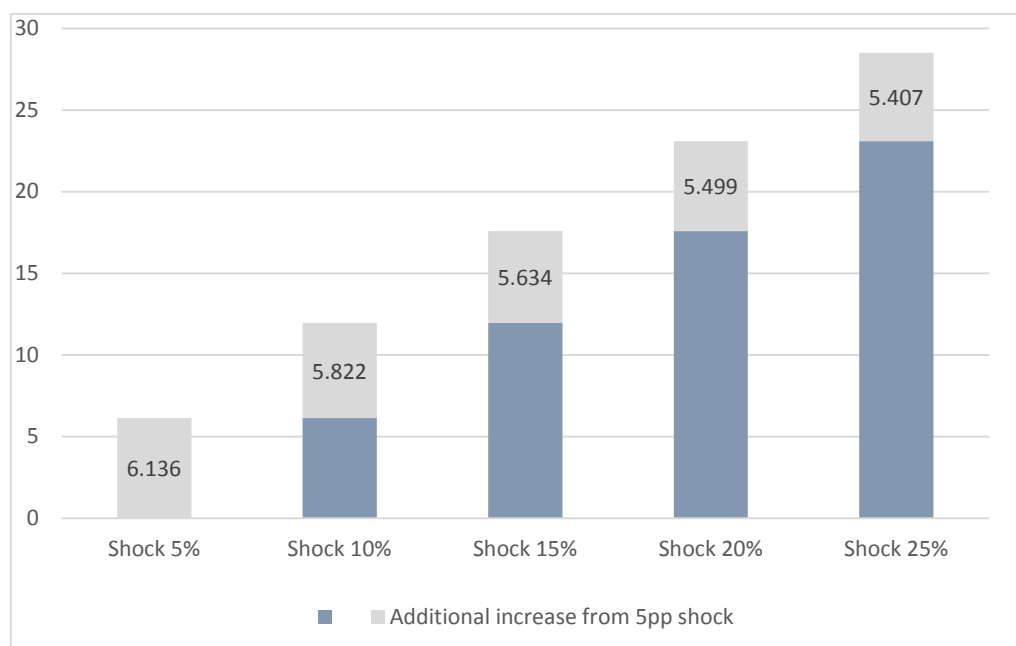
Figure A.2: EU28 GDP impacts with increasing scale of shock to exports in 2018, % difference from baseline



Source: E3ME, Cambridge Econometrics.

These supply constraints are even more apparent when examining the impact on the Manufacture of Electrical Equipment sector; while the initial 5% shock increases sectoral output by 6.1% compared to the baseline, moving from a 20% shock to 25% increases output from the sector by only a further 5.4%.

Figure A.3: EU28 impacts on the output of Manufacture of Electrical Equipment with increasing scale of shock to exports in 2018, % difference from baseline



Source: E3ME, Cambridge Econometrics.

The table below shows the impacts of the different export shocks within the Manufacture of Electrical Equipment sector. As industry output is pushed towards its productive capacity, larger increases in investment are required, and prices are pushed upwards at an accelerating rate. The increasing prices are one of the key drivers of the diminishing returns in terms of sectoral output.

At the same time, employment increases as output increases across the different scenarios; however, the larger the shock, the *larger* the marginal increase in employment, suggesting that supply constraints are being reached and more and more employment is required to facilitate the production of additional output (i.e. there is less and less scope for the increased output to be met to some extent by increasing productivity).

Table A.1: Summary of S1 results for Manufacture of Electrical Equipment in 2018

	Output		Employment		Investment		Price	
	Total	Incremental change	Total	Incremental change	Total	Incremental change	Total	Incremental change
Shock 5%	6.1	0.0	2.6	0.0	0.3	0.0	0.6	0.0
Shock 10%	12.0	5.8	5.6	2.9	1.1	0.8	2.4	1.8
Shock 15%	17.6	5.6	8.8	3.2	2.4	1.3	5.3	2.9

Shock 20%	23.1	5.5	12.3	3.5	4.2	1.7	9.3	4.1
Shock 25%	28.5	5.4	16.2	4.0	6.4	2.2	14.9	5.6

Source: E3ME, Cambridge Econometrics.

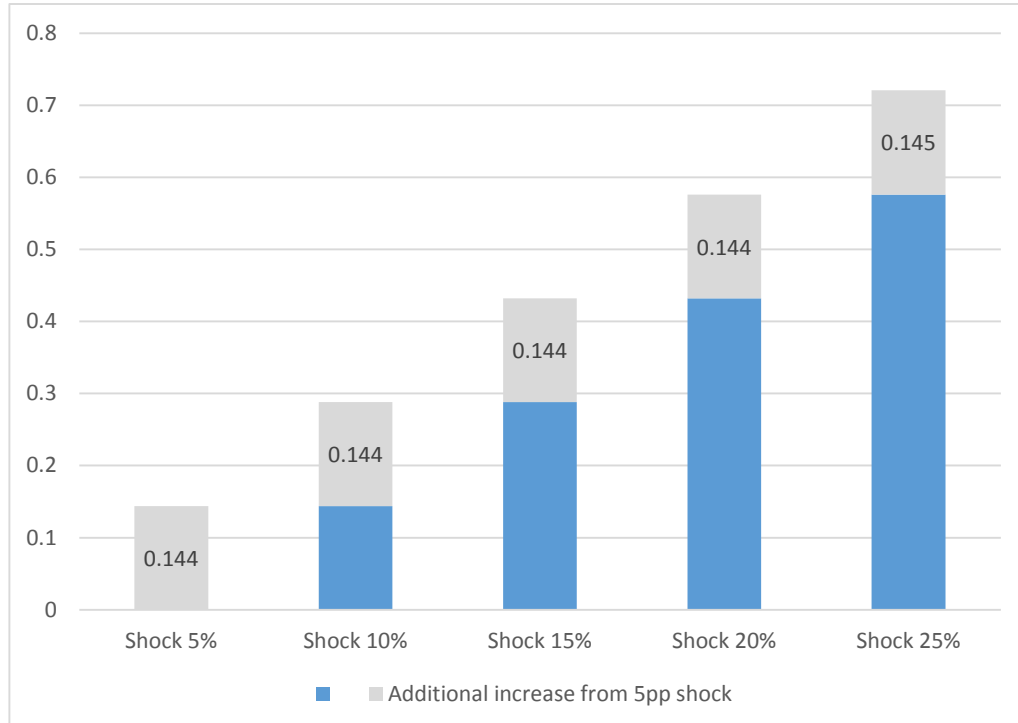
Old normal output specification

The same sectoral shock scenarios were run in an older version of E3ME, which used the older normal output specification. Under the previous treatment, normal output was only constrained when a sector is growing at a faster rate than other sectors (either other sectors within the same region or the same sector in other regions). If output of all sectors is growing then there is continual expansion of normal output productive capacity).

Under this treatment, the ratio of actual output to normal output was linear in the price and import equations, and as such the price or import response to a capacity shock of 10% of output in a single year was the same as a shock of 1% per annum over 10 years.

The scenario results using this normal output specification show larger positive GDP impacts as compared to the results obtained using the new specification, as there are fewer constraints on growth. Noticeably, there are also no diminishing returns as the scale of the export shock is increased; the impact upon GDP of the shift from a 20% to a 25% shock is the same as the impact of a 5% shock compared to baseline.

Figure A.4: EU28 GDP impacts with increasing scale of shock to exports in 2018, % difference from baseline (older E3ME version)



Source: E3ME (previous normal output specification), Cambridge Econometrics.

Larger shocks

The same analysis has been repeated with shocks up to 50% in size. In the old normal output specification, the same result is found: the additional increase is constant as the shock size is stepped up. However, in the new specification, for particularly large shocks the impact of capacity pressure on investment can outweigh the impact on prices, so that the earlier finding (the proportionate impact on output declines as the shock is increased) is not always replicated. However, shocks of this size are outside the range that would ever be relevant for real-world policy simulations.

Appendix B Relaxing Labour and Financial Constraints in CGE Models

Labour market capacity refers to the number of workers available and willing to work (labour force), the number and types of workers skills, the ease with which skills can be transformed and on workers' productivity.

The labour force (which is the labour supply of an economy) is defined as the working age population that is willing and able to work. The size of the labour force depends both on population and on the labour participation rate (schooling years, female participation in labour etc.) that characterizes each economy. Changes in the labour force over time depend on changes in demographics and socioeconomic factors. Skills and the degree at which they can be upgraded, extended or transformed (labour mobility) depend on the time available for schooling of the labour force and the capacity of the educational system to provide the necessary skills.

Labour market in static input-output modelling

Static I-O models are used to calculate the multiplier effects on the economy that an increase in final demand has, that is by how much output or employment will increase if final demand for a product increases. Two types of multipliers are used: the output multipliers and the employment multipliers. Both multipliers can compute the direct, indirect and induced effects. In I-O models, there are no capacity constraints. Production will increase to meet any increase in final and intermediate demand. Employment requirements that meet a particular increase in final demand are in fixed proportions as calculated by the employment multipliers. IO models implicitly assume that the additional demand for labour will not exert any pressure on wages and hence there will be no tendency to substitute labour with other production factors.

Labour market treatment in standard CGE

Textbook CGE models assumed that the whole labour force is employed. The choice of a worker whether or not to participate in the labour market is assumed to be voluntary and linked to preferences for leisure. Early work to include more detail and greater realism in the labour market representation in a CGE framework were undertaken by Gelauff et al. (1991) and Dewatripont et al. (1991), who analysed labour taxation and social security contributions in the Netherlands and Belgium, respectively, Sorensen (1997) who studied options of stimulating low-skilled employment in a model calibrated to the Danish economy, Hutton and Ruocco (1999), and Böhringer et al (2005) who analysed changes in labour taxation with an aggregated labour market module. Bovenberg et al (2000) focus on tax reform using a model that allows for more dimensions of labour market heterogeneity. Agénor et al (2007) simulated various labour market policy measures in a model with a dual labour market and collective wage bargaining. In another group of CGE studies, analysis is made of policy shock effects on employment and distribution which depend on the labour market specification, like wage bargaining (see for instance Ballard et al, 1985 on tax policy, de Melo and Tarr, 1992 on trade liberalization etc).

Contemporary applied CGE models are now quite advanced in realistically representing the operation of the labour market. Boeters (2013) offers a detailed review of the different implementations in a CGE framework. The most prominent options for modelling the labour market in CGE models can be summarized as the following:

- Search and matching model: The search and matching model (for a detailed discussion see Pissarides (1990)) assumes that the process of finding a job is

time- and effort-consuming. Similarly, filling a vacancy is costly, and costs increase if the number of unemployed workers to match it is small. In the search and matching model, labour market outcomes are the result of three distinctive components associated with: the way wages are set, the determination of the number of vacancies that firms decide to open, and the matching process of unemployed and vacancies. Wages result from the bargaining power between employers and workers. The wage setting and the vacancy supply curve allow determining the wage and the number of vacancies opened by firms. For determining unemployment though it is important to know the relationship between the number of vacancies and unemployment, i.e. the matching process between vacancies and unemployed so as to get filled jobs. This relationship is illustrated by the Beveridge curve.

- **Efficiency wages:** The efficiency wage model is based on the idea that firms pay above market-clearing wages to provide effort incentives to workers and is influenced in large by the shirking model developed by Shapiro and Stiglitz (1984). This model states that complete contracts rarely exist in the real world. Contracting parties have discretion and in the case of labour contracts, due to monitoring problems, it is the employee's side of the bargain which is subject to more discretion.
- **Wage bargaining:** The collective wage bargaining model assumes that wages are the result of negotiations between firms' associations and trade unions. The influential argument relating collective bargaining and unemployment was the "hump-shape" relationship between centralization of collective bargaining and real wages, proposed by Calmfors and Driffill (1988). The basis for this relationship argues that when collective bargaining takes place at firms facing competitive markets, there are no monopolistic rents to be shared among the wage-setters and real wages remain in line with productivity; when it takes place at the national level, wage-setters take into account "broader interests" and internalize the external effects of wage increases like inflation, unemployment, and taxes needed to finance unemployment benefits. Externalities induce the bargaining parties to go for wages which exceed the market-clearing level.
- **Skills mismatching:** In this model unemployment is the result of skills mismatching (skills not available to fill the respective vacancies). Labour supply depends on the efficiency of institutional mechanisms to improve skill formation and matching and on the expenditures on upgrading human capital.

Treatment in GEM-E3-FIT

The methodological approaches mentioned in the previous section lead to similar functional forms regarding labour supply based on the inverse relationship between wage (w) and unemployment (u). In the most general form this can be expressed as follows:

$$w = a + \beta/u$$

Each modeling alternative is associated with different data requirements and estimations regarding replacement rates, trade union market power, separation rates, efficient vacancy filling, detection probabilities of being caught for shirking, taxes, etc. The availability of these data and the ability to empirically validate the parameters used in each method is an important factor in selecting the method to adopt.

Based on the policy scope of GEM-E3-FIT with regards to labour markets, a generic labour supply curve that is estimated for each MS has been used. This selection results from the relatively straightforward approach of this method to modeling labor markets and to empirically validate the parameters used while at the same time it conforms to

the general approach employed in GEM-E3 and to the policy alternatives under consideration. The labour supply function that has been included in the model is:

$$w = a + \frac{b}{(U - nairu)^s}$$

Where w: is the wage rate, U: unemployment rate, nairu: natural rate of unemployment, a: minimum wage and s, b elasticity and calibrated parameters respectively.

Table_apx B.1: Labour supply elasticities for skilled and unskilled labour force for GEM-E3-FIT model countries/regions

	Unskilled	Skilled		Unskilled	Skilled
Austria	-0.13	-0.01	South Korea	-0.1	-0.08
Belgium	-0.05	-0.01	Australia	-0.1	-0.08
Bulgaria	-0.14	-0.05	Brazil	-0.1	-0.08
Croatia	-0.11	-0.08	Canada	-0.1	-0.08
Cyprus	-0.07	-0.03	China	-0.1	-0.08
Czech Republic	-0.07	-0.01	Russia	-0.1	-0.08
Denmark	-0.09	-0.04	India	-0.1	-0.08
Estonia	-0.04	-0.04	Japan	-0.1	-0.08
Finland	-0.08	-0.05	USA	-0.08	-0.01
France	-0.05	-0.03	Indonesia	-0.1	-0.08
Germany	-0.17	-0.06	Mexico	-0.11	-0.08
Greece	-0.07	-0.04	Argentina	-0.11	-0.08
Hungary	-0.03	-0.01	Turkey	-0.11	-0.08
Ireland	-0.03	-0.02	Saudi Arabia	-0.11	-0.08
Italy	-0.04	-0.01	Rest of energy pro	-0.11	-0.08
Latvia	-0.08	-0.01	South Africa	-0.11	-0.08
Lithuania	-0.08	-0.01	Rest of the World	-0.11	-0.08
Luxemburg	-0.02	-0.01			
Malta	-0.09	-0.04			
Netherlands	-0.08	-0.01			
Poland	-0.03	-0.02			
Portugal	-0.05	-0.01			
Romania	-0.03	-0.02			
Slovakia	-0.07	-0.03			
Slovenia	-0.04	-0.04			
Spain	-0.14	-0.02			
Sweden	-0.13	-0.02			
United Kingdom	-0.03	-0.03			
Rest of Europe	-0.09	-0.04			

Source: Authors' estimates and literature survey/

The GEM-E3-FIT model distinguishes labour between skilled and unskilled labour. As a default option there is full mobility across sectors but not between skills. Alternatively, a migration function can be activated based on the Harris – Todaro approach. Firms' optimal demand for labour is derived from their cost minimization.

The financial sector and macroeconomic closure rules

Tamas and Zalai (2013) provides a detailed review of CGE macroeconomic closures. They suggest that in models built in the neoclassical (Walrasian) tradition, in which the variables and equations related to production, consumption and export-import decisions are based on the assumption of optimizing representative agents (households, production sectors, foreigners)¹⁵, the closure rule problem is closely related to macroeconomic accounting identities (physical and financial balance requirements), which constrain the decisions of the microeconomic behaviour of individual agents. The working of the model will depend on the choice of the particular macroeconomic adjustment mechanism (macro-closure) that is supposed to bring about the required equilibrium of various balances

The chosen mechanism will basically determine, on the one hand, the proportions between the main components of final demand (the level of private and public consumption, investments and net exports), and the level of the key variables (the general level of wages, the rate of return on capital and foreign exchange rate), which determine the level and distribution of the primary income, on the other hand. The two sets of macro variables are connected to each other through the income redistribution rules (various transfers and savings), which should result such disposable incomes that will generate demand and supply matching each other.

As Dewatripont and Michel (1987) pointed out, the closure problem arises because financial assets, markets for stocks are lacking in the essentially static models, which determine store values and savings. However, this is only one important cause of the problem of macro closure. In more complex CGE models it reflects the fact that in these models the monetary and financial side is treated at most in an ad hoc fashion. Dynamic considerations, asset endowments, markets and expectational dynamics are not included explicitly.

GEM-E3-FIT includes a representation of the financial system, which is particularly important for the macro-economic impact assessment of policies. The model assumes that households and firms can borrow from capital markets without facing increasing unit capital costs. The model assumes that agents annually pay back interests and principal of the loans; interest rates are determined by the evolution of the debt to income ratio (representing a financial stability rule). The inclusion of the financial sector improves the policy realism of model simulations as debt accumulation directly impacts investment decisions while interest rates are computed endogenously also depending on financial stability of each agent and country.

The lack of a financial sector in a model has the following implications:

- debt accumulation does not have an impact on the real economy as in reality via the adjustment of interest rates

¹⁵ It would be hard to treat the government as a utility maximizing actor. In most CGE models, therefore, the level of government purchases and its composition is set exogenously. Government collects revenue by fixed tax rates and government savings are determined residually. Production sectors represent enterprises and rentiers.

- financing of investments projects is driven by the saving-investment closure of the model and usually follows a predetermined pattern
- depending on the closure rule the financing of an investment project takes place in one period (at the period where the investment products are constructed) and can be financed from the sector, country or abroad.
- in a given year/period alternative investment projects compete for the same financial capacity (crowding out effect)

The inclusion of a financial sector improves the model simulation capability in the following respects:

- bookkeeping of stock/flow relationships on debt accounting (domestic and external Private and Public debt)
- allow for the existence of financing schemes that expand through sectors, countries and time.
- the option to create payback schedules that span over many periods moderates considerably the crowding out effect of the model

Treatment in multiplier analysis

The financial sector is not explicitly represented in static IO models that they implicitly assume that there are abundant financial resources to meet any demand for capital capacity expansion. There is no crowding – out effect in multiplier models as any increase in final demand can be met by the appropriate increase in capital stock.

Treatment in standard CGE

CGE models simulate the working of a market economy and solves for a set of prices that clears all markets. The markets may concern labour, commodities and foreign exchange while the corresponding prices are the wage rate, the domestic price and the exchange rate.

Traditional CGE models adopt a neoclassical macro closure (the rule to equilibrate savings to investments). Recently there are various applications of CGE models, however that aim to include non-neoclassical features in order to capture economic characteristics specific to a market or country.

Recent examples are the Dixon et al (2014) where they develop a financial CGE model and run simulations to investigate the impact of tighter monetary policy in Papua New Guinea and Lewis (2009) where they apply a computable general equilibrium (CGE) framework to the evaluation of financial stability of the banking sector in Jamaica. His model incorporates heterogeneous banks and capital requirements with incomplete markets, money and default. Most of the recent implementations of the financial sector in CGE are based on the *Bourguignon, W. H. Branson & J. de Melo (1989) work* which has been further extended by *Fargeix & Sadoulet (1990)* and *Capros & Karadeloglou (1994)*.

Treatment in GEM-E3-FIT

GEM-E3-FIT includes a representation of the financial system, which is particularly important for the macro-economic impact assessment of policies. The model assumes different closures where i) a world bank collects all savings and then supplies these savings to agents at market clearing interest rates, ii) agents can have access to national bank (domestic) savings and to the world bank savings, iii) agents have access only to domestic savings (crowding out option) and iv) part of this year savings are transferred for next periods investments. The model assumes that agents annually pay back interests and principal of the loans; interest rates are

determined by the evolution of the debt to income ratio (representing a financial stability rule). The inclusion of the financial sector improves the policy realism of model simulations as debt accumulation directly impacts investment decisions while interest rates are computed endogenously also depending on financial stability of each agent and country.

The GEM-E3_FIT financial module combines the traditional CGE formulation for the real side of the economy with an IS-LM mechanism that serves as a macro-economic closure rule. This mechanism covers all aspects of the monetary/financial side of the economy and permits the determination of all equilibrium prices, the exchange and the interest rates.

The model framework allows for the representation of different market clearing regimes and other institutional characteristics. Each alternative regime corresponds to a special structural feature or institutional condition and refers to the commodity markets, the labour market, the exchange rate determination mechanism and several issues of the financial/monetary sector.

The standard CGE theoretical framework requires that all markets are clearing through prices. This procedure is usually called price-adjustment of the markets. The empirical applications of CGE models do not always assume market clearing through price mechanisms in all markets; on the contrary authors often incorporate non-neoclassical assumptions concerning market rigidities and imperfections in an attempt to capture the macro-economic forces that prevail in real-world cases. In such cases some markets of the model may be cleared through price-adjustment, while some others include an endogenous determination of the price level which guarantees a quantity-adjusted equilibrium.

The following sets of equations illustrate the alternative mechanisms for representing market types:

	$D = f(p)$		$D = f(p)$
			$\bar{S} = g(p)$
Competitive markets	$S = g(p)$	Excess Markets	$S = D$
	$D = S$		$U = S/\bar{S}$
			$p = h(S, \bar{S})$

where D , S and p denote demand, supply and prices, respectively, bars indicate potential production and the absence of bars corresponds to effective supply and demand. U is then the rate of capacities utilisation or the rate of unemployment, depending on the nature of the market. The model accepts only one type of regime per market and per model variant.

The formulation found in the competitive market type is adopted for the market of goods and labour in most CGE models; see De Melo (1988). The excess supply market illustrates the formulation used for the labour market (or the foreign exchange market) when unemployment (and usually a trade deficit) prevails. This type of market is also the typical formulation of all markets represented in neo-Keynesian macro-econometric models; see Capros et al. (1989a). In a multi-market CGE model, all three types of market-clearing formulations may co-exist, in the sense that some markets are perfectly competitive, while others are not.

The mechanisms that achieve consistency of transactions at the macro-economic level, called often macro-framework, is particularly important for appraising the

model's properties, and this is independent of the way markets clear. The macro-framework mechanism may be represented by four simultaneous identities: the national income identity, the balance of payment, the public budget balance and the savings-investment identity. In traditional CGE models, the savings-investment identity is usually adopted as the "closure rule" and it is often used for evaluating investment. Such a restrictive assumption is necessary because in these models there is no financial-monetary sector. In traditional econometric models which formulate the IS-LM scheme, the savings-investment identity is implicitly induced by the flow-of-funds identity which equalises demand and supply of money.

The macro-framework, as it will be presented below in a simple manner, is used in the GEM-E3-FIT to integrate the real and the monetary/financial sectors of the economy and overcome the closure rule limitation. This is based on the approach followed by Bourguignon, Branson and de Melo (1989).

The national income identity may be written as:

$$C + I + G + (X - M) = Y + T \text{ while } Y = C + S$$

where C , I , G , X , M , T and S denote, respectively, private consumption, investment, government expenditure, exports, imports, net tax receipts and savings. The balance of payment identity is written as:

$$X - M = EX (\Delta A_f + \Delta B_R - \Delta B_f)$$

which represents the financing of deficits (or the allocation of surplus) by changes in net foreign assets A_f , bank reserves B_R and foreign borrowing B_f , depending on the exchange rate EX . The public budget identity also represents the financing of deficit through bank borrowing B_g , private domestic borrowing P_g and foreign borrowing B_f , as follows:

$$G - T = \Delta B_g + \Delta P_g + E_x \cdot \Delta B_f$$

The strict equality of savings and investments, which is used in traditional CGE models, is expanded in a way that any difference between them is financed through changes in money supply M_s , private domestic borrowing of government, net foreign assets and private lending from banks B_p , as follows:

$$S - I = \Delta M_s + \Delta P_g + E_x \cdot \Delta A_f - \Delta B_p$$

The Walrasian closure, which may be further interpreted as flow-of-funds identity, is re-written as follows:

$$-(G - T) + (S - I) - (X - M) = 0$$

which implies:

$$-(\Delta B_g + \Delta P_g + E_x \cdot \Delta B_f) + (\Delta M_s + \Delta P_g + E_x \cdot \Delta A_f - \Delta B_p) - E_x \cdot (\Delta A_f + \Delta B_R - \Delta B_f) = 0$$

and:

$$\Delta M_s = \Delta B_p + \Delta B_g + E_x \cdot \Delta B_R$$

The last equation is the monetary identity and constitute the expansion of the "closure rule" when incorporating a financial sector into the CGE framework.

The above macro-framework, i.e. the set of accounting identities, is able to cover a large spectrum of financial market conditions and institutional characteristics. Alternative situations may be represented by choosing the appropriate set of endogenous variables to be solved by these identities.

The Financial/Monetary Sector

The financial behaviour of economic agents is based on a portfolio model which is derived by maximising expected utility. The model allocates financial wealth among various assets. The allocation is made on the basis of expected yields and other determining factors [see van Erp et al (1989), van der Beken and van der Putten (1989)]. Such an approach avoids reduced-form models of financial mechanisms and uses relative interest rates as explanatory variables. These interest rates together with the exchange rate can be derived from the equilibrium of financial supply and demand flows.

The GEM-E3-FIT accounting structure, based on a matrix of flows of funds, involves four economic agents, namely the private, government, banking¹⁶ and foreign sectors. We adopt a hybrid approach where the flow of funds approach is mixed with a "deficit financing approach". More specifically, the foreign and public sectors are represented only with respect to the financing of their surpluses, while the banking and private sectors are represented following an "assets-liabilities balance" approach. However, we fully guarantee stock-flow consistency for all transactions.

On the assets side of the private sector, total wealth (W) is evaluated, dynamically, by private net savings, a variable coming from the real part of the model.

The allocation of total wealth of the private sector is described as "risk averse investment behaviour". Private agents are assumed to maximise the utility of the return from a portfolio. In this respect future returns are uncertain and the risk aversion is formalised as diminishing marginal utility. It is also assumed that changes in the composition of the portfolio in relation to the starting point entail costs. This portfolio model is based on Parkin (1970) and used in the Freia-Kompas model of the Dutch economy and has also been applied to Belgium [see Van Erp et alii (1989) and Van de Beken and Van der Putten (1989)].

The basic model, expanded with a number of sector-specific variables, determines the optimum portfolio composition, in terms of cash, saving deposits and government bonds. The allocation mainly depends on the relative rates of return (assimilated to interest rates) from the above assets. The corresponding equations are simultaneously estimated and a set of restrictions on parameters are imposed. Restrictions include symmetry and additivity conditions, the latter implying that one of the equations is redundant. Also, adjustment costs and dynamic behaviour are incorporated in these equations.

Foreign exchange deposits are explained by the evolution of the exchange rate, the foreign to domestic interest rate differential and the capital and transfer inflow which enters the country.

The demand of credit by the private sector bears the influence of the real interest rate, the profit rate and the volume of total investments of the sector. This demand behaviour is important, since it enters the equilibrium condition.

The "assets-liabilities" balance of the private sector is used to determine the change in saving deposits, as a residual so as to respect additivity condition.

The financing of the public sector's deficit can be effected by borrowing from the domestic sectors (from the private sector and the commercial banks), the foreign sector, and from the central bank. The share of public deficit covered by foreign loans

¹⁶ The banking system, as defined in this model comprises, a world bank and national banks and credit institutions.

depends mainly on the interest rates differential. The amount of total foreign debt could be considered as an additional explanatory variable.

Domestic borrowing of government is based on government bonds which can be acquired by the private sector and by commercial banks. Concerning the private sector, investment in this asset emanates from portfolio allocation. For the banking sector, we retain a formulation which explicitly reflects one possible institutional regime, in which commercial banks are obliged to buy government bonds at a rate proportional to their total liabilities. The demand/supply equilibrium in financing public deficits serves to determine the rate of interest of government lending, i.e. r_g , which further leads the interest rates of bonds and treasury bills.

Assets-liabilities balance in the banking sector serves to evaluate the capacity of banks to lend the private sector which is a supply behaviour. This formulation also is in accordance with that institutional regime in which prevails a leakage in capital supply to the private sector induced by the imperative financing of public deficit.

Demand/supply equilibrium of the capital flows addressed to the private sector serves to determine the private lending interest rate, which is used in both the real and the monetary sectors of the model, and further leads the interest rates of assets.

Modelling of the foreign sector is oriented towards determining the ways for covering the current account deficit. Foreign capital inflow is an independent variable and is a function of relative profitability of investment assets. We assume that changes in bank reserves are maintained at some predetermined level.

Total public debt is updated dynamically by accumulating deficits. Public debt further influences interests and annuities which determines net savings of the public sector.

In summary, the present model variant, of the financial/monetary sector, determines endogenously three equilibrium prices: (i) the private sector lending interest rate, (ii) the government lending interest rate and the (iii) exchange rate.

The above specification does not exclude, however, the possibility to include different structural or institutional changes that may occur in the economy. This may be effected by some other selection of endogenous and exogenous variables. For example, it is possible to consider that the exchange rate is exogenously determined by the authorities. In this case foreign exchange reserves should be endogenous and be estimated as a residual variable. Furthermore, if the lending interest rate is fixed by the central bank, a credit rationing regime would occur.